ATHENA Collaboration, Costing, and Schedule

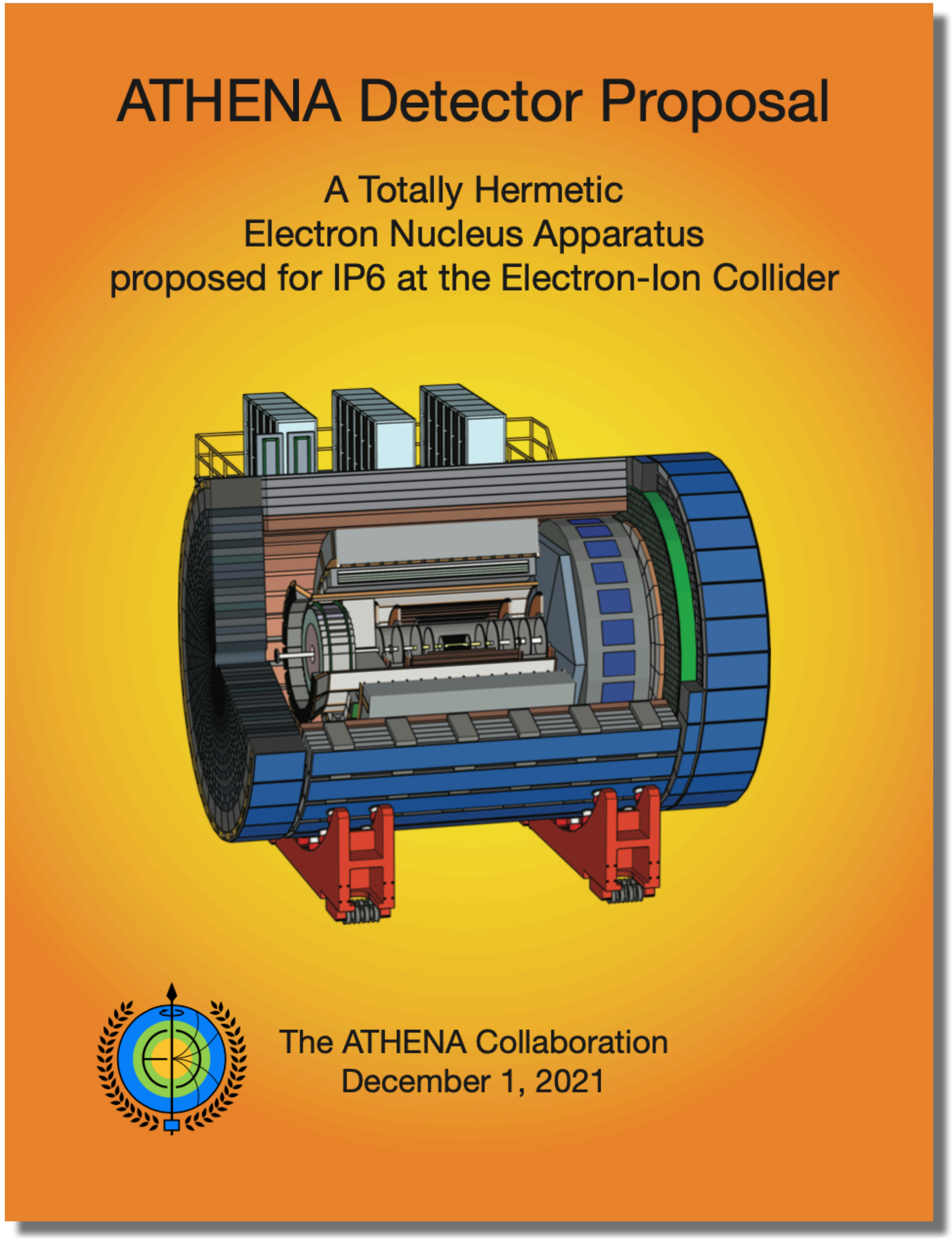
Bernd Surrow (Temple University)
(On behalf of the ATHENA collaboration)

EIC Detector Proposal Advisory Panel Meeting, December 13-15, 2021

ATHENA

Outline

- ➢ Collaboration
- ➢ Costing
  - ❖ Introduction
  - ❖ Costing of ATHENA sub-systems
  - ❖ Costing of ATHENA global systems
  - ❖ Summary of costing
- ➢ Schedule
- ➢ Conclusions

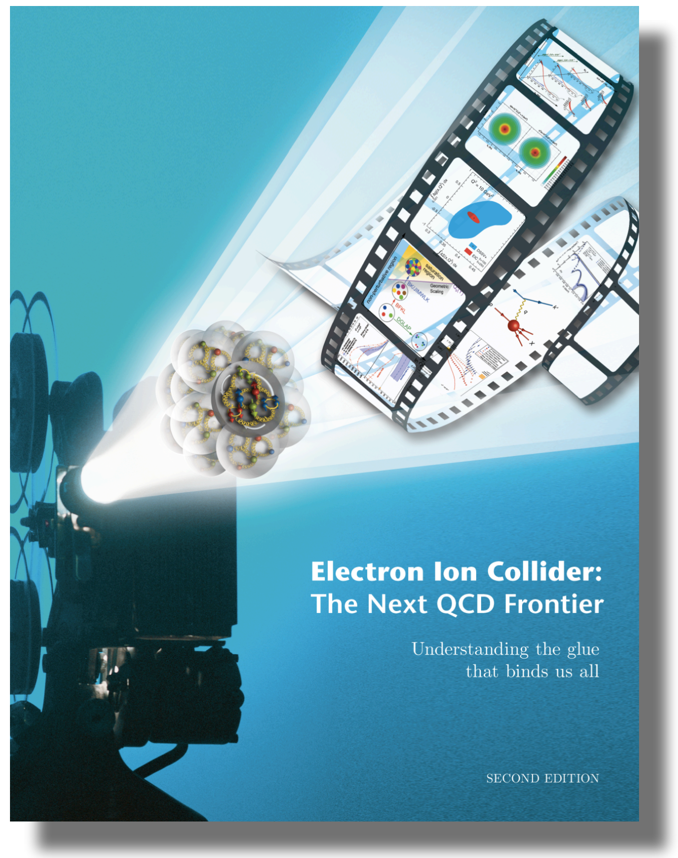


Collaboration - Introduction

- ATHENA - International collaboration: 94 institutions / 13 countries
- ATHENA detector proposal effort: Launched in March 2021 - Kick-Off meeting following completion EIC User Group Yellow Report studies
- Initial coordination by organizing committee
- Vision:
  - Realize a comprehensive general-purpose detector at IP6, characterized by a
  - New high-field 3T solenoid, and
  - State-of-the-art detector technologies,

  building-upon the Yellow Report reference detector design studies
- ATHENA collaboration: Formulation of charter by ad-hoc charter committee:
  - Organizational structure
  - Role of various bodies,

  besides "bonding activities" of selecting the name "ATHENA" and "Logo" involving the entire ATHENA community!

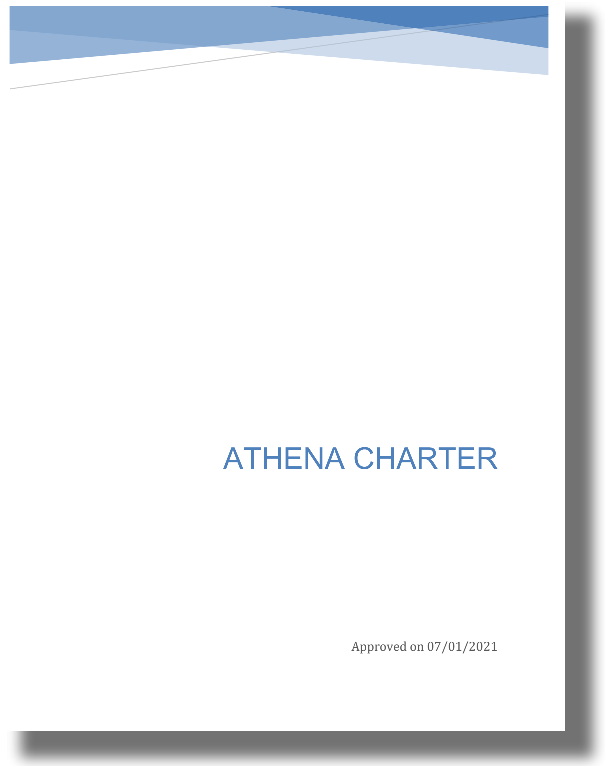


EIC White paper:
"Understand the glue that binds us all!"
arXiv: 1212.1701

ATHENA

EIC Yellow Report:

arXiv: 2103.05419

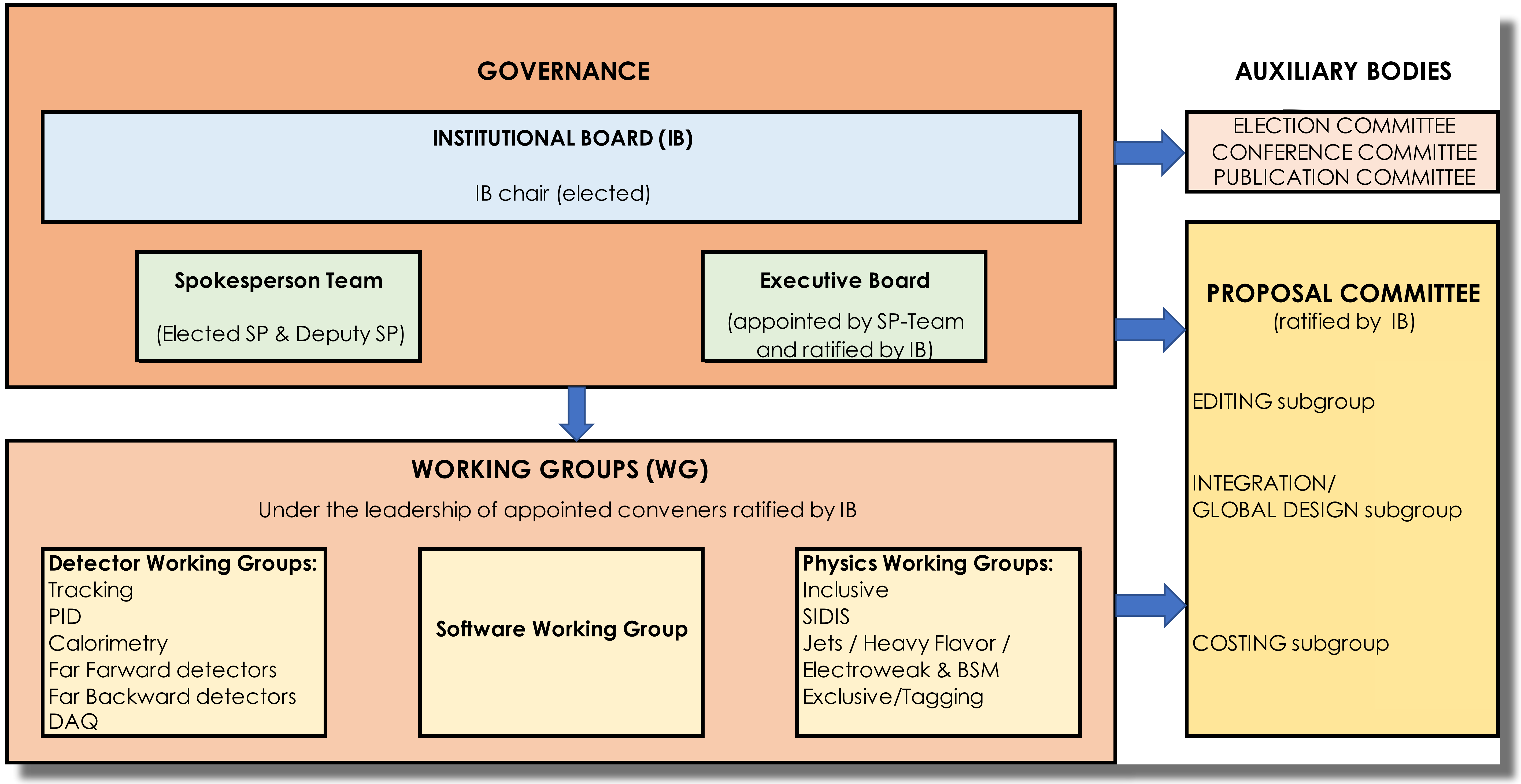


A
Totally
Hermetic
Electron
Nucleus
Apparatus

ATHENA

Collaboration - Governance

- ATHENA Charter documents organizational structure
- Institutional Board (IB): Governing body - Composed of all participating institutions
- Spokesperson (SP) Team: Representing collaboration and responsible for scientific and technical direction of experiment
- Executive Board (EB): Advising body to SP Team
- Working Groups (WG): Central scientific bodies
  - Detector WGs (5)
  - Physics WGs (4)
  - Software Working Group
- Proposal Committee:
  - Editing subgroup
  - Integration/Global Design subgroup
  - Costing subgroup



Collaboration - Governance

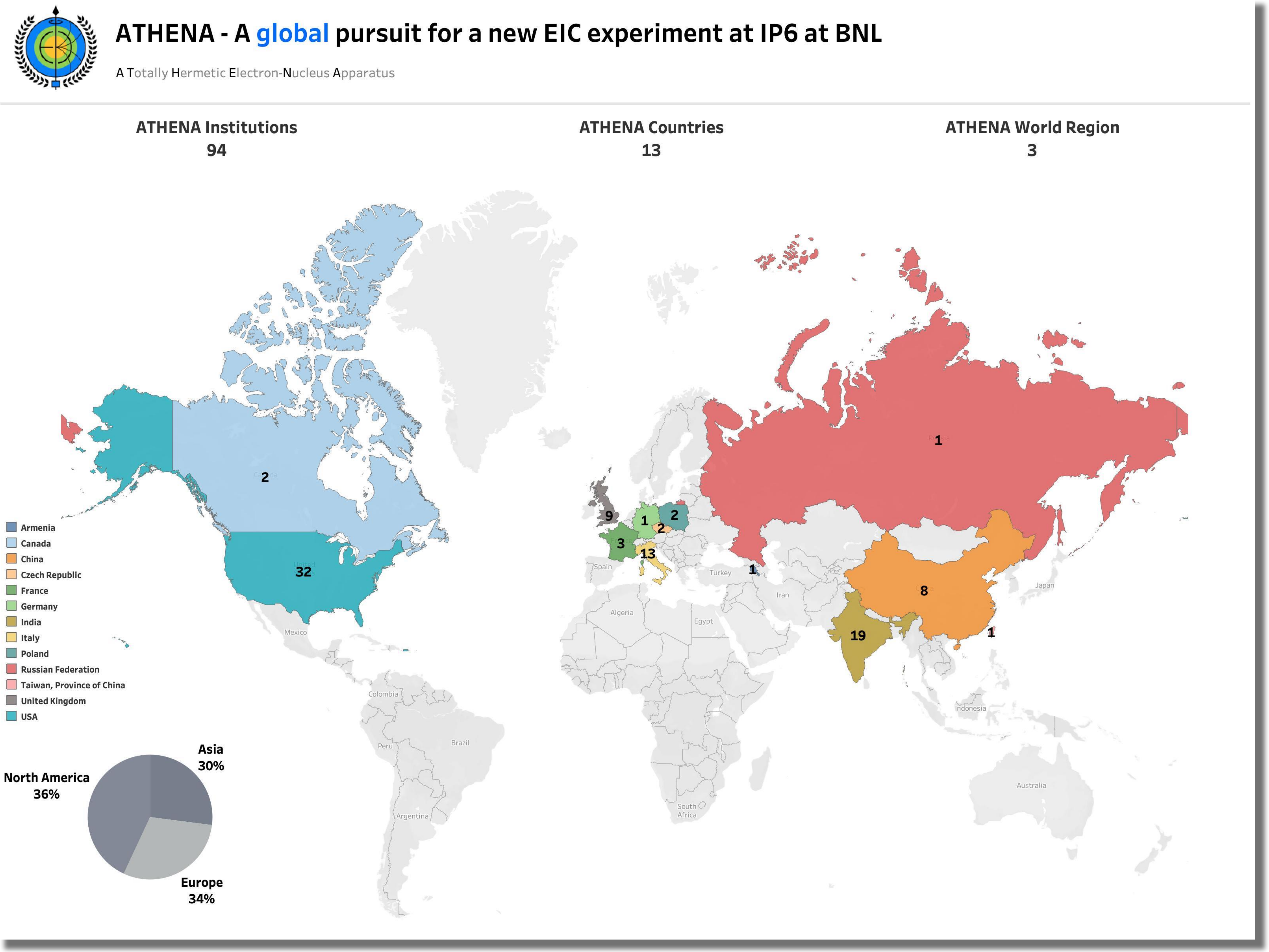
- Compilation of current composition of committees and WGs:
- Key focus areas of EB include: Construction, Operation, Maintenance, and Upgrades, Data Management, Software / Computing, WGs, Committees, and Diversity, Equity & Inclusion
- Integral part: Growth opportunities for young scientists

  → Path to scientific excellence!
- Structure and composition will evolve from the current proposal phase to the realization, and subsequent operation!

MANAGEMENT	Before implementing the Charter	Coordination Committee	Silvia Dalla Torre (INFN Trieste, Italy) Abhay Deshpande (Stony Brook University, USA) Olga Evdokimov (University of Illinois at Chicago, USA) Yulia Furletova (Jefferson Lab, USA)	Barbara Jacak (UC Berkeley, USA) Alexander Kiselev (BNL, USA) Franck Sabatie (IRFU, CEA, France) Bernd Surrow (Temple University, USA)	
		Preliminary Institutional Board	One representative from each Institution		
	Charter imlementation	Institutional Board	Members from each Institution according to the group size as specified in the Charter		
			Chair: Ernst Sichtermann (LBL, USA)		elected
		Spokesperson (SP) team	SP: Silvia Dalla Torre (INFN Trieste, Italy)	Deputy SP: Bernd Surrow (Temple University, USA)	elected
		Executive Board	Chair: Silvia Dalla Torre (INFN Trieste, Italy) Ex-officio: Ernst Sichtermann (LBL, USA) Ex-officio: Bernd Surrow (Temple University, USA) Abhay Deshpande (Stony Brook University,USA) Olga Evdokimov (University of Illinois at Chicago, USA)	Yulia Furletova (Jefferson Lab, USA) Barbara Jacak (UC Berkeley, USA) Sylvester Joosten (ANL, USA) Franck Sabatie (IRFU, CEA, France) Thomas Ullrich (BNL, USA)	ratified by IB
COLLABORATION SUPPORT		Election Committee	Pietro Antonioli (INFN Bologna, Italy) John Arrington (LBL, USA) Nicole d'Hose (CEA, France)	Yulia Furletova (Jefferson Lab, USA) Sylvester Joosten (ANL, USA) Brian Page (BNL, USA)	ratified by IB
AD HOC BODIES		Charter Committee	Ken Barish (UC Riverside, USA) Nicole d'Hose (CEA, France) Zein-Eddine Meziani (ANL, USA) Olga Evdokimov (University of Illinois at Chicago, USA) David Gaskell (Jefferson Lab, USA) Thomas Hemmick (Stony Brook University, USA) Bedangadas Mohanty (NISER, India)	Marta Ruspa (INFN Torino, Italy) Murad Sarsour (Georgia State University, USA) Ernst Sichtermann (LBL, USA) Daria Sokhan (Glasgow, UK and CEA, France) Thomas Ullrich (BNL, USA) Anselm Vossen (Duke University, USA) Qinghua Xu (Shandong University, China)	ratified by IB
SCIENTIFIC BODIES	Working Groups (WG)	Software WG	Whitney Armstrong (ANL, USA) Andrea Bressan (INFN Trieste, Italy) Wouter Deconinck (University of Manitoba, Canada)	Sylvester Joosten (ANL, USA) Dmitry Romanov (Jefferson Lab, USA)	ratified by IB
	Working Groups (WG) – Detector WGs	Tracking WG	Francesco Bossu (CEA, France) Domenico Elia (INFN Bari, Italy)	Laura Gonella (University of Birmimgham, UK) Matt Posik (Temple University, USA)	
		Calorimetry WG	Vladimir Berdnikov (Catholic University of America, USA) Paul Reimer (ANL, USA)	Oleg Tsai (UCLAL, USA)	
		PID WG	Frank Guerts (Rice University, USA) Thomas Hemmick (Stony Brook University, USA)	Roberto Preghenella (INFN Bologna, Italy)	
		Far Forward WG	John Arrington (LBL, USA)	Alexander Jentsch (BNL, USA)	
		Far Backward WG	Jaroslaw Adam (BNL, USA)	Krzyzstof Piotrzkowski (AGH, Poland)	
		DAQ WG	Alexandre Camsonne (Jefferson Lab, USA)	Jeffery Landgraf (BNL, USA)	
	Working Groups (WG) – Physics WGs	Inclusive WG	Paul Newman (University of Birmimgham, UK) Barak Schookler (Stony Brook University, USA)	Qinghua Xu (Shandong University, China)	
		SIDIS WG	Marco Radici (INFN Pavia, Italy)	Anselm Vossen (Duke University, USA)	
		Jets/Heavy Flavors/ Electroweak & BSM WG	Miguel Arratia (UC Riverside, USA) Brian Page (BNL, USA)	Stephen Sekula (SMU, USA) Ernst Sichtermann (LBL, USA)	
		Exclusive/Tagging	Salvatore Fazio (INFN Cosenza, Italy) Spencer Kein (LBL, USA)	Daria Sokhan (Glasgow, UK and CEA, France)	
	Proposal Committee	Editing Subgroup	Abhay Deshpande (Stony Brook University, USA) Barbara Jacak (UC Berkeley, USA)	Peter Jones (University of Birmimgham, UK) Zein-Eddine Meziani (ANL, USA)	ratified by IB
		Integration/Global Design Subgroup	Silvia Dalla Torre (INFN Trieste, Italy) Bedangadas Mohanty (NISER, India) Alexander Kiselev (BNL, USA)	Franck Sabatie (IRFU, CEA, France) Thomas Ullrich (BNL, USA)	
		Costing Subgroup	Olga Evdokimov (University of Illinois at Chicago, USA) Bernd Surrow (Temple University, USA) Zhangbu Xu (BNL, USA)	Yulia Furletova (Jefferson Lab, USA) James Symons (LBL, USA)	

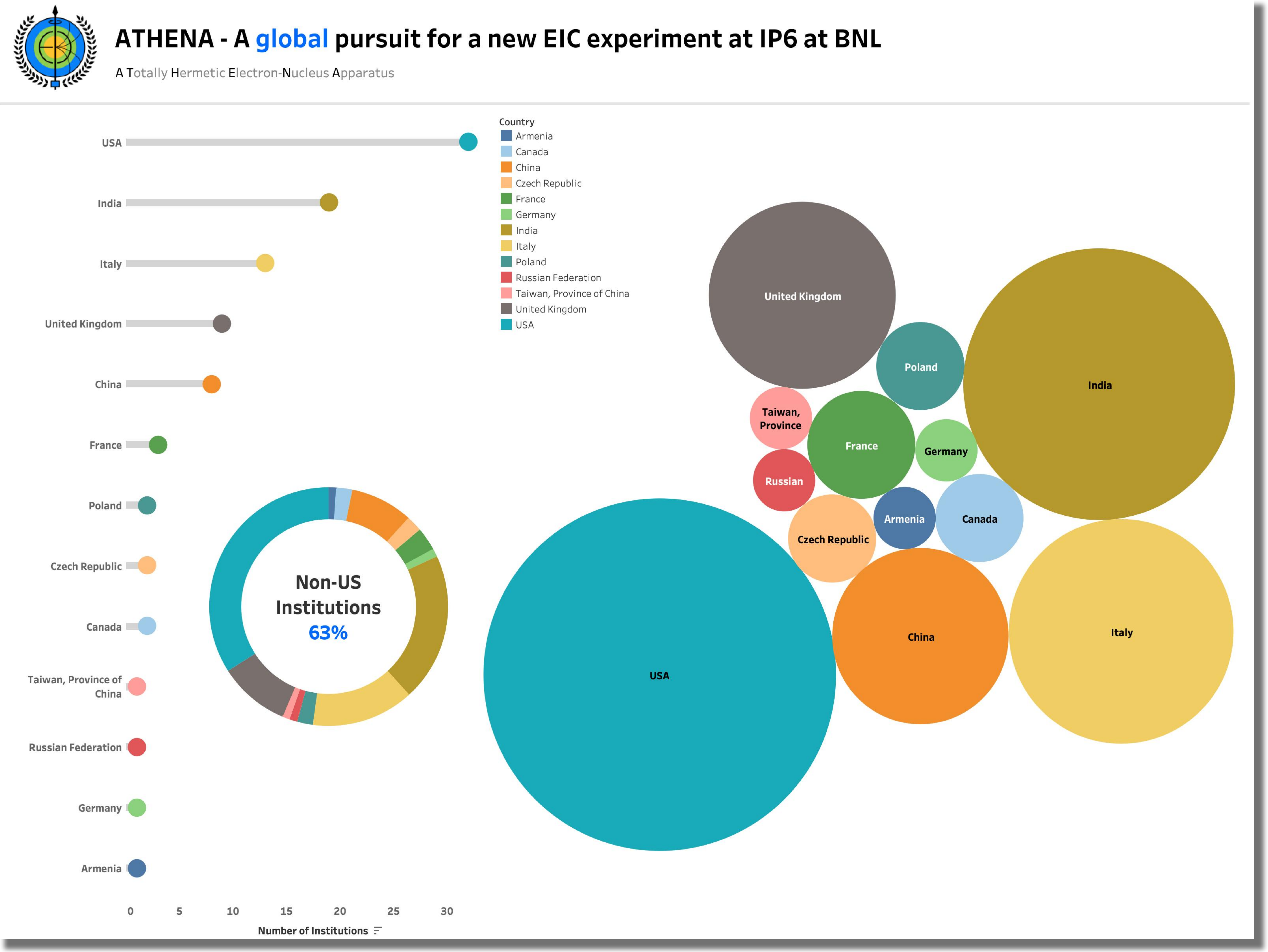
Collaboration

- ATHENA institutions roughly evenly split among three world regions of North America, Europe, and Asia
- ATHENA Institutions provide vast experience and interest in nucleon & nuclear structure and relativistic heavy-ion physics
- ATHENA institutions played leadership roles worldwide at BNL, CERN, DESY, GSI, and JLab



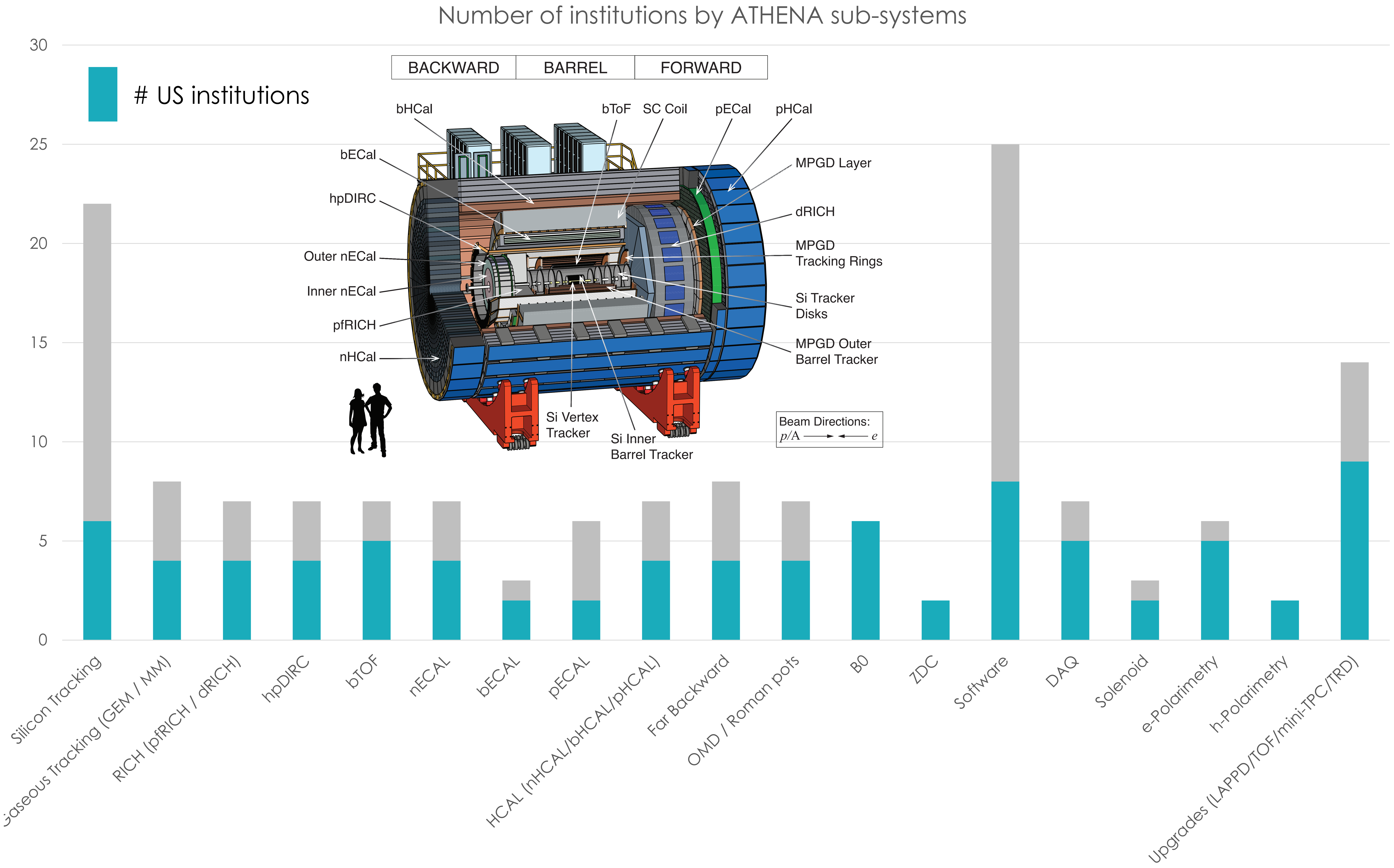
Collaboration

- ATHENA is truly a global pursuit for a new EIC experiment at IP6
- Non-US Institutions account for roughly 2/3 of all institutions with
- Large institutional participation from various single non-US countries
- ATHENA is committed to to expanding its worldwide coverage to other world regions
- Growth opportunities for new institutions!



Collaboration

- ATHENA institutions cover a broad scientific background: Nucleon/ nuclear structure at RHIC/ JLab & HERA/COMPASS, Relativistic Heavy-Ion Physics at RHIC/LHC, HEP (LHC, FNAL, Belle II)
- Numerous ATHENA institutions: Dedicated detector EIC R&D programs
- ATHENA provides at its core significant experience in all detector areas

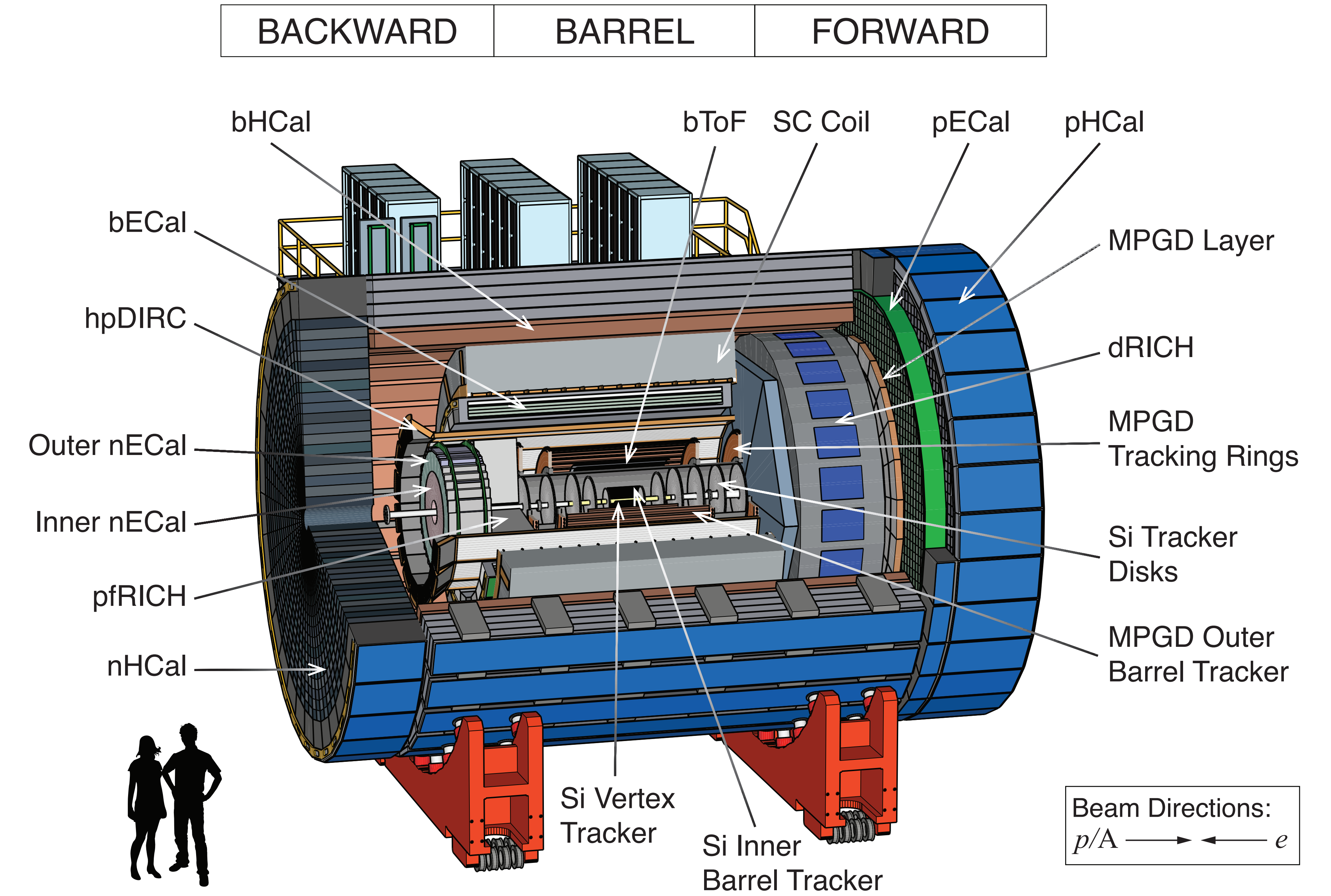


Collaboration

Silicon Tracking	RICH (pfRICH / dRICH)	nECAL	Far Backward	Software	Solenoid	Upgrades (LAPPD/TOF/mini-TPC/TRD)
BNL	Banaras Hindu University	A.I. Alikhanyan National Science Laboratory (Yerevan Physics Institute)	AGH University of Science and Technology, Krakow	A.I. Alikhanyan National Science Laboratory (Yerevan Physics Institute)	BNL	ANL
Brunel University	Duke University	CUA	BNL	ANL	CEA-Saclay	BNL
CCNU Wuhan	GSU	Florida International University	Daresbury Laboratory	Brunel University	Jlab	FZJ ZEA2
Central University of Tamil Nadu	INFN	IJCLab, Université Paris-Saclay	IFJ PAN	Central University of Karnataka	**e-Polarimetry**	INFN
Czech Technical University in Prague	National Institute of Science & Education and Research	JLAB	JLAB	DAV College, Chandigrah	JLAB	Institute of Physics
Daresbury Laboratory	Stony Brook University	Lehigh University	Temple University	Goa University	Mississppi State University	JLAB
Goa University	University of Massachusetts Amherst	University of Kentucky	University of Glasgow	Indian Inst. of Sci. Research & Edu.	Stony Brook University	Mississppi State University
Indian Inst. of Tech. Madras	**hpDIRC**	**bECAL**	University of Michigan	Indian Institute of Technology Bombay	University of Manitoba	National Cheng Kung University
INFN	Banaras Hindu University	ANL	**OMD / Roman pots**	Indian Institute of Technology Delhi	University of Massachusetts Amherst	National Institute of Science & Education and Research
LANL	BNL	University of Massachusetts Amherst	BNL	Indian Institute of Technology Indore	University of Virginia	Rice University
LBNL	CUA	Yerevan Physics Institute	IFJ PAN	Indian Institute of Technology Madras	**h-Polarimetry**	Stony Brook University
National Institute of Science & Education and Research	GSI	**pECAL**	IJCLab, Université Paris-Saclay	Indian Institute of Technology Patna	BNL	Temple University
Nucl. Phys. Inst. of the Czech Acad.	Mississppi State University	Fudan University	JLAB	INFN	Stony Brook University	University of Illinois at Chicago
RAL CMOS Sensor Design Group	Nat. Inst. of Sci. Edu. and Research	Shandong University	Stony Brook University	JLAB		Yale University
RAL Particle Physics Division (PPD)	Stony Brook University	South China Normal University	University of Illinois at Chicago	LBNL		
UC Berkeley	**bTOF**	Tsinghua University	University of Manitoba	LLNL		
UC Davis	ANL	UC Riverside	**B0**	Malaviya National Institute of Technology		
University of Birmingham	BNL	UCLA	BNL	Mississppi State University		
University of Jammu	Indian Institute of Science Research and Education	**HCAL (nHCAL/bHCAL/pHCAL)**	JLAB	Panjab University		
University of Lancaster	National Cheng Kung University	Abilene Christian University	LANL	Ramakrishna Mission Resid. College		
University of Liverpool	Rice University	BNL	LBNL	Stony Brook University		
University of Michigan	University of Illinois at Chicago	Czech Technical University in Prague	University of Illinois at Chicago	Temple University		
Gaseous Tracking (GEM / MM)	UT Austin	Nucl. Phys. Inst. of the Czech Acad.	University of Kansas	University of Glasgow		
FIT		UC Riverside	**ZDC**	University of Kentucky		
Institute of Physics		UCLA	LBNL	University of Manitoba		
CEA-Saclay		University of Manitoba	University of Kansas	**DAQ**		
JLAB				BNL		
National Institute of Science & Education and Research				Central University of Karnataka		
Rama. Mission Residential College				FZJ ZEA2		
Temple University				JLAB		
Yale University				SMU		
				Stony Brook University		
				University of Massachusetts Amherst		

US institutions

- Strong US and non-US institutional participation - well balanced!
- Growth opportunities for new institutions, particularly for young collaborators!



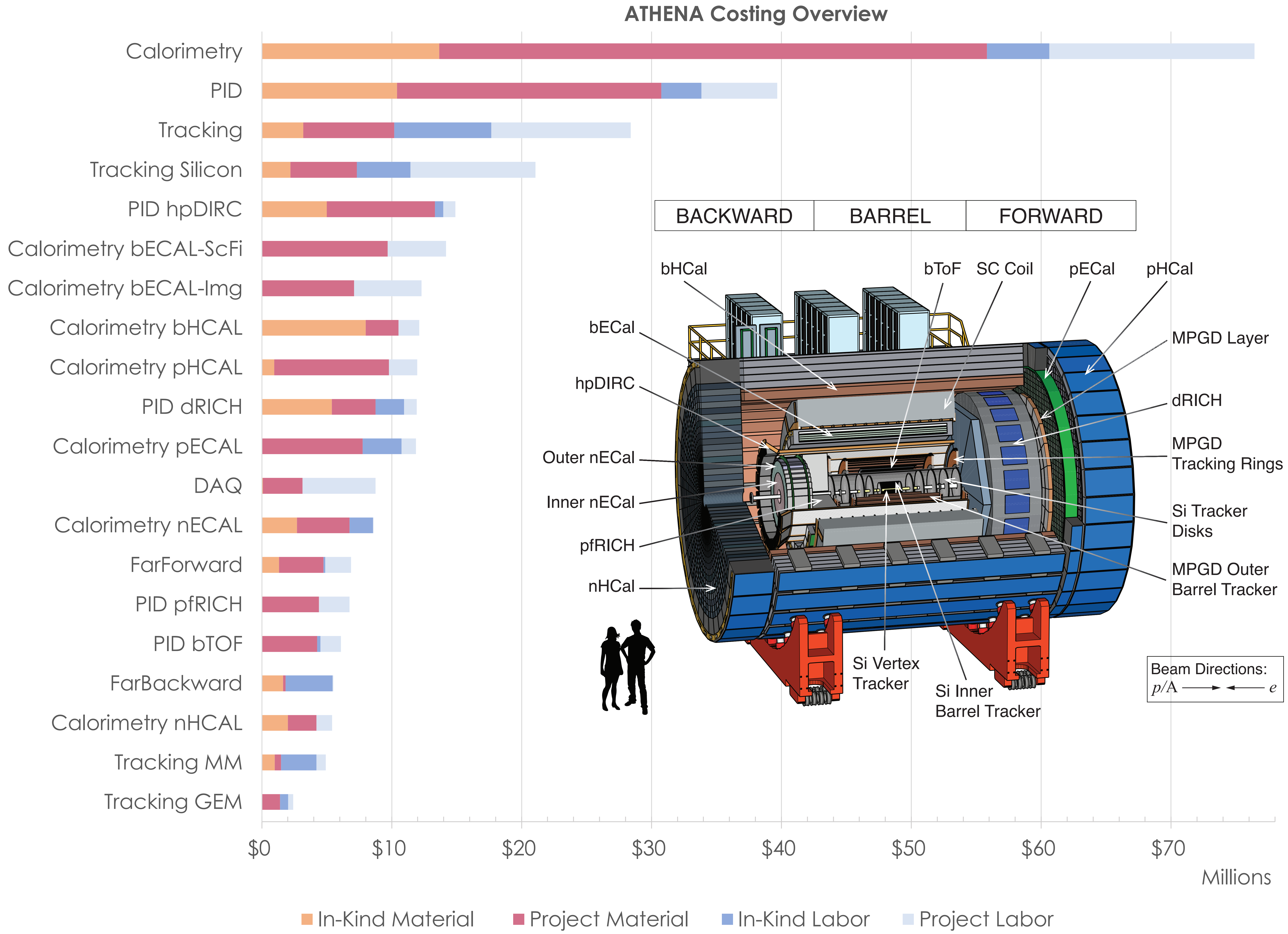
Costing - Introduction

- ATHENA launched a coordinated effort to estimate the cost of the ATHENA sub-systems:
  - In-Kind Material
  - Project Material
  - In-Kind Labor
  - Project Labor
- Weekly costing meetings of costing sub-group together with costing representatives of each sub-system!
- Guidance provided by EIC project: EXCEL template and Readme instructions
  - No contingency included
  - Labor costs: Quoted in US Dollars (USD) using standard BNL labor rates
  - Costing of Global Systems for Detector Management, Magnet, Detector Infrastructure, and Detector Pre-Ops & Commissioning provided by EIC project
- In-Kind contributions are expected to increase with evolution of the EIC project: Lower limit!
- ATHENA sub-system costing (Construction and R&D) in 2021 USD
- Escalation of sub-system costing based on 3.5% growth rate and combination with R&D, and Global System provided!

Costing

- ATHENA costing for sub-system construction in 2021 USD:
- Largest cost drivers:
  - Calorimetry
  - PID
  - Tracking
- Total for sub-system construction in 2021 USD: $166M

	In-Kind	Project	Total	
Material	$30M	$76M	$106M	64%
Labor	$19M	$40M	$59M	36%
Total	$49M	$116M	$166M	
	30%	70%		



Costing

- Complete ATHENA costing table:
- Total for sub-system construction in 2021 USD: $166M
- Total for sub-system R&D in 2021 USD: $25M

Sub-system	Sub-system components	In-Kind Material	Project Material	Total Material	In-Kind Labor	Project Labor	Total Labor	Total: 2021	Total: Escalated (Sub-system)
Calorimetry	nECAL	$2,697,908	$4,050,357	$6,748,264	$1,804,621	$55,079	$1,859,700	$8,607,964	$10,438,168
	nHCAL	$1,999,800	$2,204,300	$4,204,100	$0	$1,205,512	$1,205,512	$5,409,612	$6,593,356
	bECAL-Img	$0	$7,102,048	$7,102,048	$0	$5,184,005	$5,184,005	$12,286,053	$14,185,197
	bECAL-ScFi	$0	$9,691,520	$9,691,520	$0	$4,481,037	$4,481,037	$14,172,557	$17,611,694
	bHCAL	$7,999,800	$2,518,710	$10,518,510	$0	$1,592,452	$1,592,452	$12,110,962	$14,999,623
	pECAL	$0	$7,768,700	$7,768,700	$2,993,097	$1,111,678	$4,104,775	$11,873,475	$14,831,909
	pHCAL	$950,000	$8,842,327	$9,792,327	$0	$2,167,408	$2,167,408	$11,959,735	$14,783,373
	Calorimetry Total	$13,647,508	$42,177,962	$55,825,470	$4,797,718	$15,797,171	$20,594,889	$76,420,359	$93,443,319
DAQ	DAQ	$84,000	$3,054,300	$3,138,300	$0	$5,607,651	$5,607,651	$8,745,951	$11,685,584
FarBackward	FarBackward	$1,627,608	$200,000	$1,827,608	$3,628,367	$47,097	$3,675,464	$5,503,072	$7,020,595
FarForward	FarForward	$1,334,097	$3,405,480	$4,739,577	$151,153	$1,972,247	$2,123,400	$6,862,977	$8,623,207
PID	pfRICH	$0	$4,399,900	$4,399,900	$0	$2,349,762	$2,349,762	$6,749,662	$8,712,913
	bTOF	$0	$4,263,600	$4,263,600	$257,990	$1,570,518	$1,828,508	$6,092,108	$7,826,676
	hpDIRC	$5,005,000	$8,327,000	$13,332,000	$640,916	$934,886	$1,575,802	$14,907,802	$16,938,918
	dRICH	$5,395,960	$3,360,000	$8,755,960	$2,194,791	$976,202	$3,170,993	$11,926,953	$15,509,226
	PID Total	$10,400,960	$20,350,500	$30,751,460	$3,093,697	$5,831,369	$8,925,066	$39,676,526	$48,987,734
Tracking	Tracking GEM	$0	$1,396,200	$1,396,200	$623,628	$387,346	$1,010,973	$2,407,173	$2,956,895
	Tracking MM	$1,000,000	$475,260	$1,475,260	$2,719,636	$731,526	$3,451,162	$4,926,422	$6,253,342
	Tracking Silicon	$2,196,300	$5,124,700	$7,321,000	$4,124,521	$9,623,883	$13,748,405	$21,069,405	$26,798,949
	Tracking Total	$3,196,300	$6,996,160	$10,192,460	$7,467,785	$10,742,755	$18,210,540	$28,403,000	$36,009,186
Grand Total	Total 2021	$30,290,473	$76,184,402	$106,474,875	$19,138,720	$39,998,289	$59,137,009	$165,611,884	$205,769,626
	(Fraction to Total 2021)	18.3%	46.0%	64.3%	11.6%	24.2%	35.7%	100.0%	
	Detector R&D							$25,339,863	$28,921,946
Global Systems	Detector Management								$7,400,000
	Magnet								$28,700,000
	Detector Infrastructure								$26,400,000
	Detector Pre Ops & Com.								$8,700,000
Grand Total	Total Escalated								$305,891,572

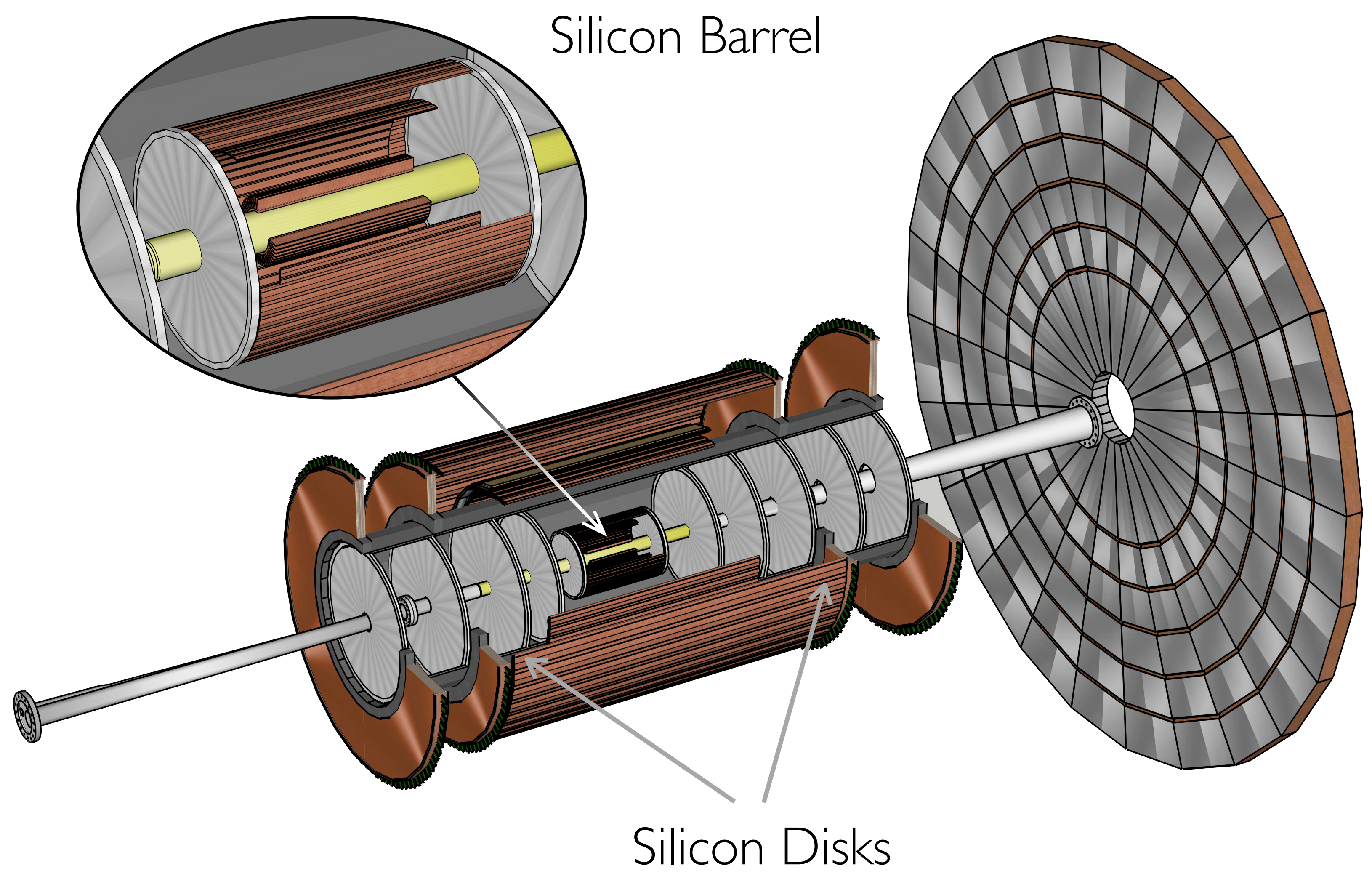
Costing - R&D

- Complete ATHENA R&D costing table:
- Main cost drivers: bECAL ($2.2M), FarBackward ($1.3M), PID ($7.3M), and Tracking ($14.5M)
- Total for sub-system R&D in 2021 USD: $25M

Sub-system	Sub-system components	In-Kind Material	Project Material	Total Material	In-Kind Labor	Project Labor	Total Labor	Total: 2021	Total: Escalated (Sub-system)
Calorimetry	nECAL	$0	$0	$0	$0	$0	$0	$0	$0
	nHCAL	$0	$0	$0	$0	$0	$0	$0	$0
	bECAL-Img	$0	$315,263	$315,263	$0	$1,726,613	$1,726,613	$2,041,875	$2,183,607
	bECAL-ScFi	$0	$200,000	$200,000	$0	$0	$0	$200,000	$225,325
	bHCAL	$0	$0	$0	$0	$0	$0	$0	$0
	pECAL	$0	$0	$0	$0	$0	$0	$0	$0
	pHCAL	$0	$0	$0	$0	$0	$0	$0	$0
	Calorimetry Total	$0	$515,263	$515,263	$0	$1,726,613	$1,726,613	$2,241,875	$2,408,932
DAQ	DAQ	$0	$0	$0	$0	$0	$0	$0	$0
FarBackward	FarBackward	$437,326	$0	$437,326	$883,071	$0	$883,071	$1,320,397	$1,473,164
FarForward	FarForward	$0	$0	$0	$0	$0	$0	$0	$0
PID	pfRICH	$0	$70,000	$70,000	$0	$749,654	$749,654	$819,654	$965,035
	bTOF	$49,995	$760,005	$810,000	$539,158	$1,597,781	$2,136,939	$2,946,939	$3,274,098
	hpDIRC	$140,000	$260,000	$400,000	$347,128	$376,450	$723,578	$1,123,578	$1,194,110
	dRICH	$252,900	$217,100	$470,000	$1,532,934	$374,827	$1,907,761	$2,377,761	$2,757,999
	PID Total	$442,895	$1,307,105	$1,750,000	$2,419,220	$3,098,712	$5,517,932	$7,267,932	$8,191,242
Tracking	Tracking GEM	$0	$252,000	$252,000	$244,102	$0	$244,102	$496,102	$511,602
	Tracking MM	$142,700	$0	$142,700	$1,066,489	$0	$1,066,489	$1,209,189	$1,375,056
	Tracking Silicon	$233,100	$1,555,900	$1,789,000	$4,189,509	$6,825,859	$11,015,368	$12,804,368	$14,961,950
	Tracking Total	$375,800	$1,807,900	$2,183,700	$5,500,100	$6,825,859	$12,325,959	$14,509,659	$16,848,608
Grand Total	Total	$1,256,021	$3,630,268	$4,886,289	$8,802,391	$11,651,184	$20,453,575	$25,339,863	$28,921,946
	(Fraction to Total 2021)	5.0%	14.3%	19.3%	34.7%	46.0%	80.7%	100.0%	

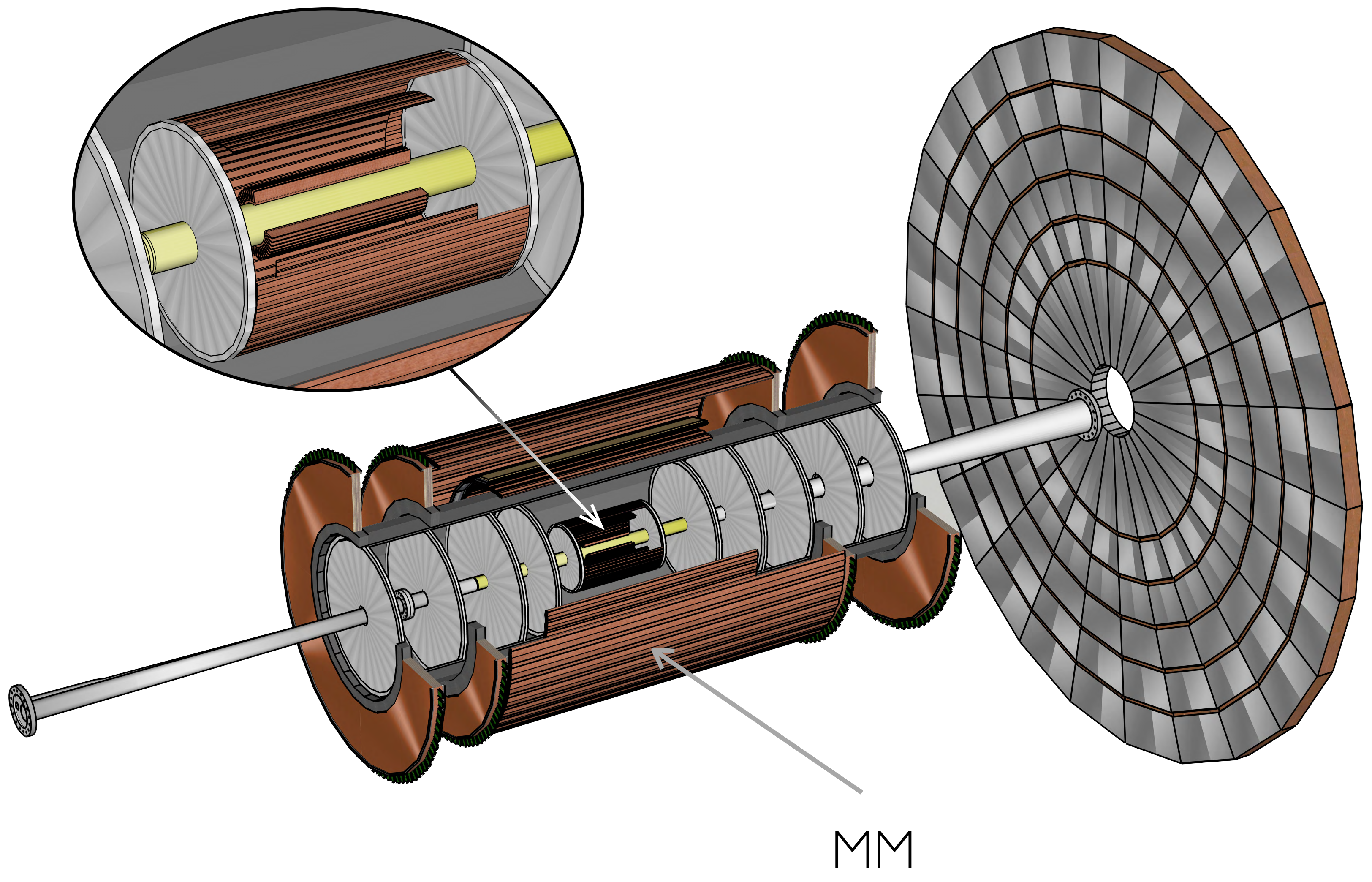
Costing - Tracking Silicon

- Proposed silicon-based vertex and tracking detectors will use 65nm CMOS MAPS sensors, developed by the EIC Silicon Consortium (SC) with the ALICE ITS3 collaboration
- Sensor costing: Conservative estimate, pending completion of R&D at CERN and EIC SC institutions
- Mechanics, Readout, Cooling, and Services costing: Actual costing for recently completed ALICE ITS2 detector with improvements of lower mass
- In-Kind contributions: ~30%
  - UK planned contribution of ~$7M for material and labor
  - INFN planned contribution of ~$1M for material and ~$1M for labor



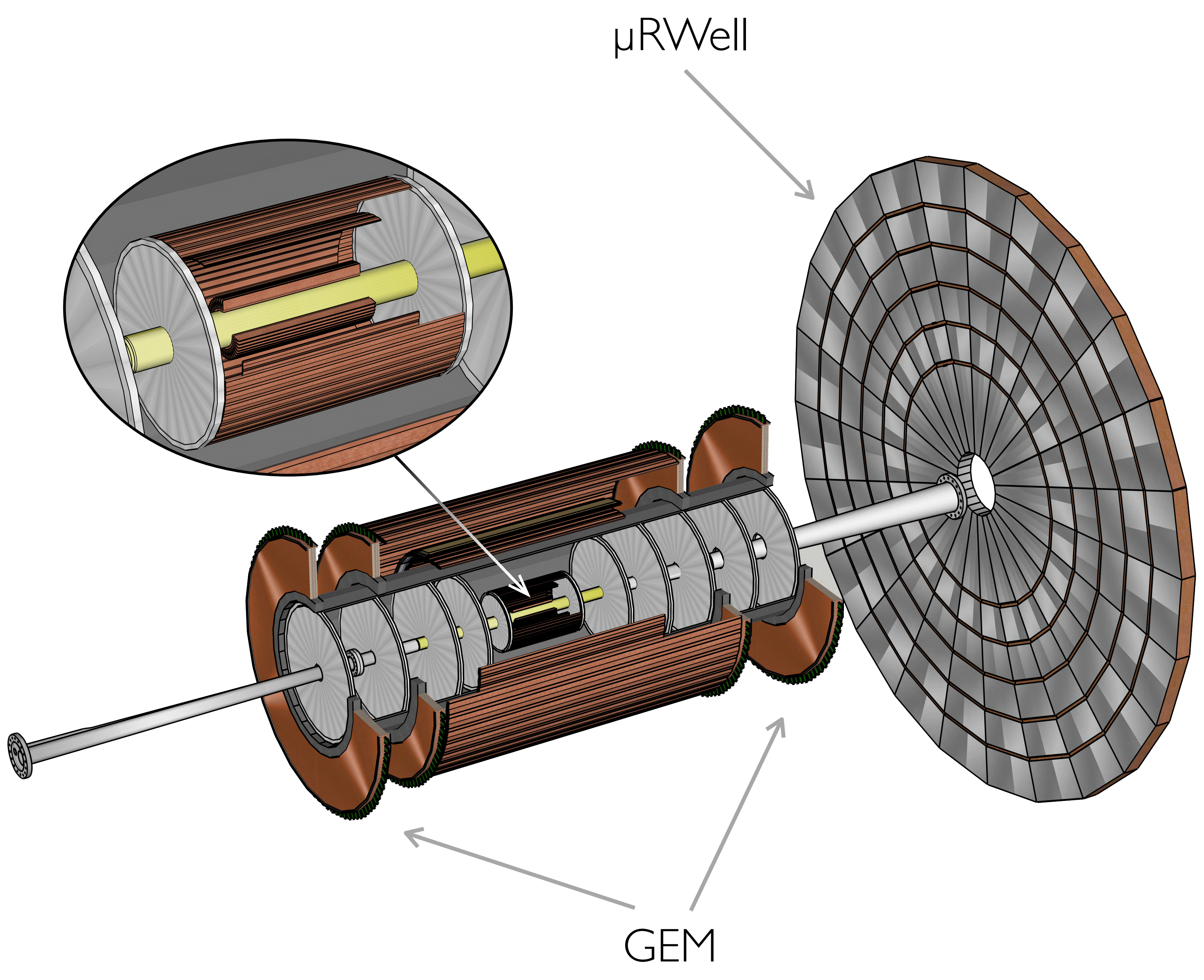
Costing - Tracking MM

- Proposed Cylindrical Barrel MicroMegas tracker is based on the Barrel MicroMegas Tracker (BMT) for CLAS12 at JLab under the leadership of CEA-Saclay
- R&D focuses on 2-D readout optimization and new ASIC development, serving all MPGD detector systems
- Cost basis: CLAS12 BMT and ATLAS New Small Wheel detector, including development, testing, and production for detector components and readout
- Costing for FEE and electronics based on currently available technology!
- In-Kind contributions by CEA-Saclay:
  - R&D labor cost and prototype phase
  - $1M In-Kind equipment towards construction of MM

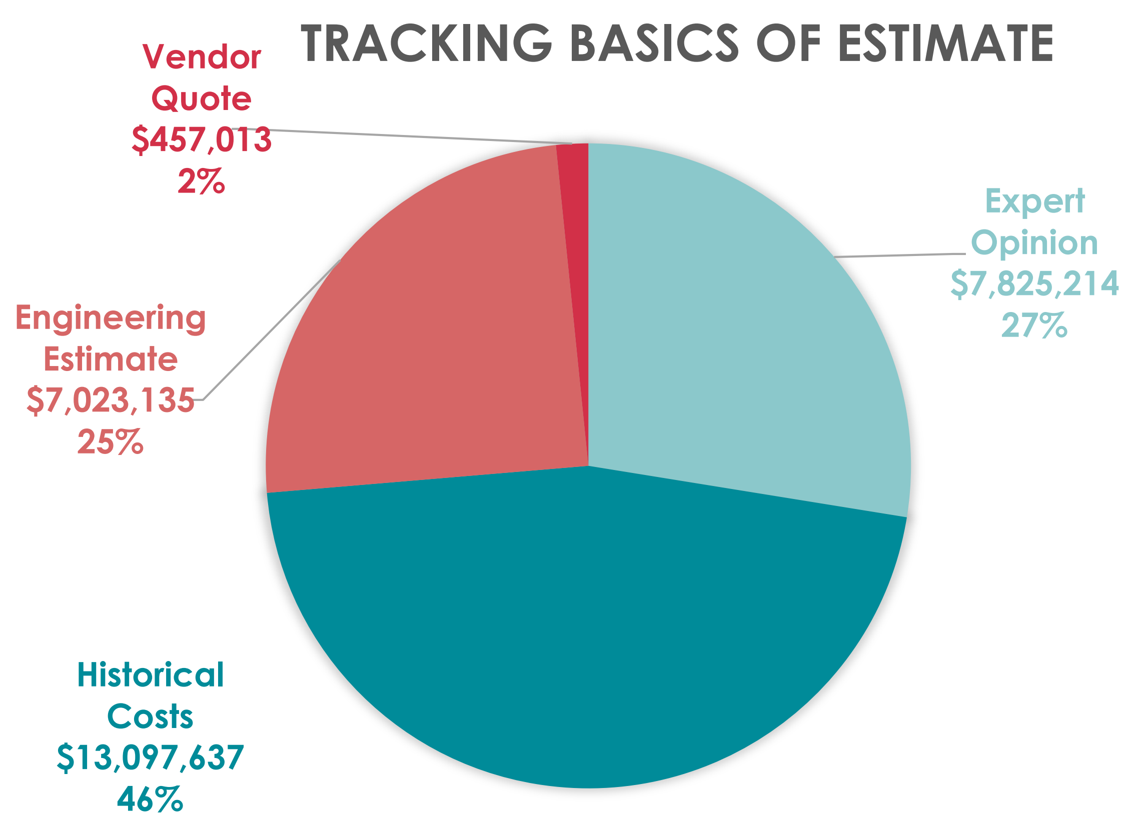


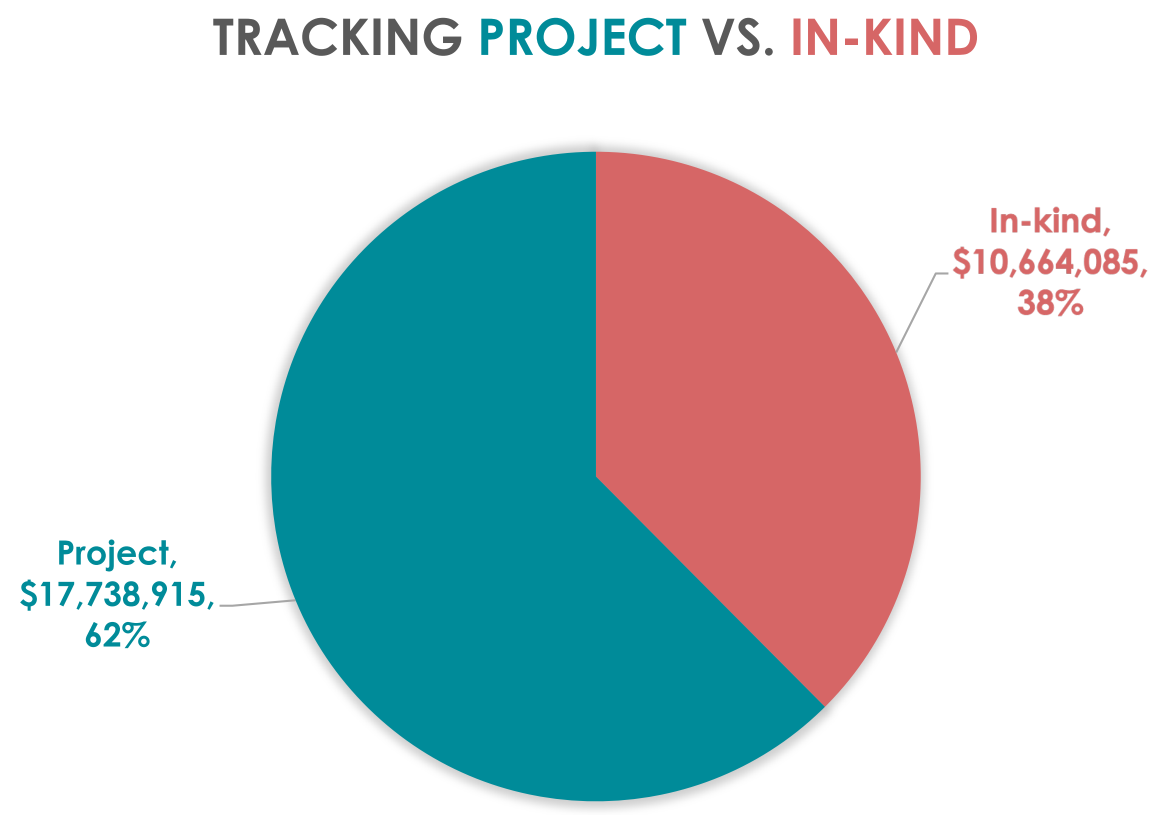
Costing - Tracking GEM

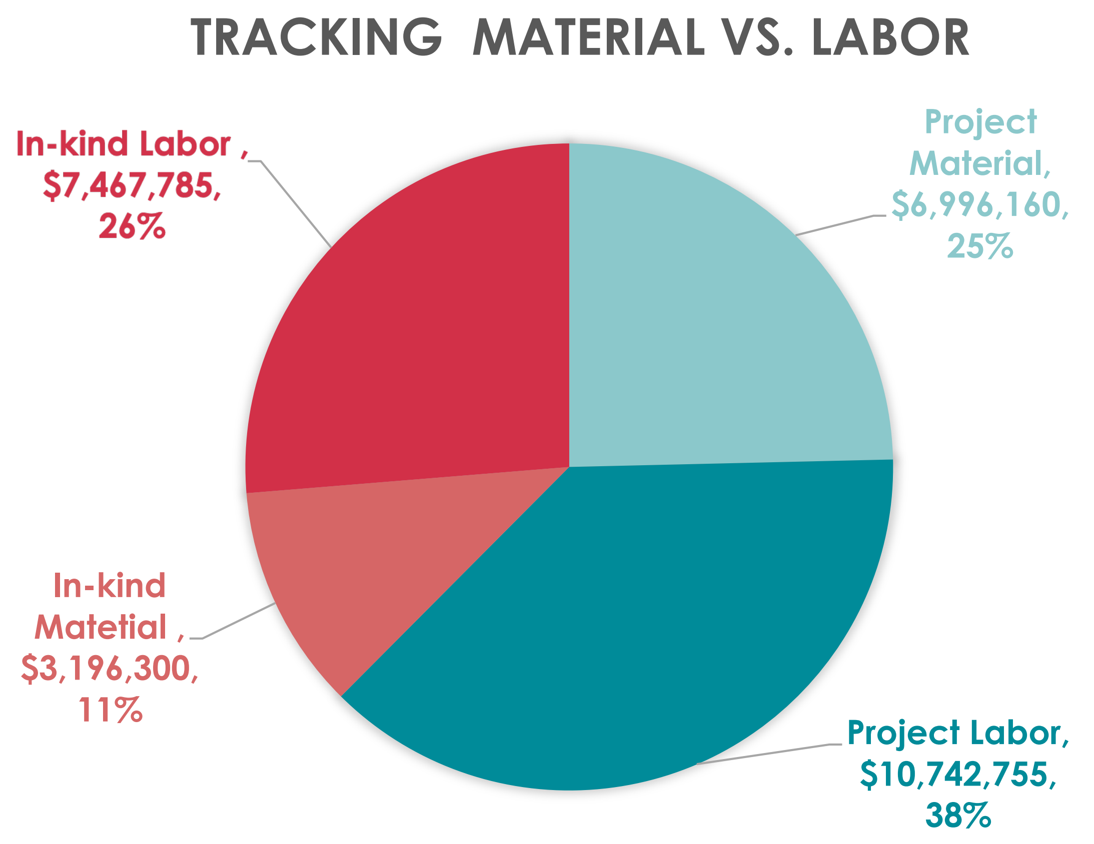
- Proposed MPGD-type disk tracker based on GEM technology and µRWell technology with numerous applications at BNL, JLab, and CERN, paired with multi-year experience and resources
- R&D focuses on readout layer optimization, prototyping and µRWell development
- Cost basis: Triple-GEM detector layout at BNL (STAR/sPHENIX) and quotations from CERN for GEM foils, HV foils, 2-D readout foils - Scaled by channel count and number of modules for HV and gas system
- Costing for µRWell based on GEM-detector costing, adapted to µRWell configuration
- Costing for FEE based on complete FEE layout of GEM Tracker at STAR
- In-Kind contributions: Student and scientist labor!

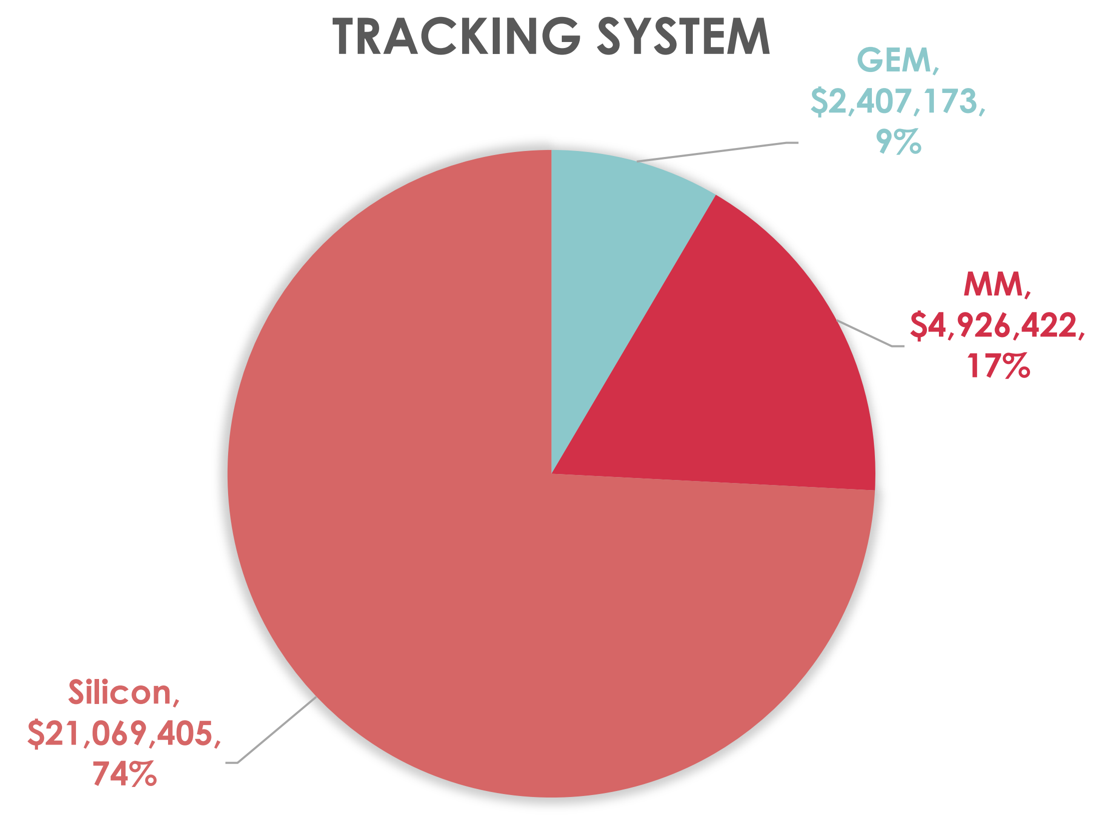


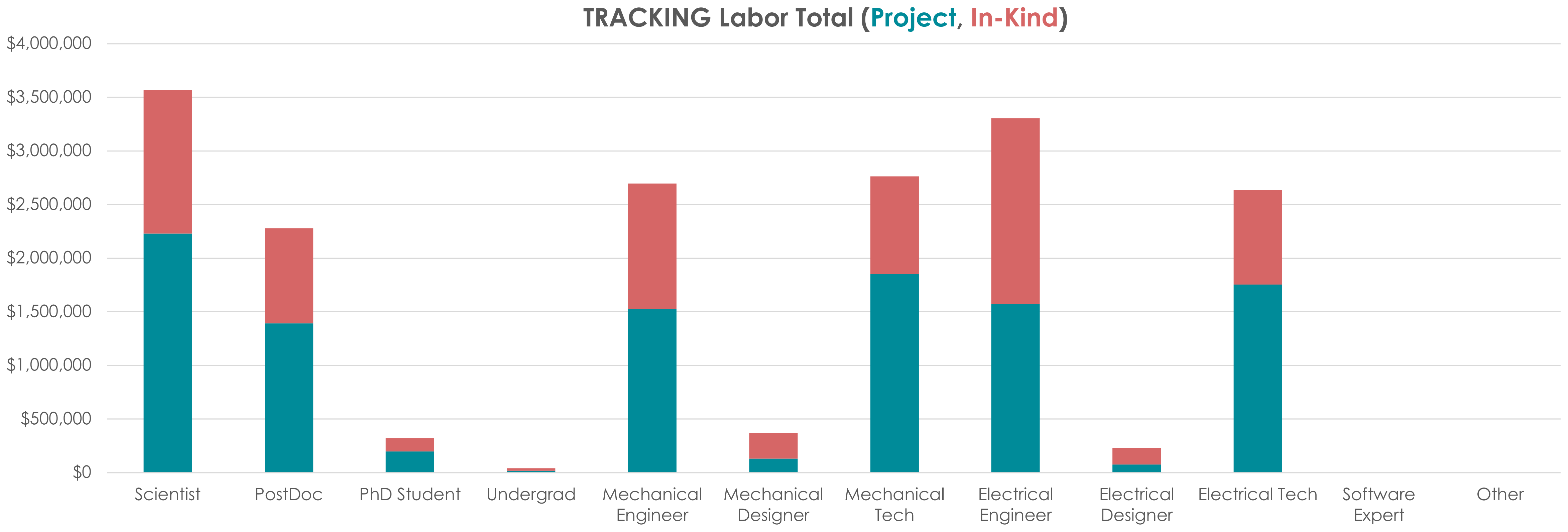
Costing - Tracking Overview

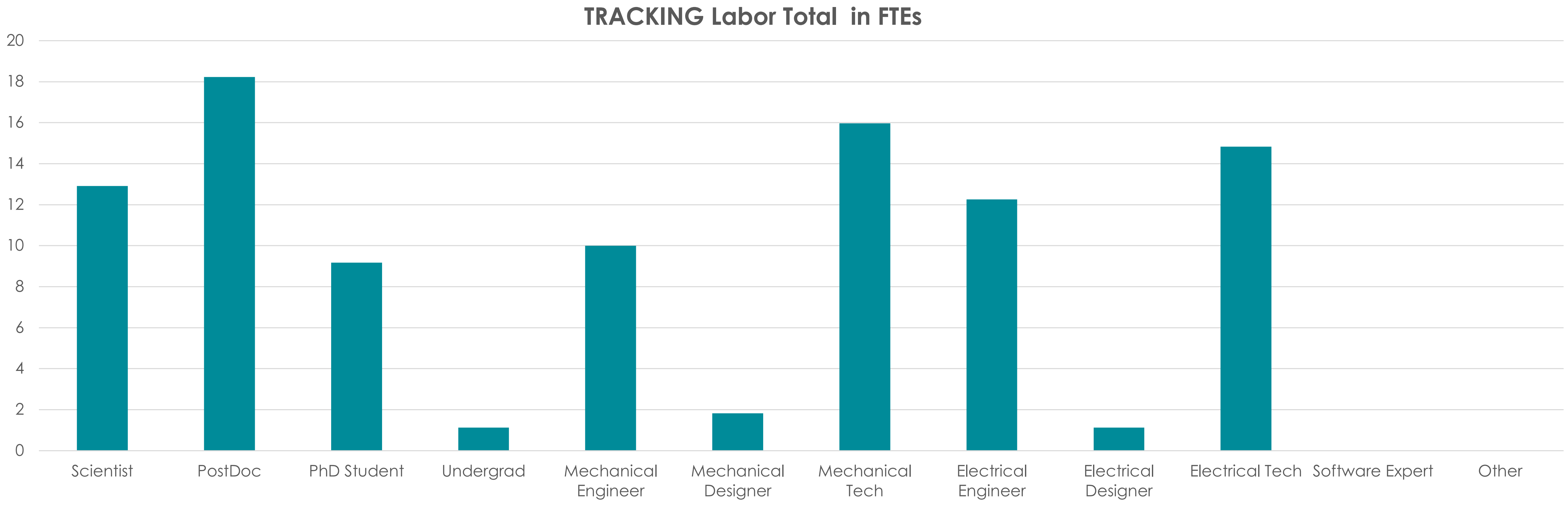






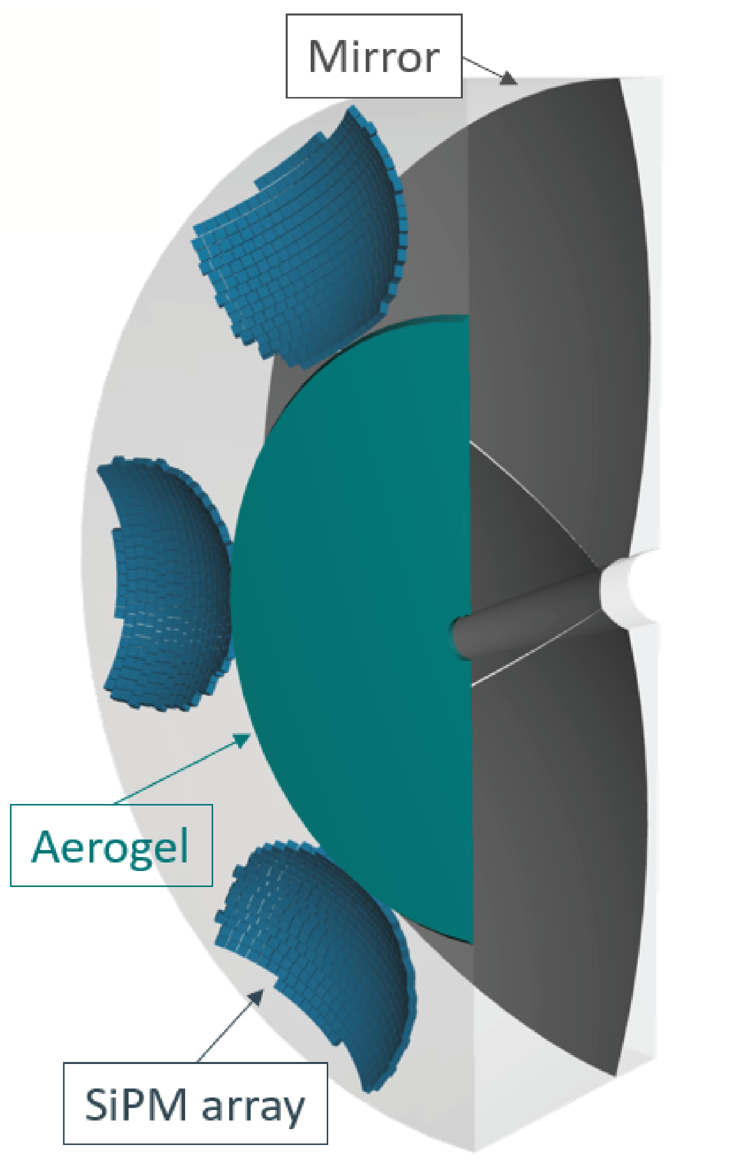




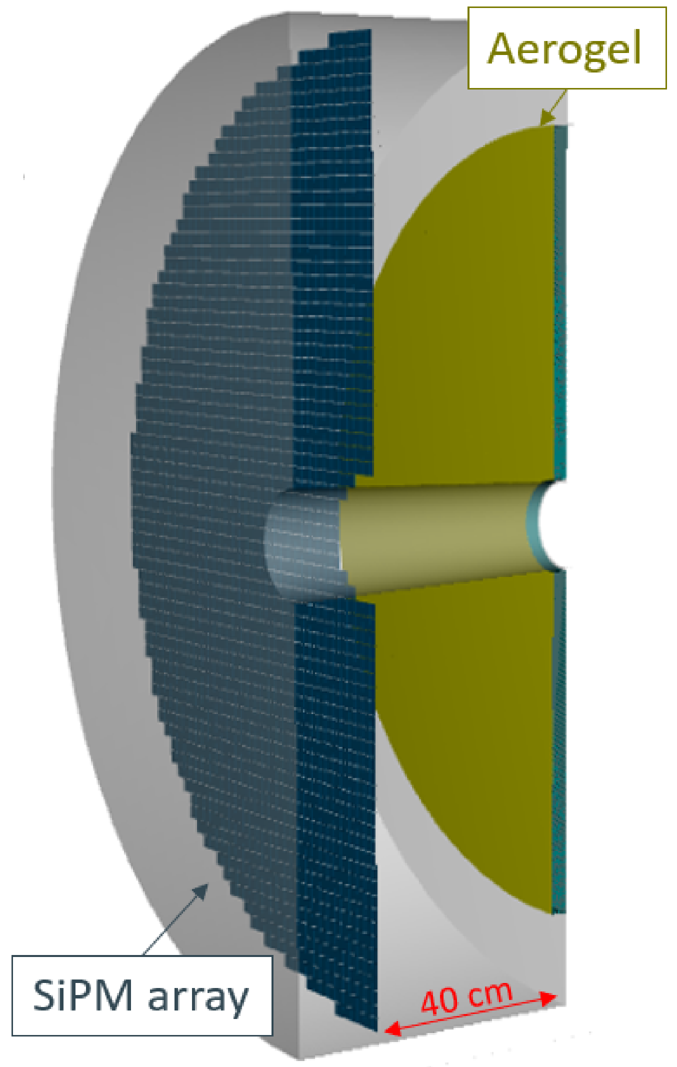


Costing - dRICH and pfRICH

- Proposed RICH detectors profit from expertise from RICH detector applications at CLAS12 and COMPASS and existing projects involving SiPM and readout electronics
- R&D focuses on geometry definition, including radiator and production of small-scale prototypes (Photosensor definition with SiPM baseline) and ASIC and related electronics
- pfRICH derives from dRICH layout, including costing scaled to pfRICH size for sensor area and aerogel tiles
- In-Kind contributions:
  - INFN planned contribution of ~\$6M in material and \$3.7M in labor costs
  - Goal: ~65% of total in-kind contribution!



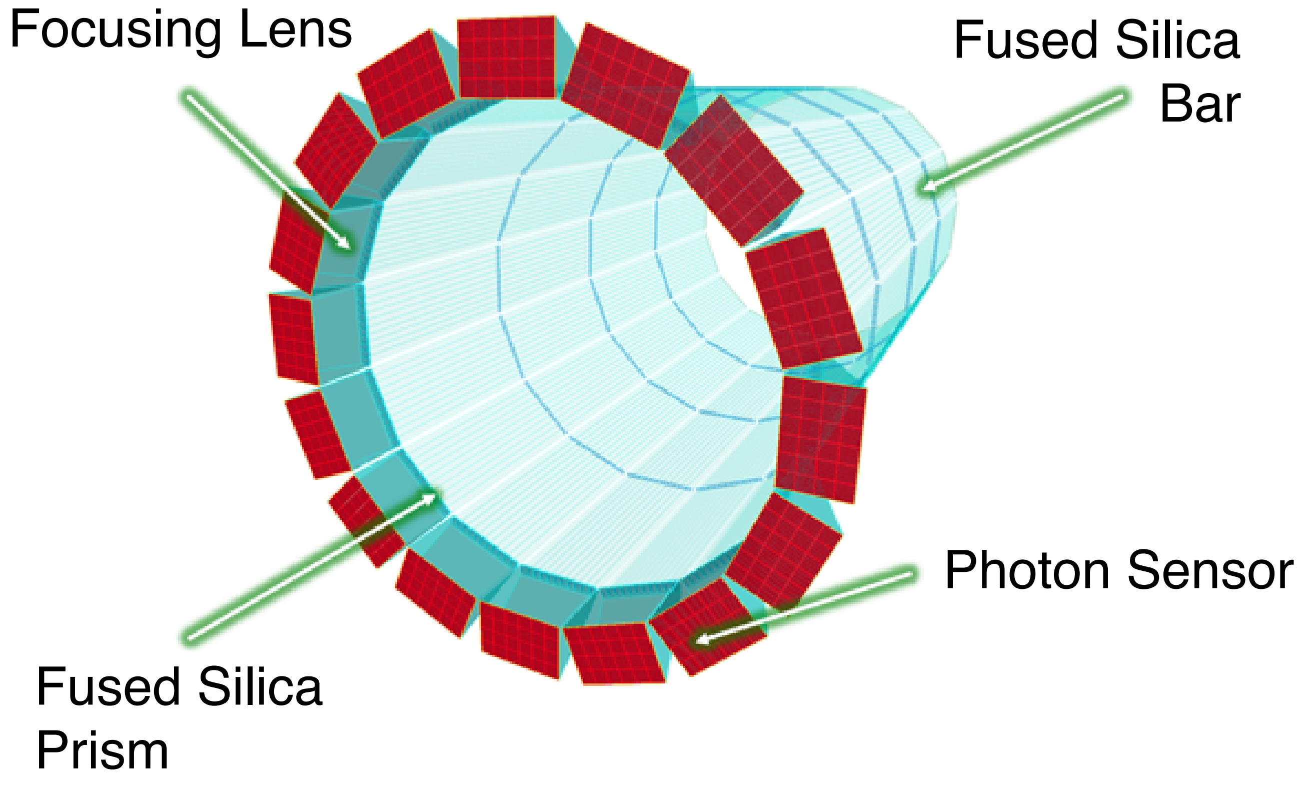
dRICH



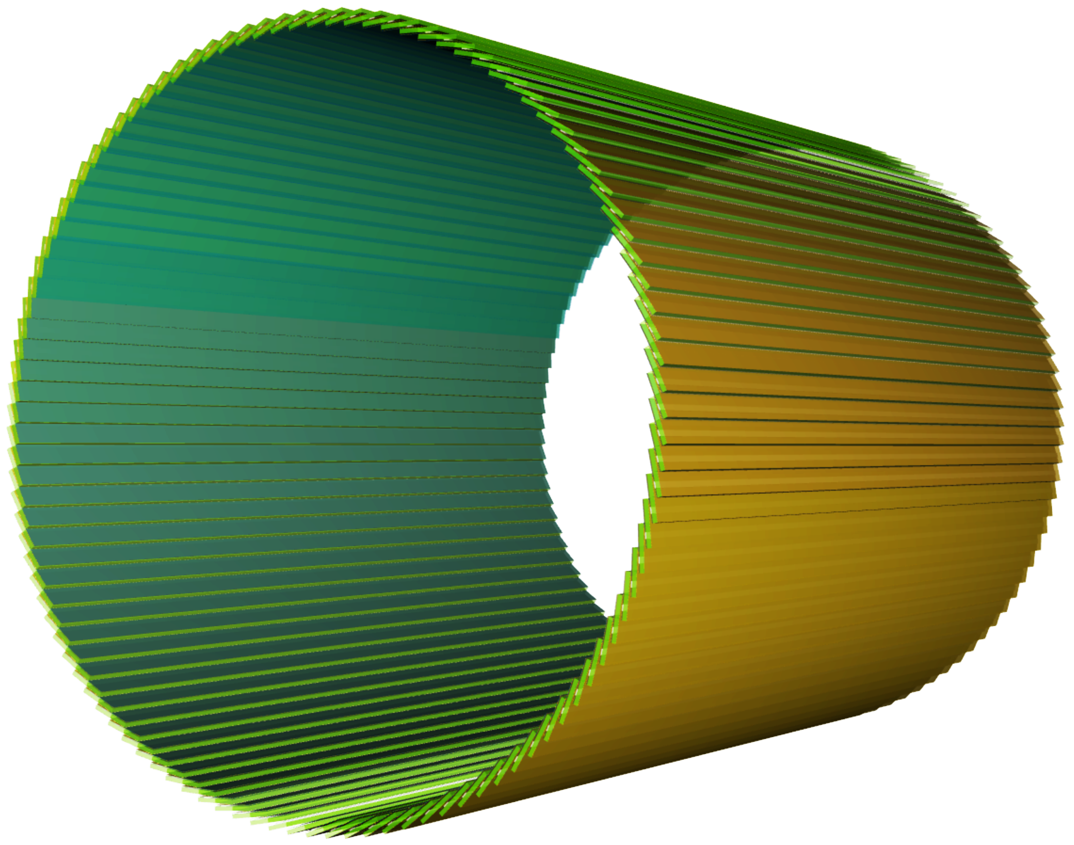
pfRICH

Costing - hpDIRC and bTOF

- Proposed hpDIRC detector is based on costing experience from the PANDA Barrel DIRC and expertise from BaBar and Belle-II
- Main cost drivers: Bars and sensors
- Assumption: Disassembly of BaBar boxes will yield sufficient number of high-quality bars
- In-kind contributions and project R&D: Bar boxes, disassembly, and bar QA
- Additional in-kind labor contributions: CUA and GSI DIRC experts
- Costing for bTOF is derived from similar projects
- bTOF R&D is focusing on AC-LGAD sensor development and corresponding ASIC

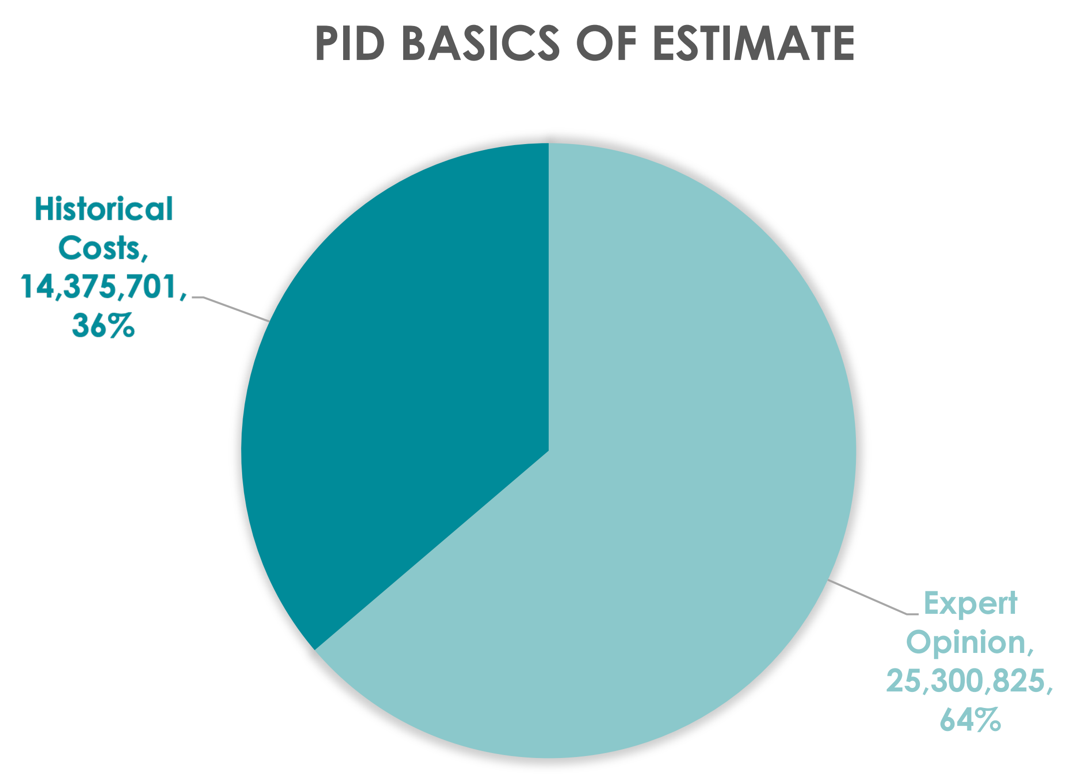


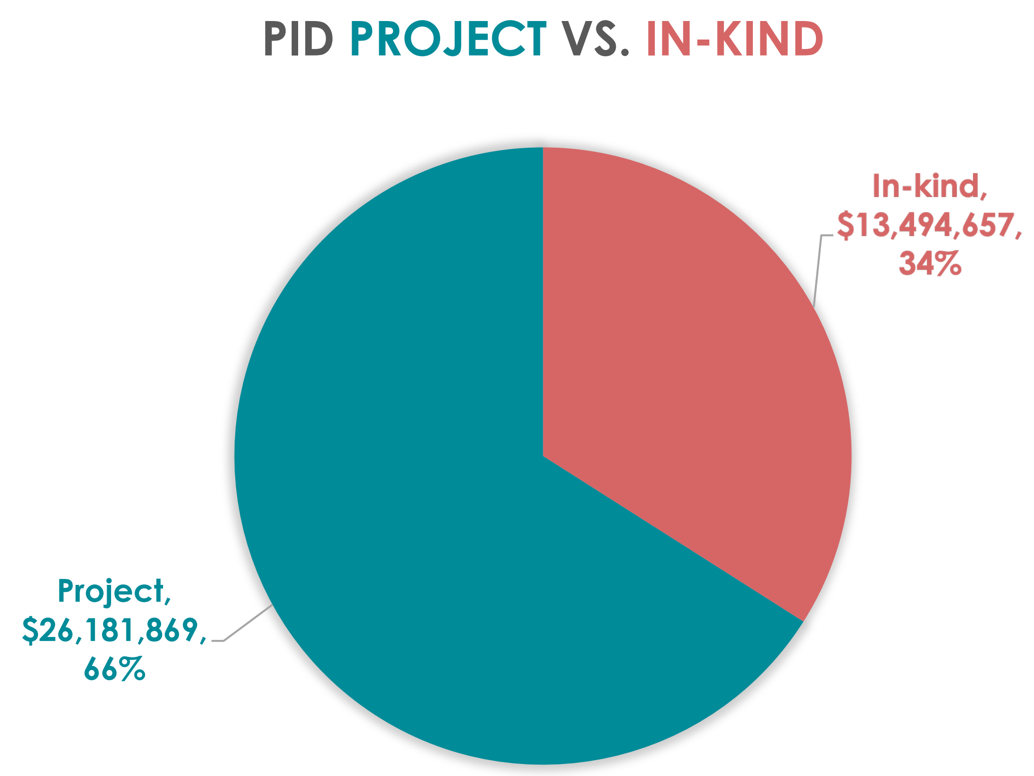
hpDIRC

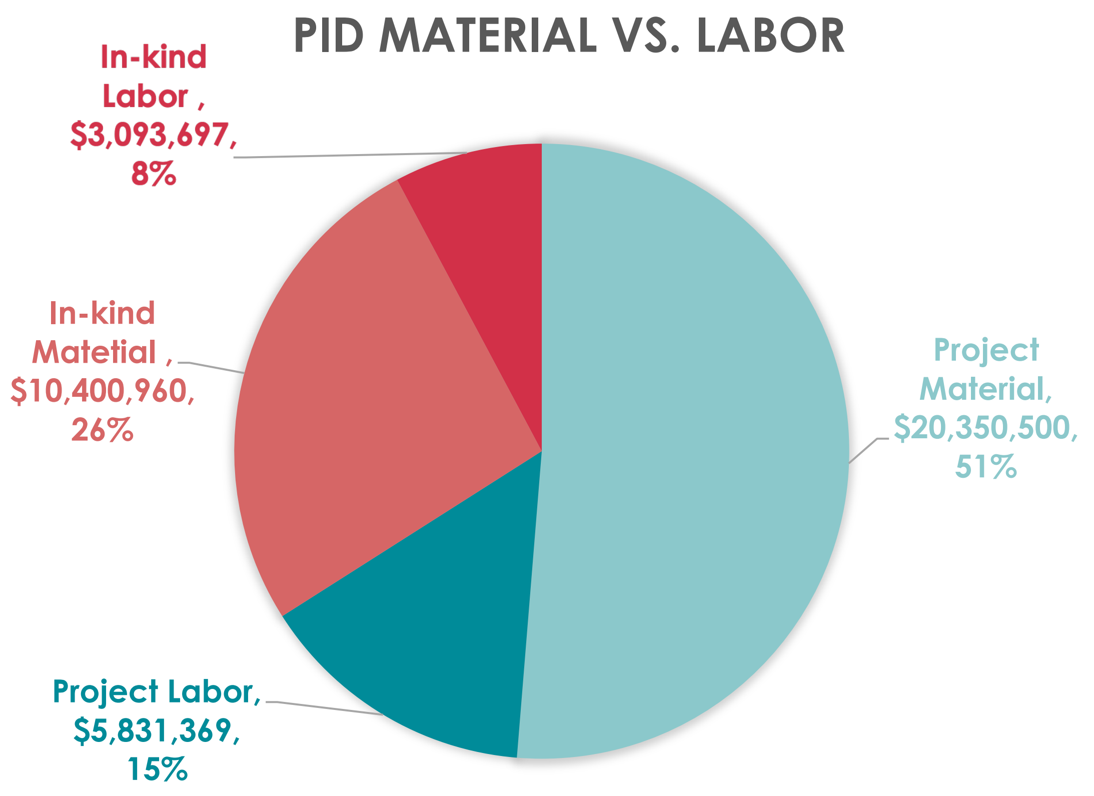


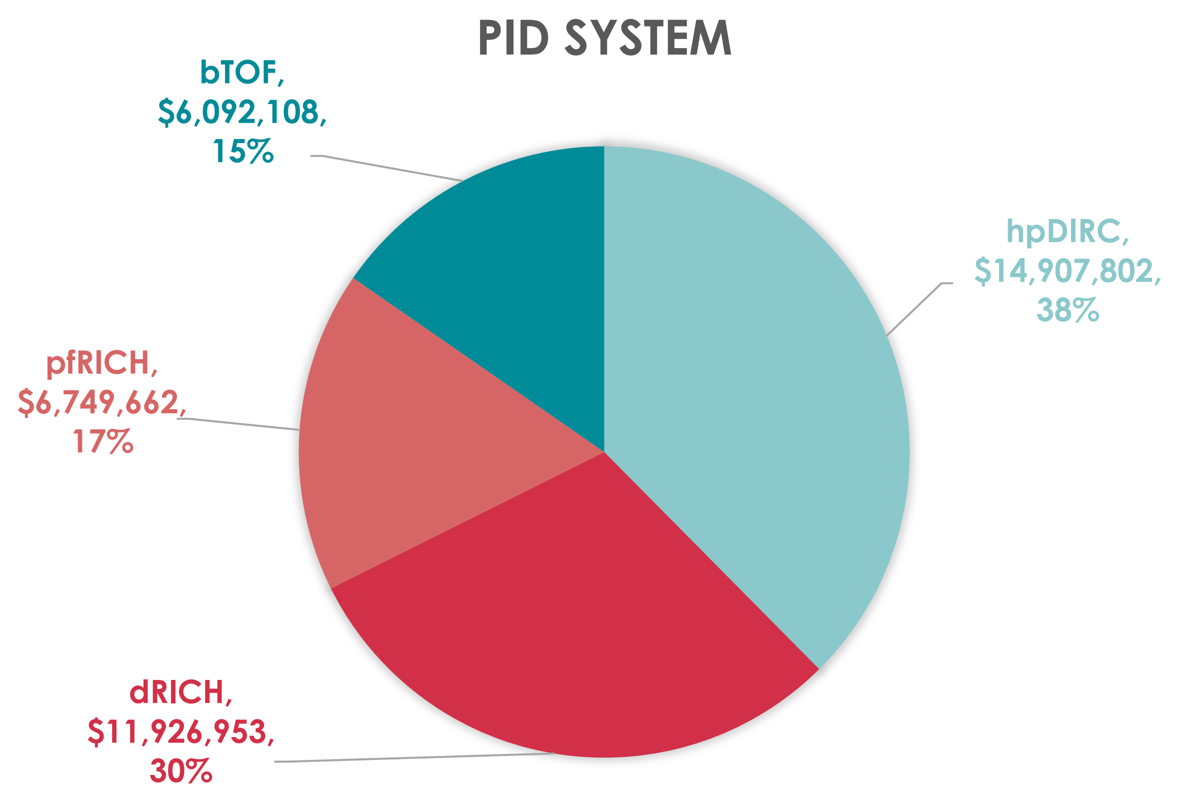
bTOF

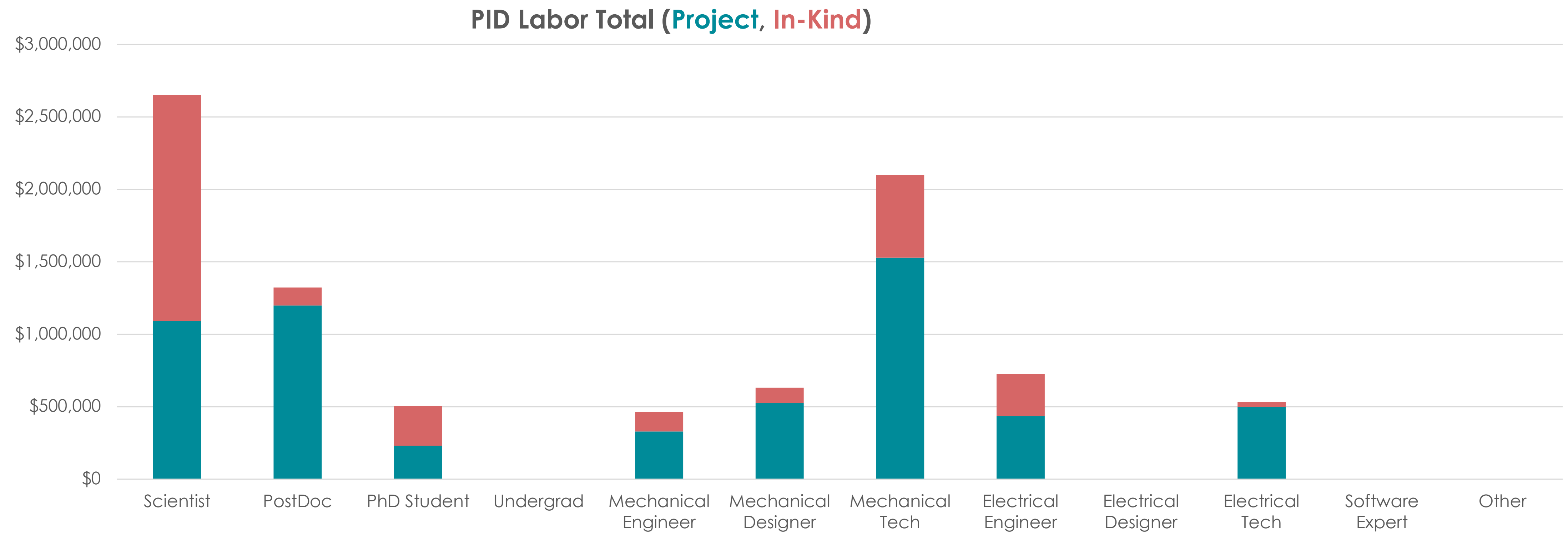
Costing

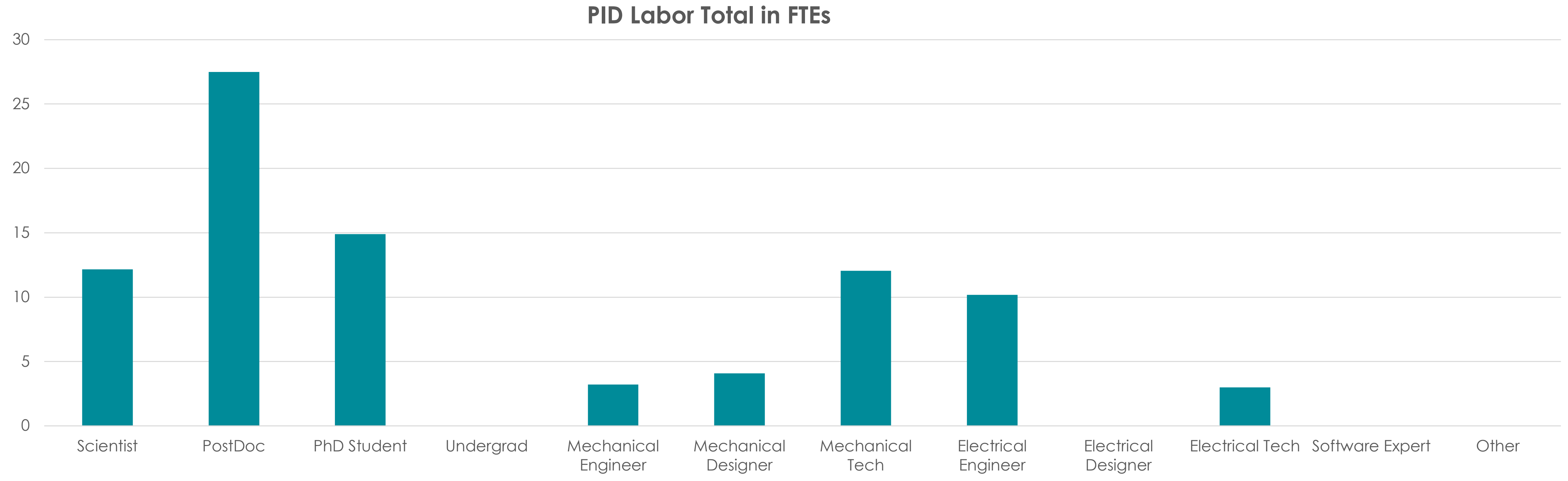

PID BASICS OF ESTIMATE
Historical Costs, 14,375,701, 36%
Expert Opinion, 25,300,825, 64%


PID PROJECT VS. IN-KIND
In-kind, $13,494,657, 34%
Project, $26,181,869, 66%


PID MATERIAL VS. LABOR
In-kind Labor , $3,093,697, 8%
In-kind Matetial , $10,400,960, 26%
Project Material, $20,350,500, 51%
Project Labor, $5,831,369, 15%

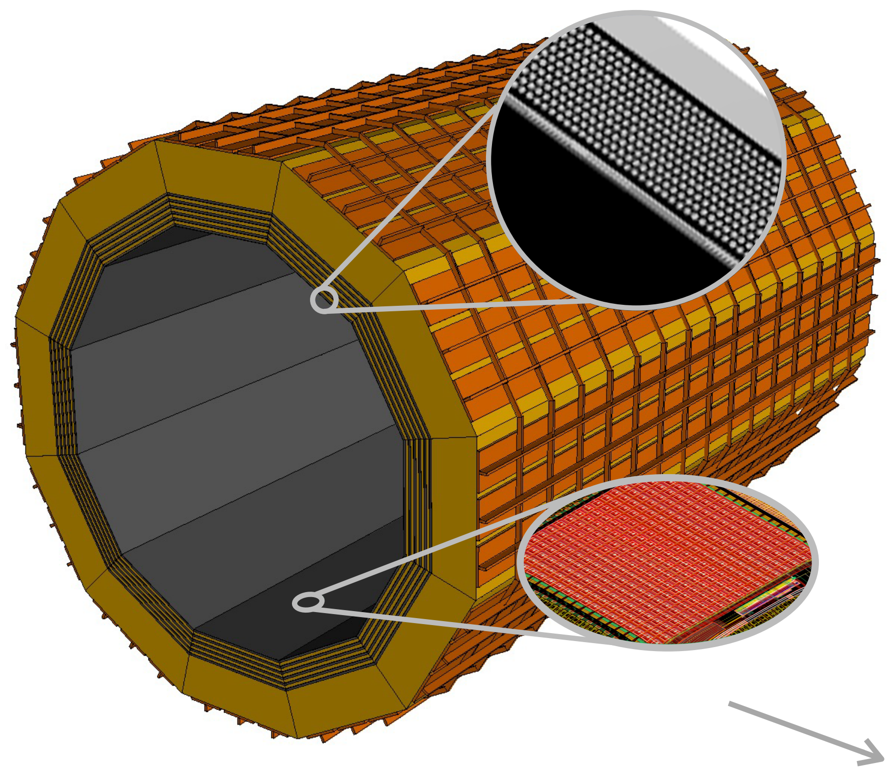

PID SYSTEM
bTOF, $6,092,108, 15%
hpDIRC, $14,907,802, 38%
pfRICH, $6,749,662, 17%
dRICH, $11,926,953, 30%


PID Labor Total (Project, In-Kind)
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

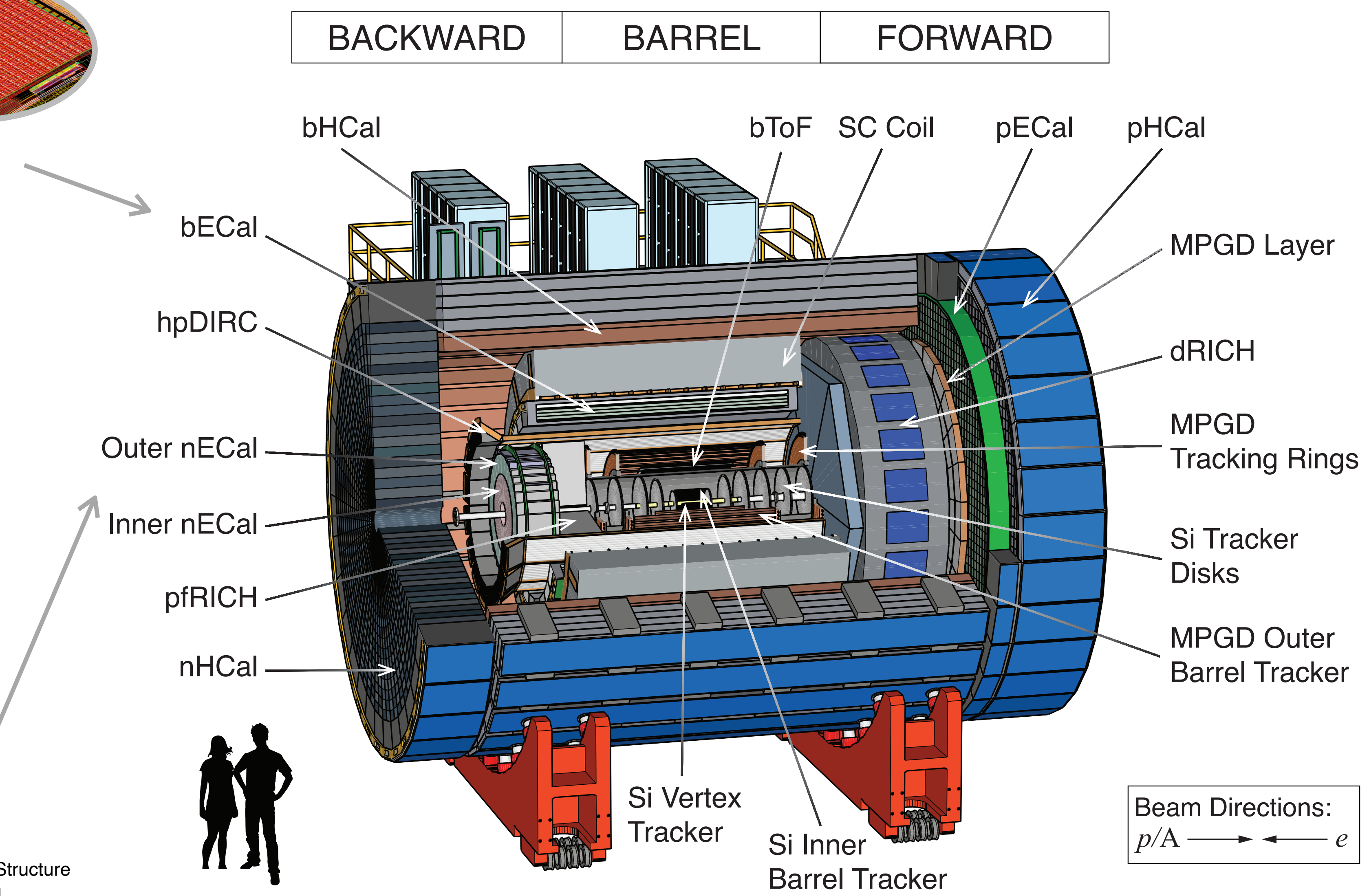

PID Labor Total in FTEs
30
25
20
15
10
5
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

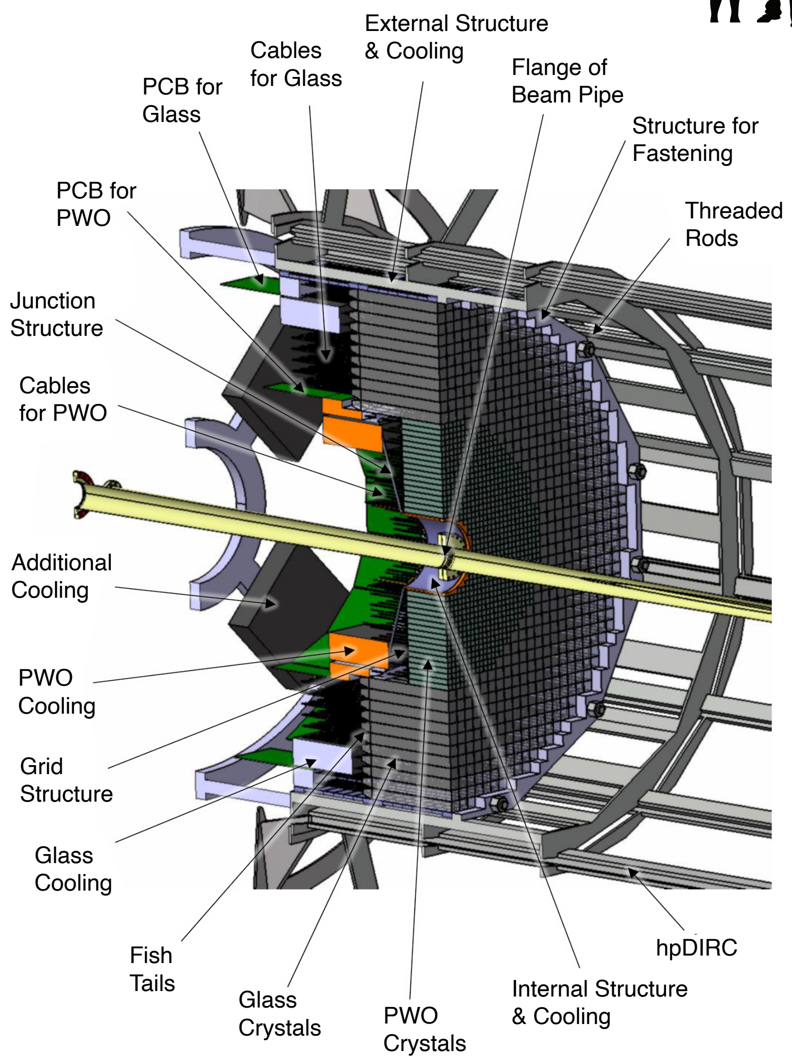
Costing - ECAL / HCAL

- Proposed ATHENA calorimeter systems based on extensive experience with several large-scale calorimeter construction projects funded by DOE and NSF at BNL and JLab
- Costing includes design, R&D, procurement, fabrication, assembly, installation, and testing of each calorimeter sub-system
- Material costs: Based on recently obtained quotes whenever possible
- Labor costs: Based on scaling from other calorimeter projects
- In-Kind contributions:
  - Re-purposed components from STAR experiment (Flux return steel, cradles, EMC scintillation megatiles for nHCal, bHCal, and pHCal)
  - Labor contributions estimated from similar construction projects



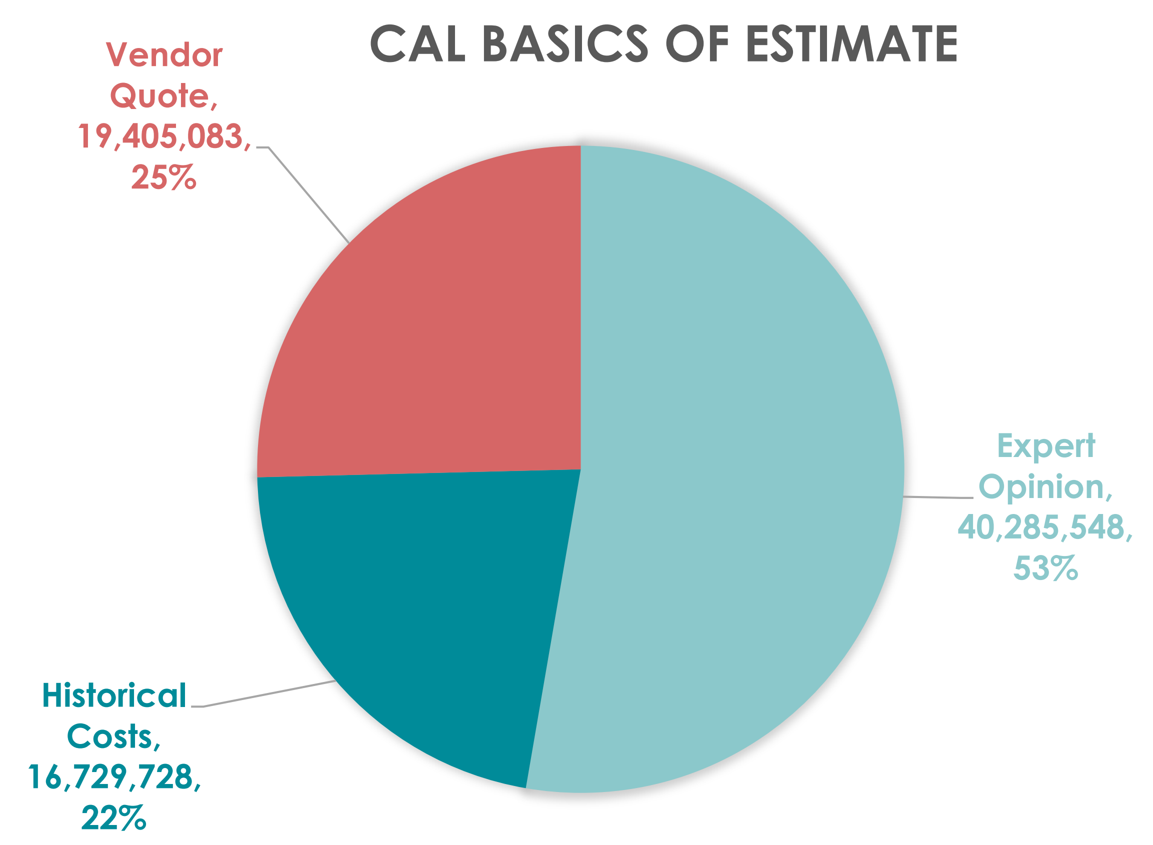
bECAL

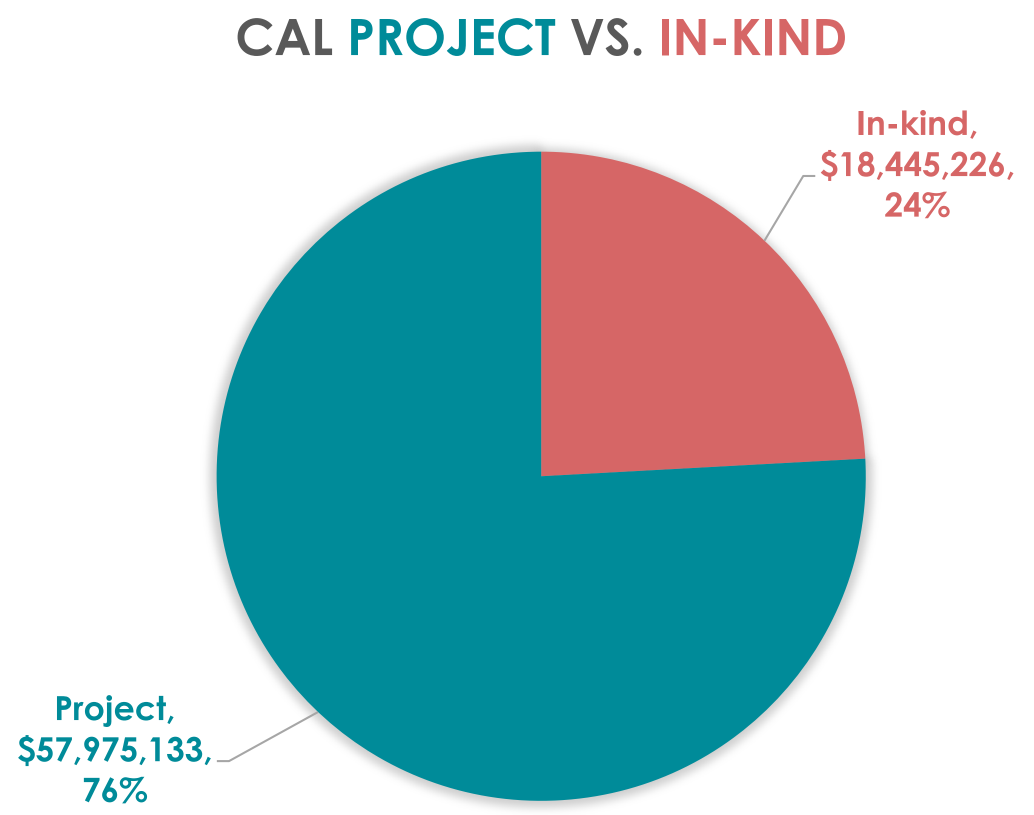


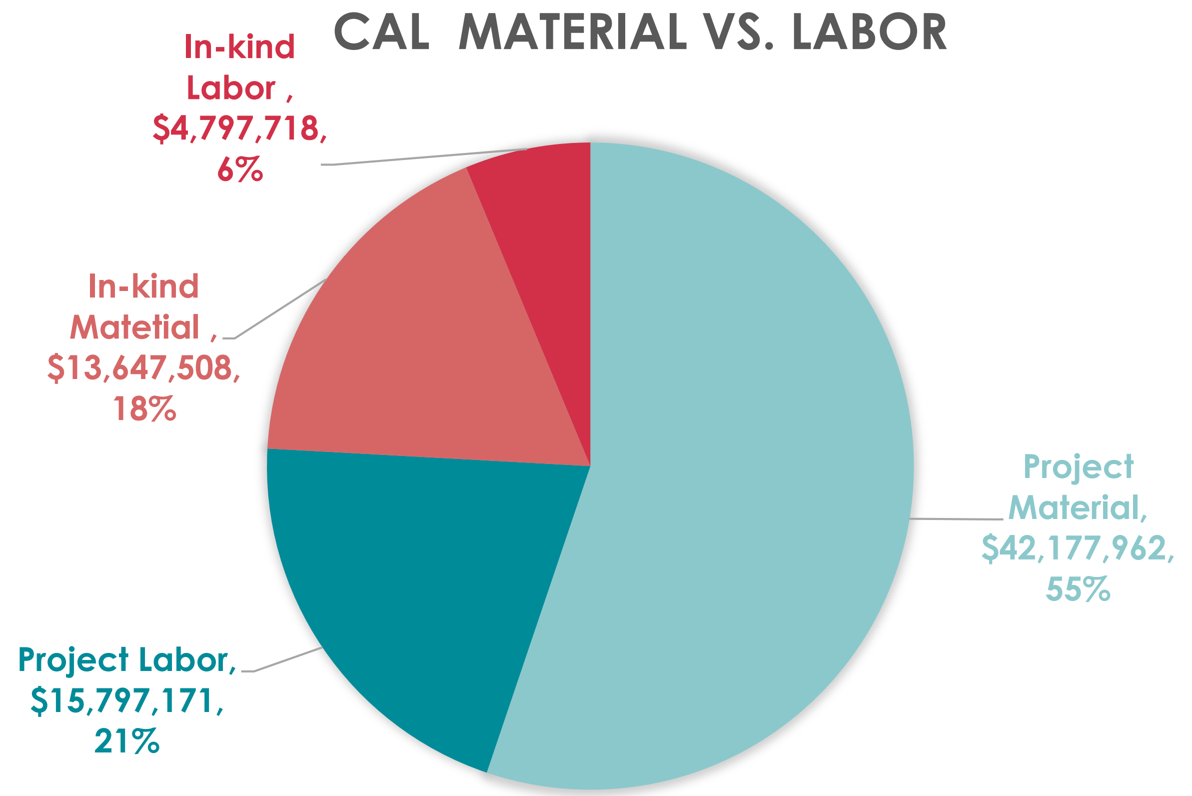


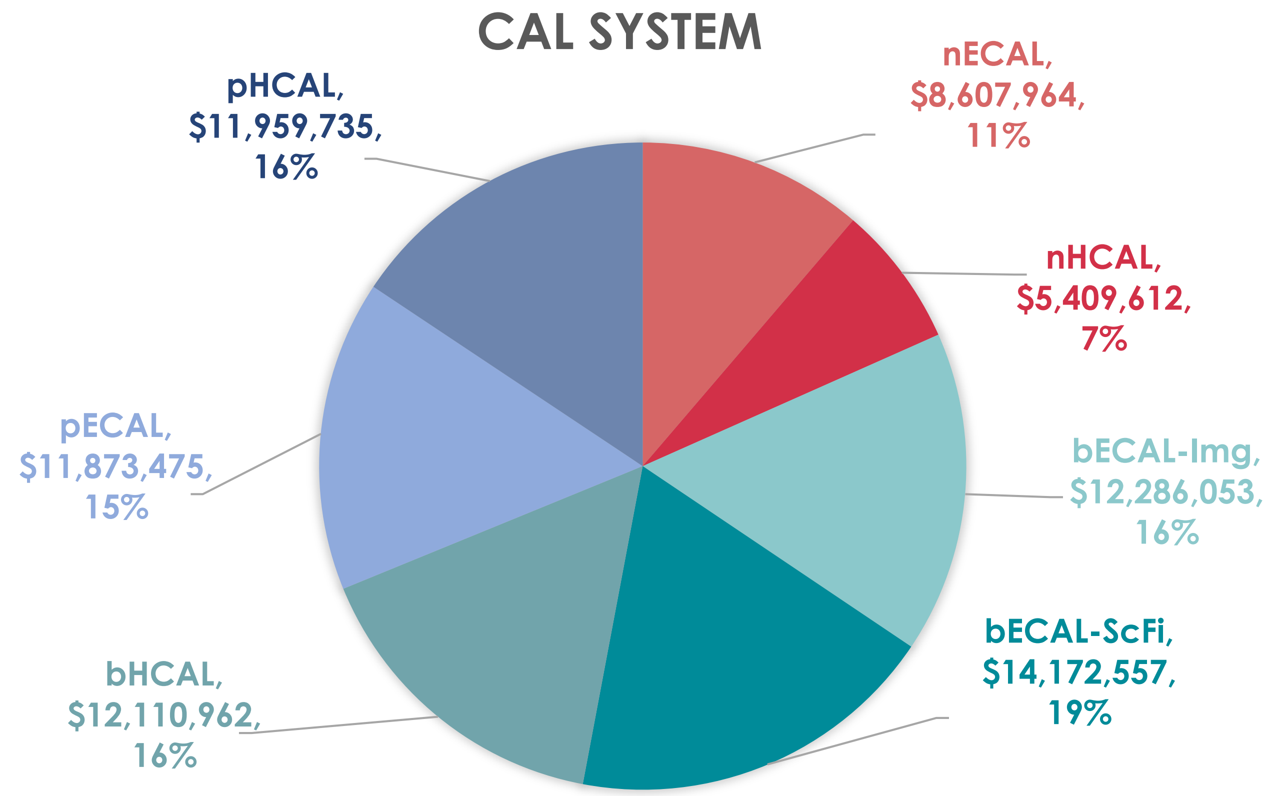
nECAL

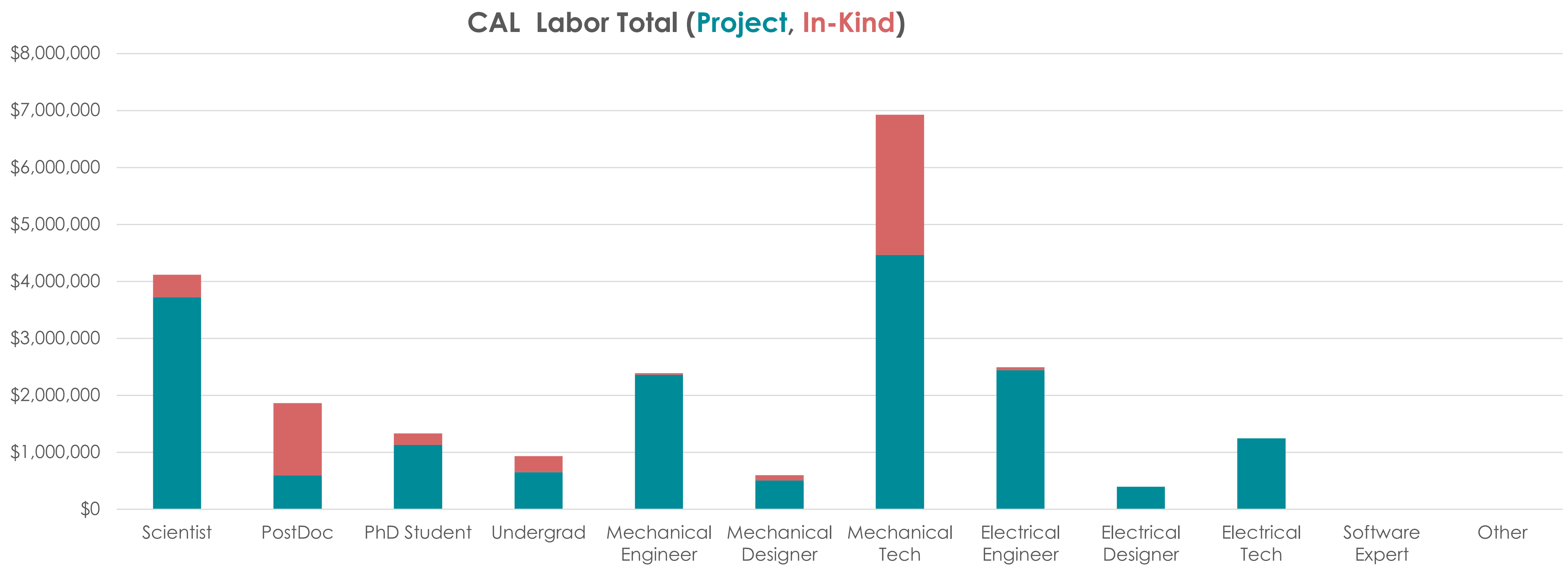
Costing

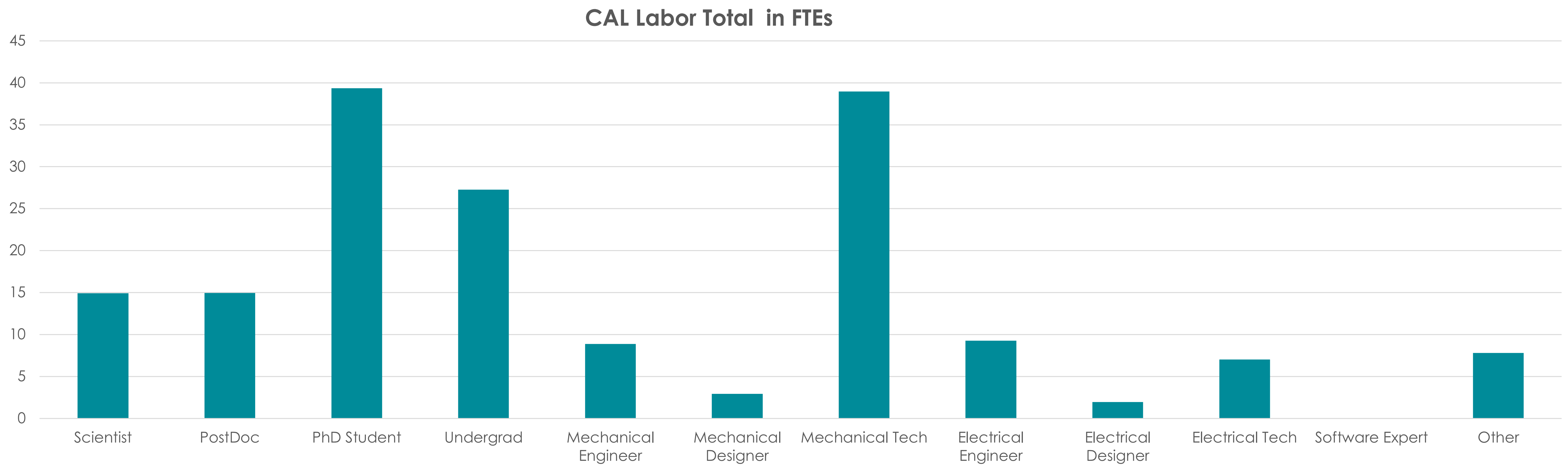

CAL BASICS OF ESTIMATE
Vendor Quote, 19,405,083, 25%
Expert Opinion, 40,285,548, 53%
Historical Costs, 16,729,728, 22%


CAL PROJECT VS. IN-KIND
In-kind, $18,445,226, 24%
Project, $57,975,133, 76%


CAL MATERIAL VS. LABOR
In-kind Labor , $4,797,718, 6%
In-kind Matetial , $13,647,508, 18%
Project Material, $42,177,962, 55%
Project Labor, $15,797,171, 21%

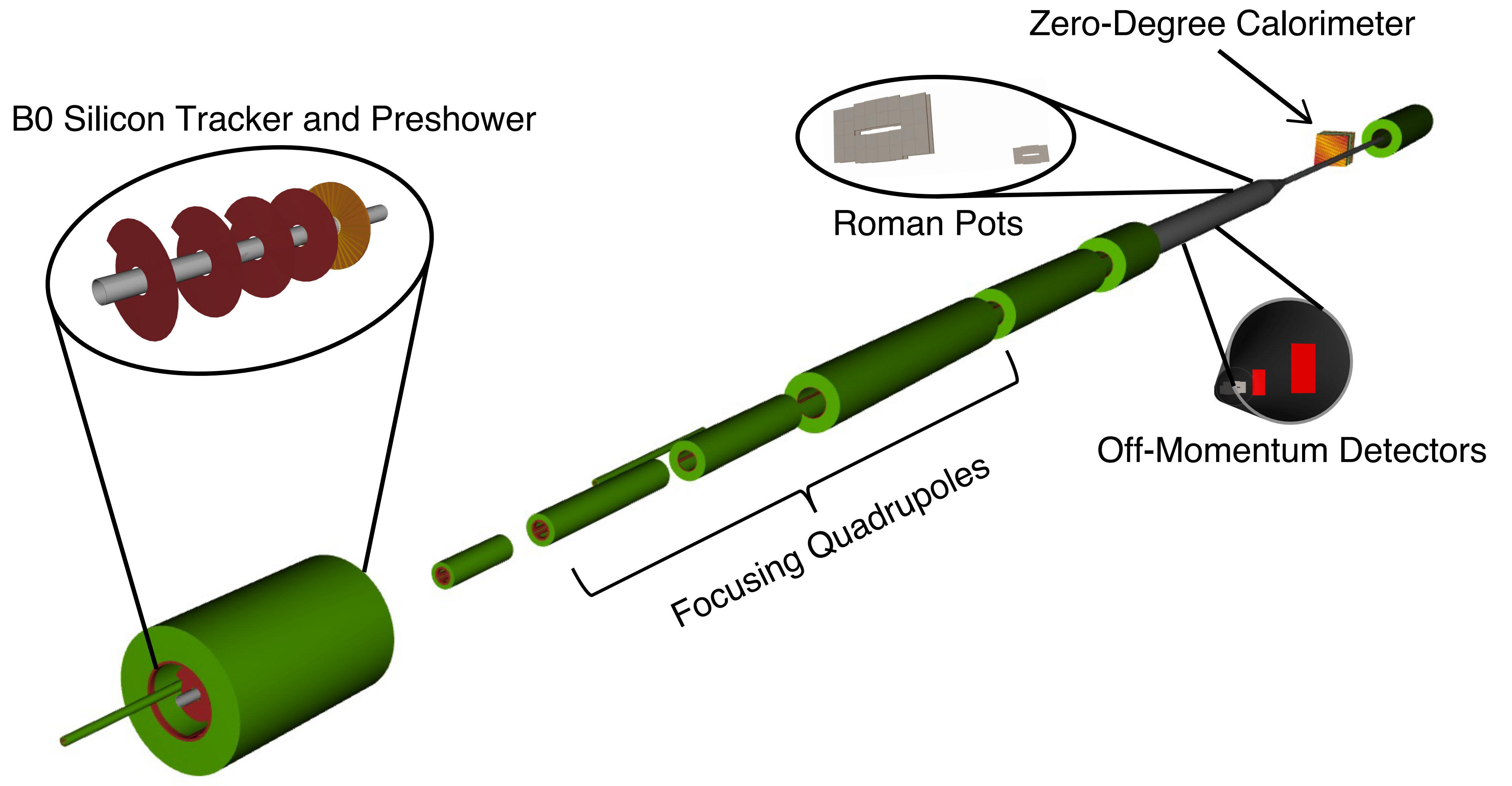

CAL SYSTEM
nECAL, $8,607,964, 11%
nHCAL, $5,409,612, 7%
bECAL-Img, $12,286,053, 16%
bECAL-ScFi, $14,172,557, 19%
bHCAL, $12,110,962, 16%
pECAL, $11,873,475, 15%
pHCAL, $11,959,735, 16%


CAL Labor Total (Project, In-Kind)
$8,000,000
$7,000,000
$6,000,000
$5,000,000
$4,000,000
$3,000,000
$2,000,000
$1,000,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other


CAL Labor Total in FTEs
45
40
35
30
25
20
15
10
5
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

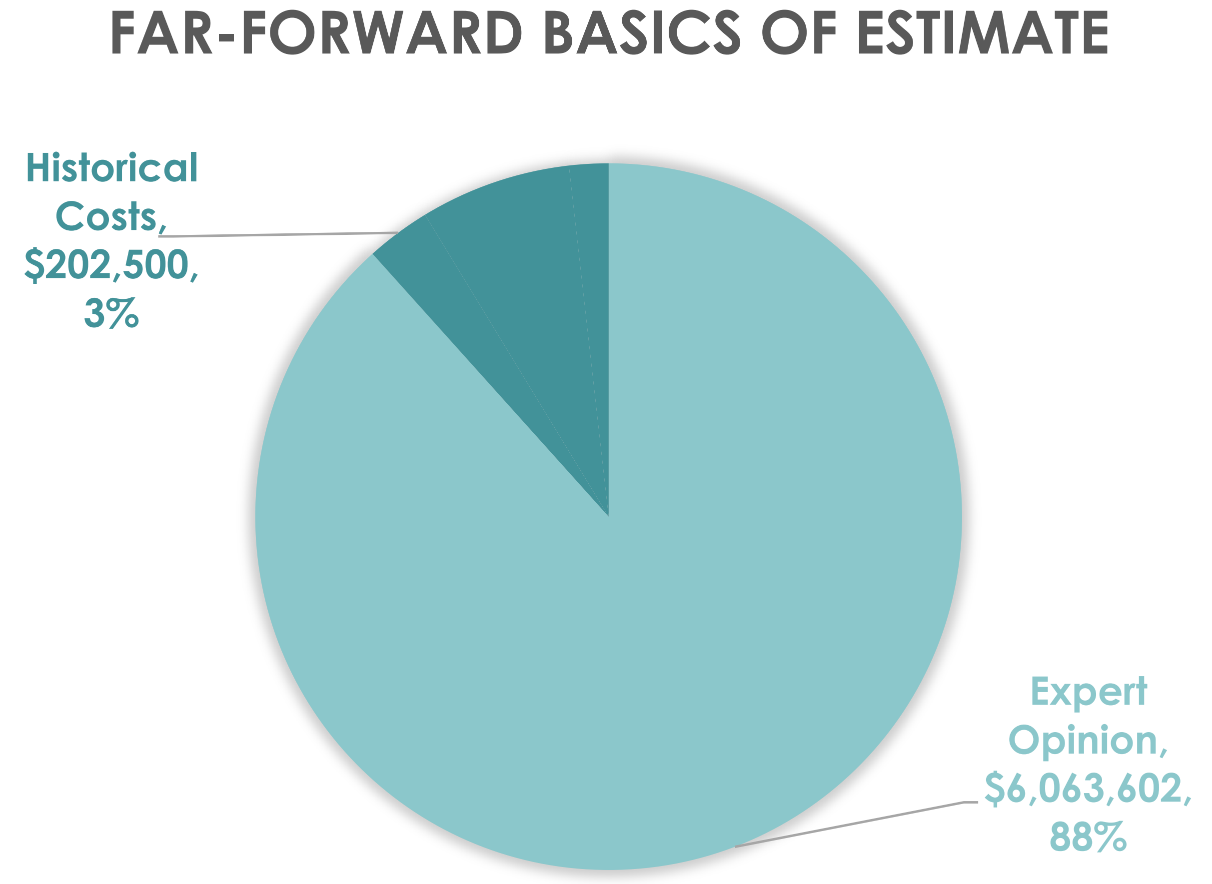
Costing - FarForward

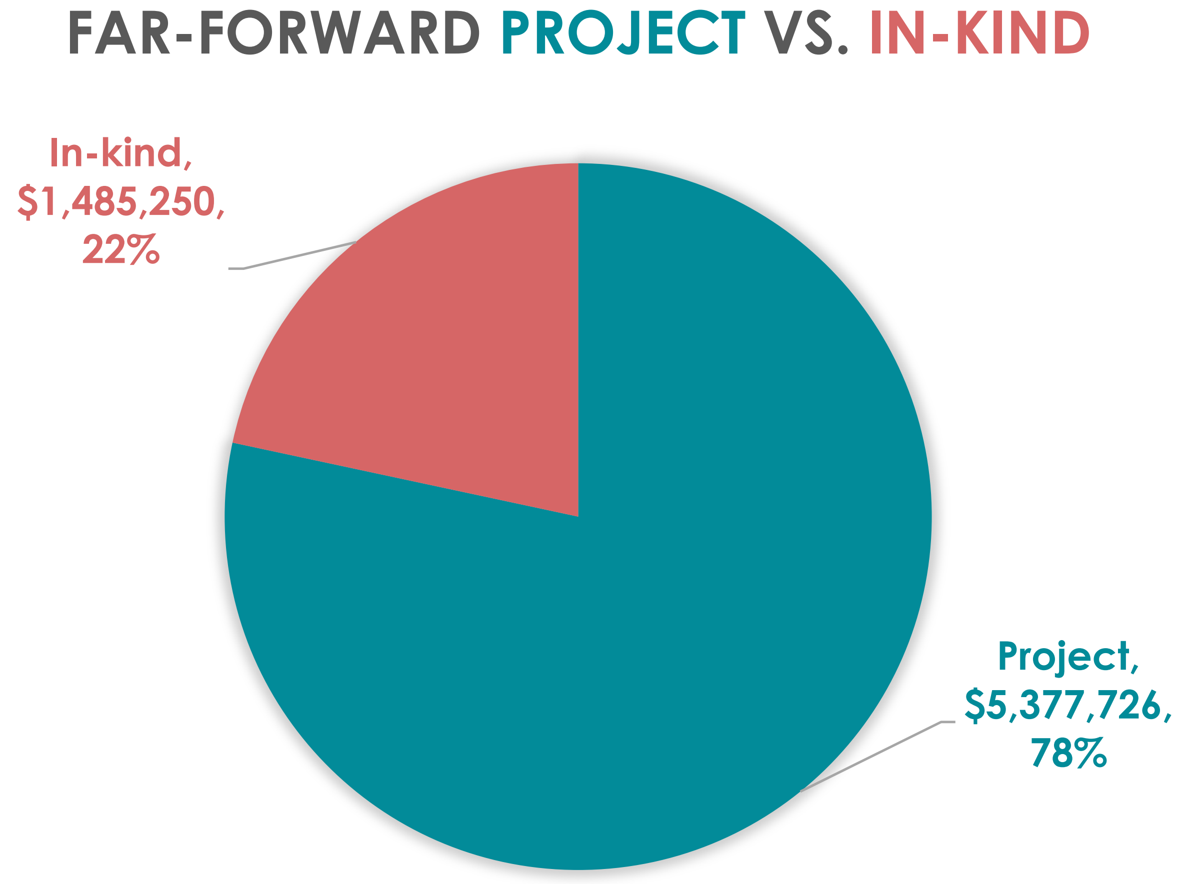
- Proposed FarForward detector systems based on historical costs at STAR, EIC generic R&D work (e.g. AC-LGAD consortium) and quotes from vendors
- Roman pots and Off-momentum detector: Employ AC-LGAD silicon sensors, profiting from bTOF R&D effort with material/labor estimates from AC-LGAD experts
- B0 costing: Based on ALICE ITS3 and AC-LGAD development
- ZDC costing: Expert opinion for WScFi detector system (pECAL) / Scintillating tiles and readout costing based on eRD27
- In-kind contributions: ZDC absorber material

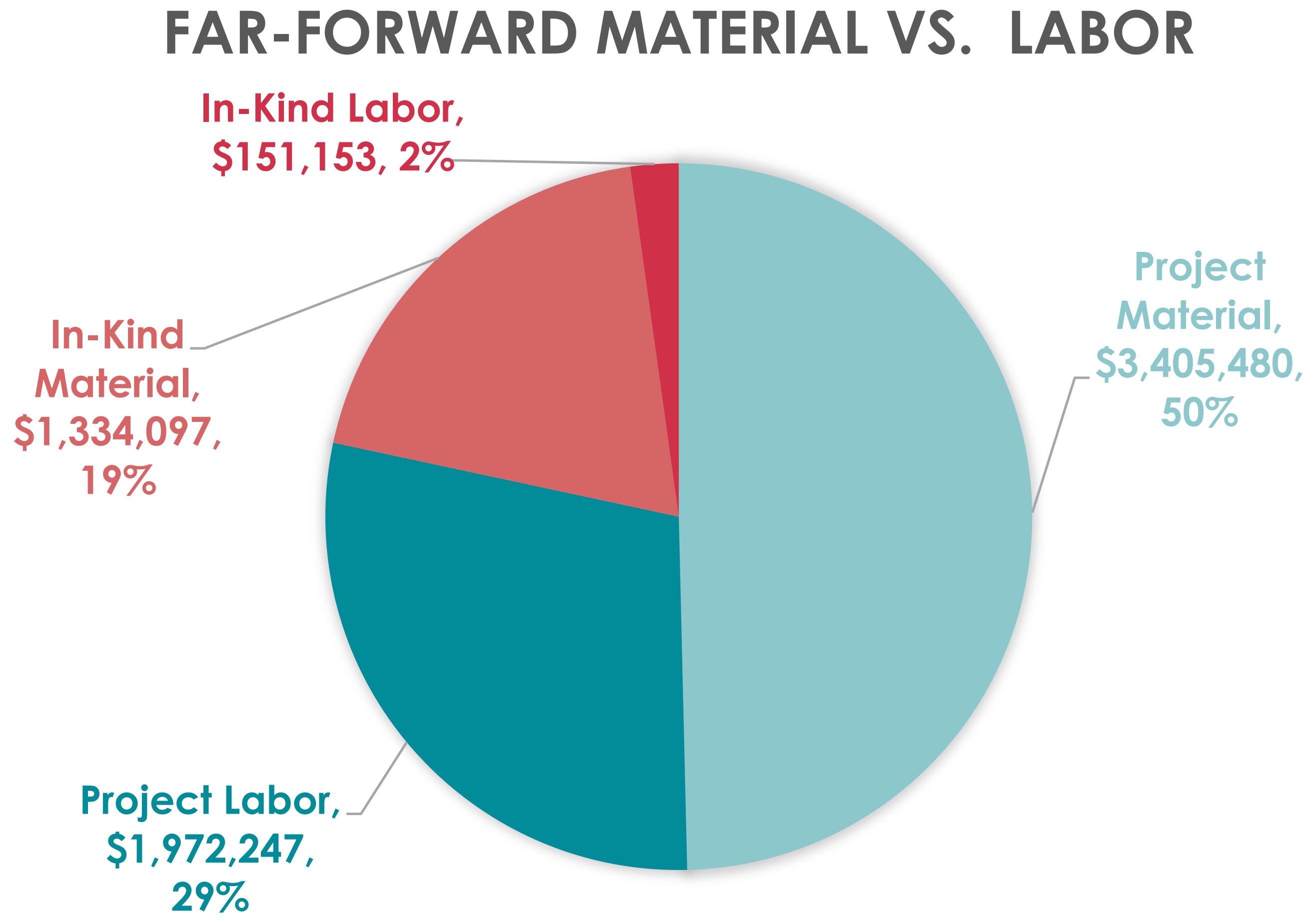


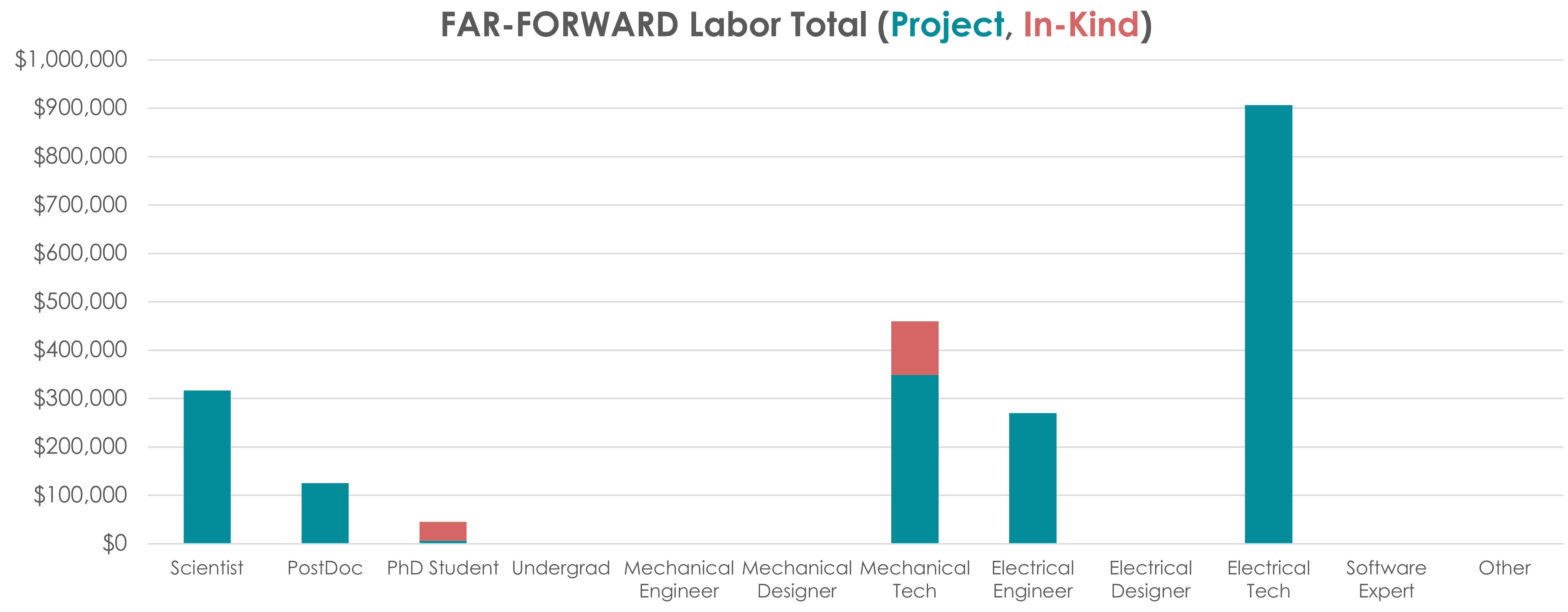
FarForward

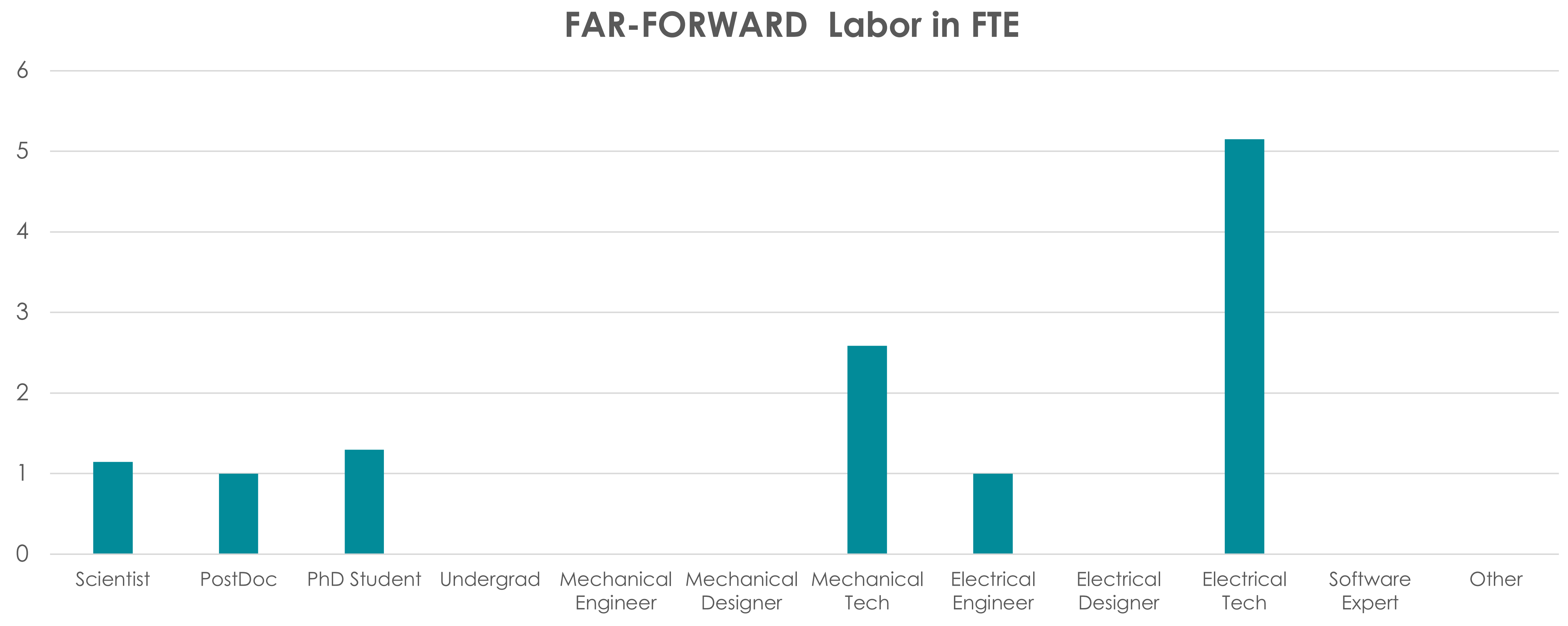
Costing


FAR-FORWARD BASICS OF ESTIMATE
Historical Costs, $202,500, 3%
Expert Opinion, $6,063,602, 88%


FAR-FORWARD PROJECT VS. IN-KIND
In-kind, $1,485,250, 22%
Project, $5,377,726, 78%

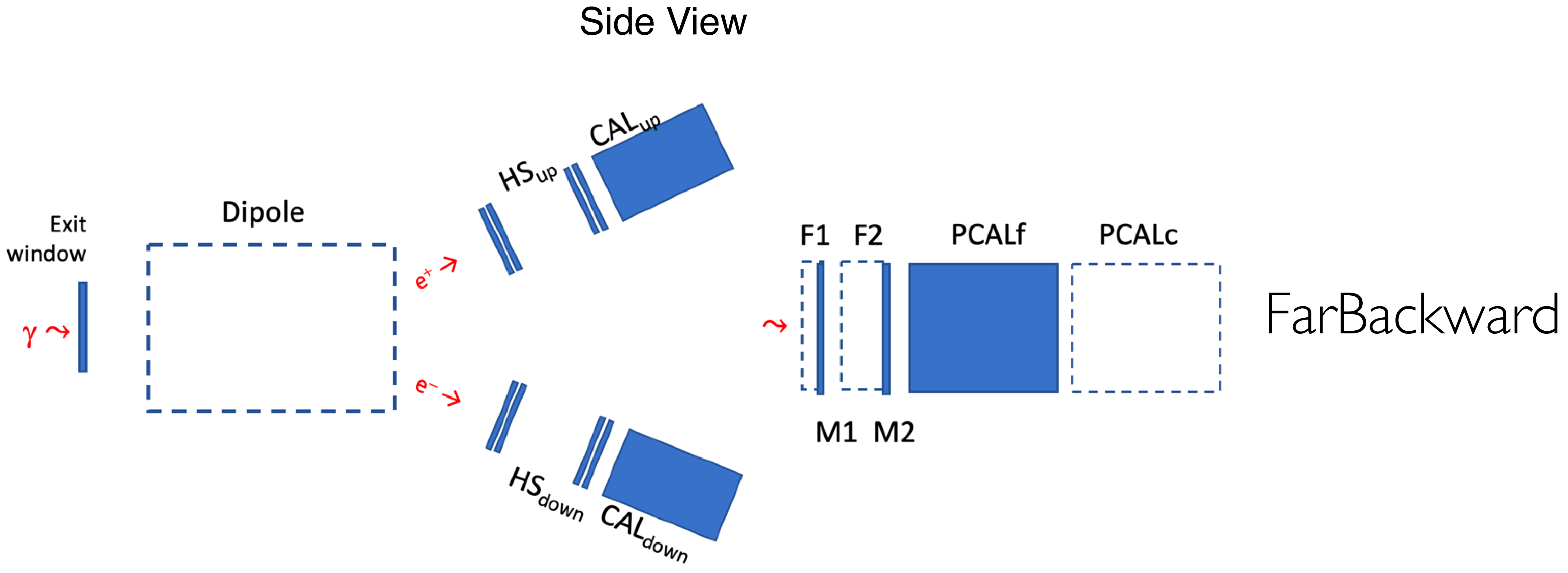

FAR-FORWARD MATERIAL VS. LABOR
In-Kind Labor, $151,153, 2%
In-Kind Material, $1,334,097, 19%
Project Material, $3,405,480, 50%
Project Labor, $1,972,247, 29%


FAR-FORWARD Labor Total (Project, In-Kind)
$1,000,000
$900,000
$800,000
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

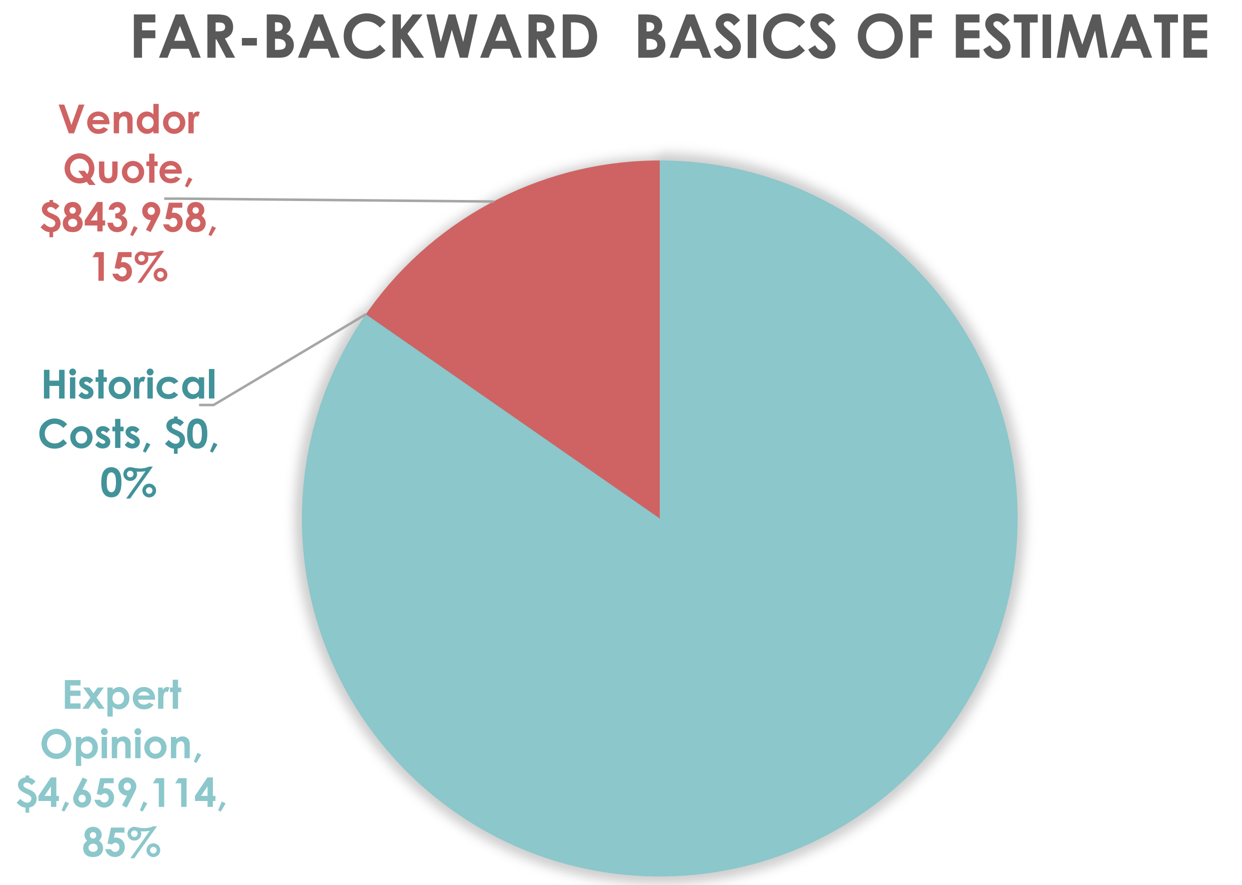

FAR-FORWARD Labor in FTE
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

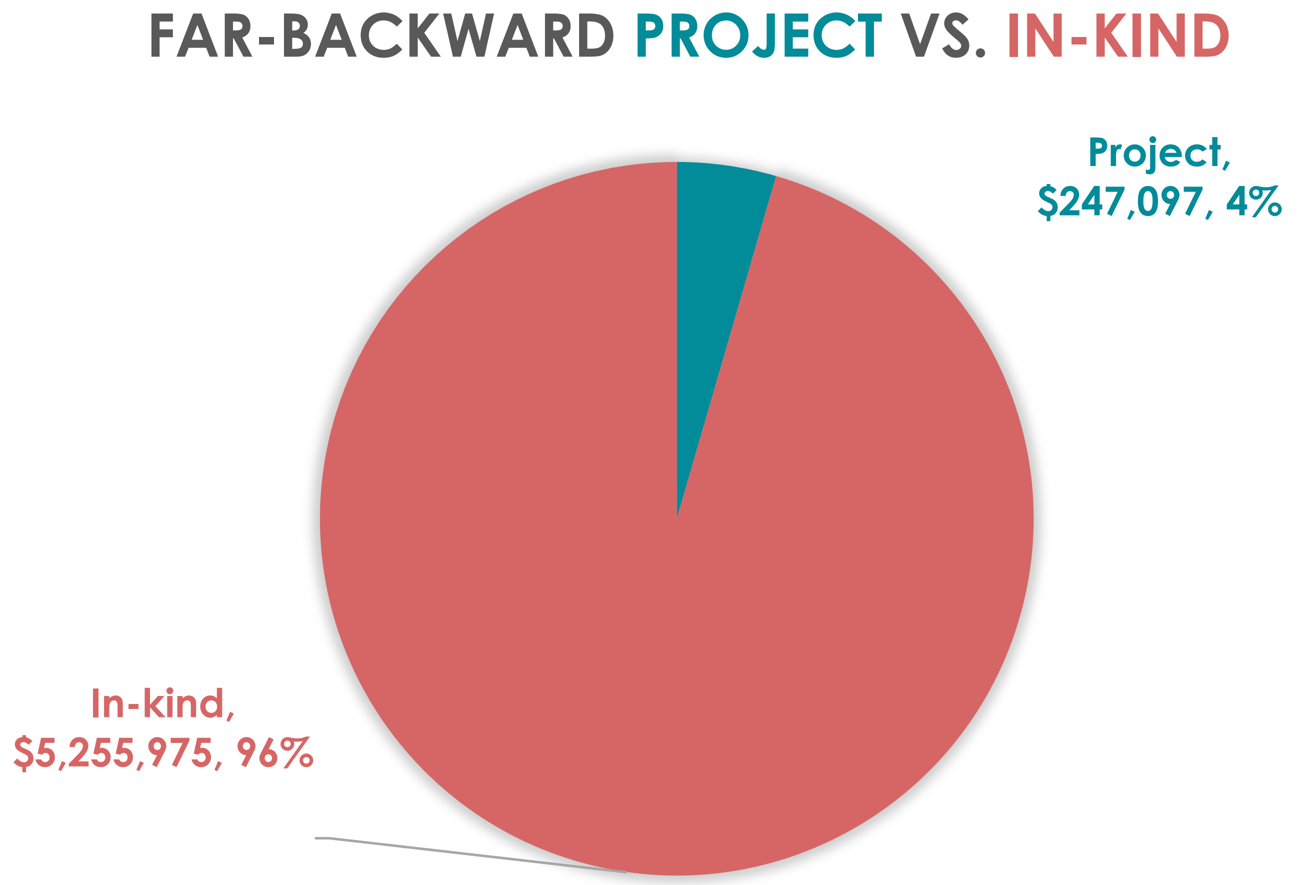
Costing - FarBackward

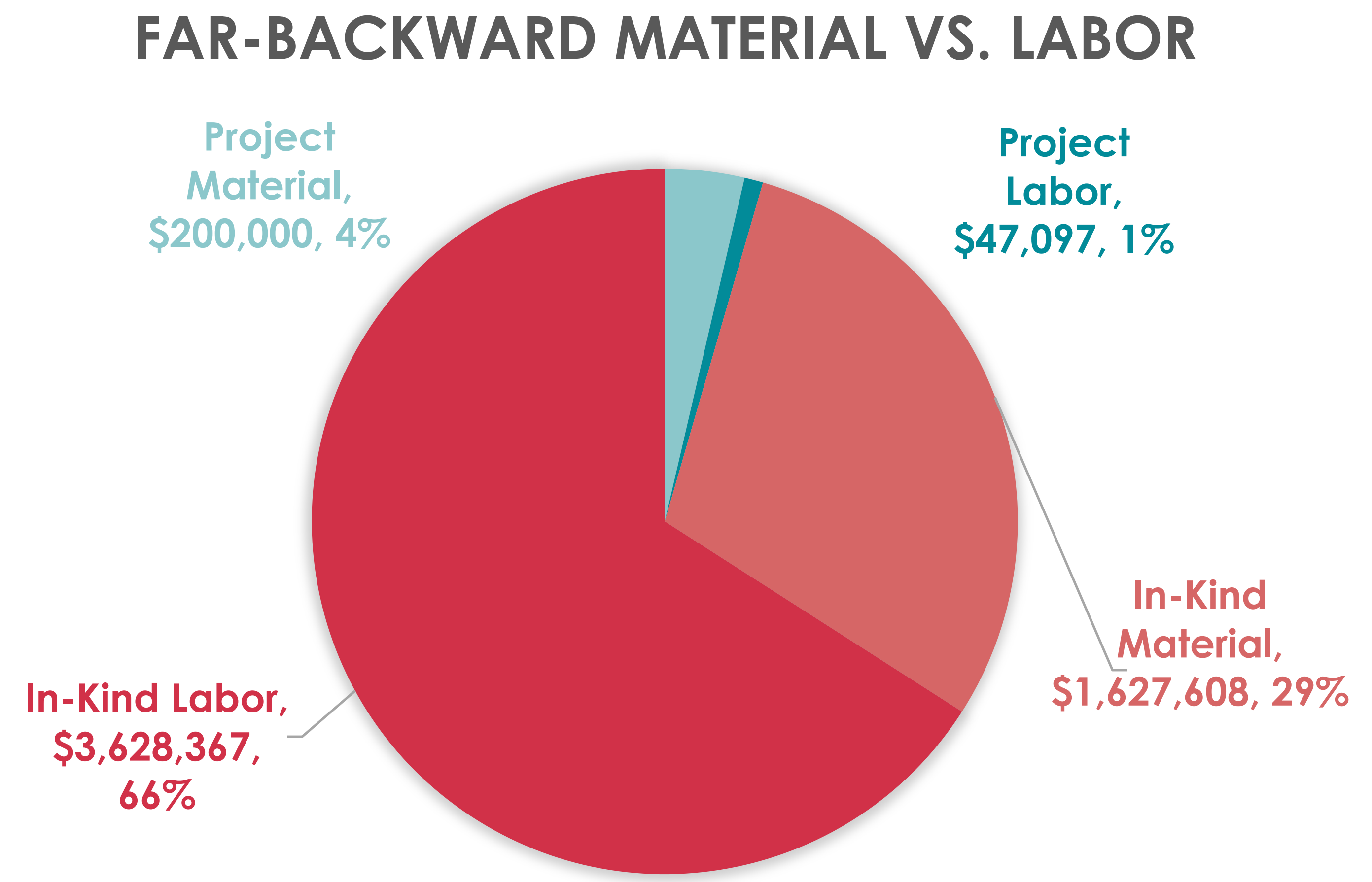
- Proposed FarBackward detector system covers luminosity monitor and low-Q^2 tagger profiting from experience with similar systems (e.g. ZEUS at HERA)
- Costing includes labor, component costs, including prototyping, ASIC, and assembly of FEE readout cards
- Labor costing: Profit from prior experience!
- In-Kind contribution planned for entire FarBackward system from AGH University of Science and Technology and Institute of Nuclear Physics, Kraków, Poland
  - Luminosity monitor
  - Low Q^2-tagger

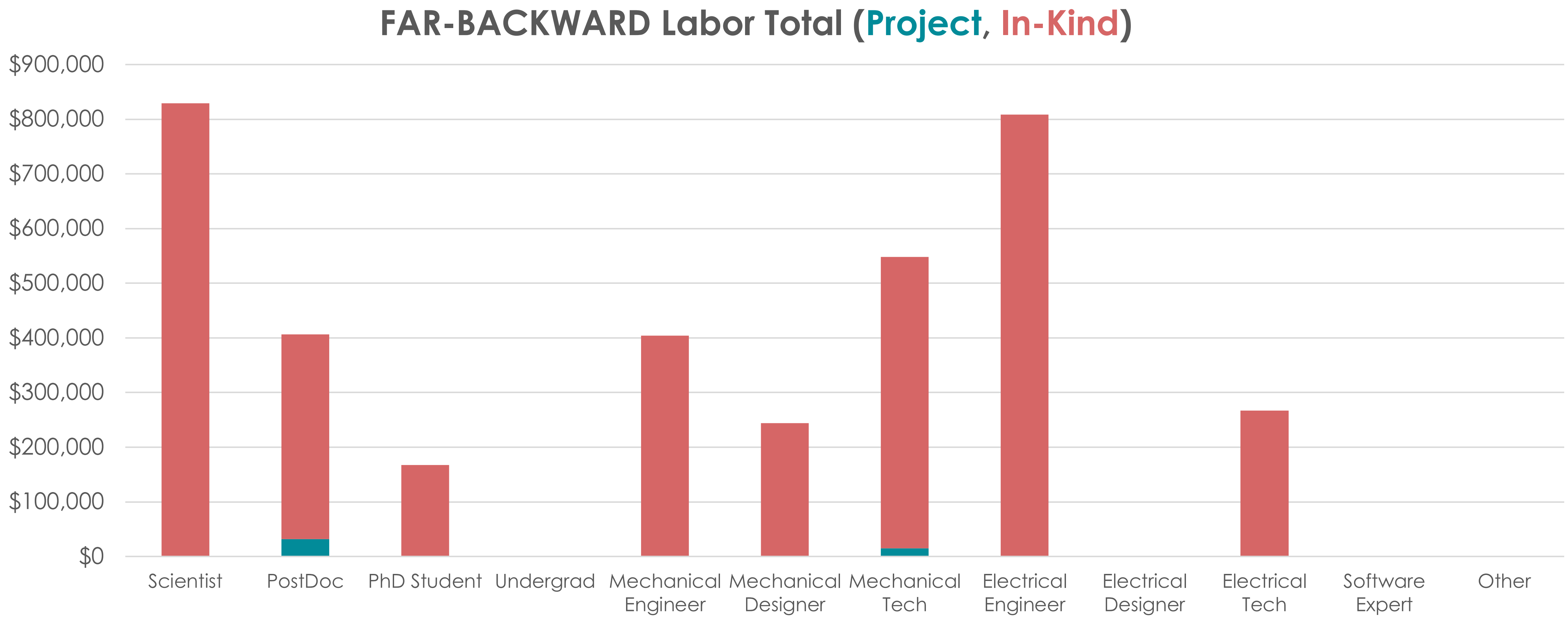


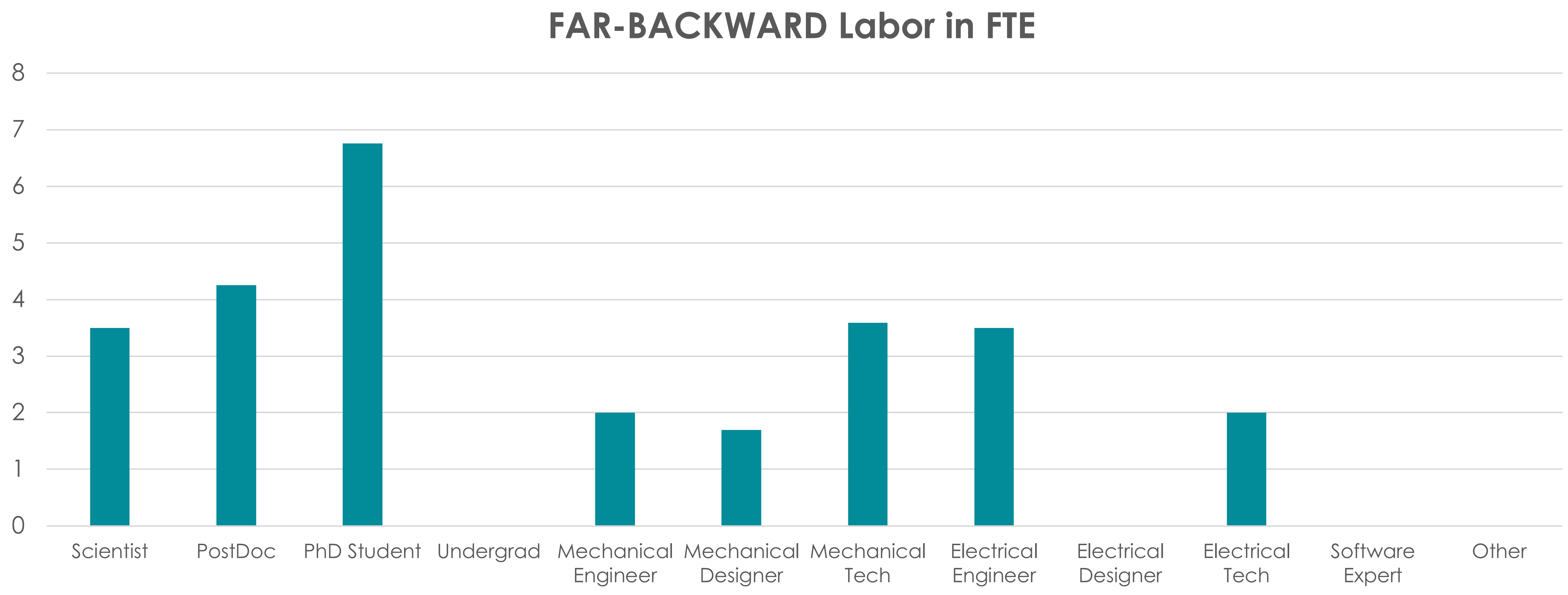
Costing


FAR-BACKWARD BASICS OF ESTIMATE
Vendor Quote, $843,958, 15%
Historical Costs, $0, 0%
Expert Opinion, $4,659,114, 85%


FAR-BACKWARD PROJECT VS. IN-KIND
Project, $247,097, 4%
In-kind, $5,255,975, 96%

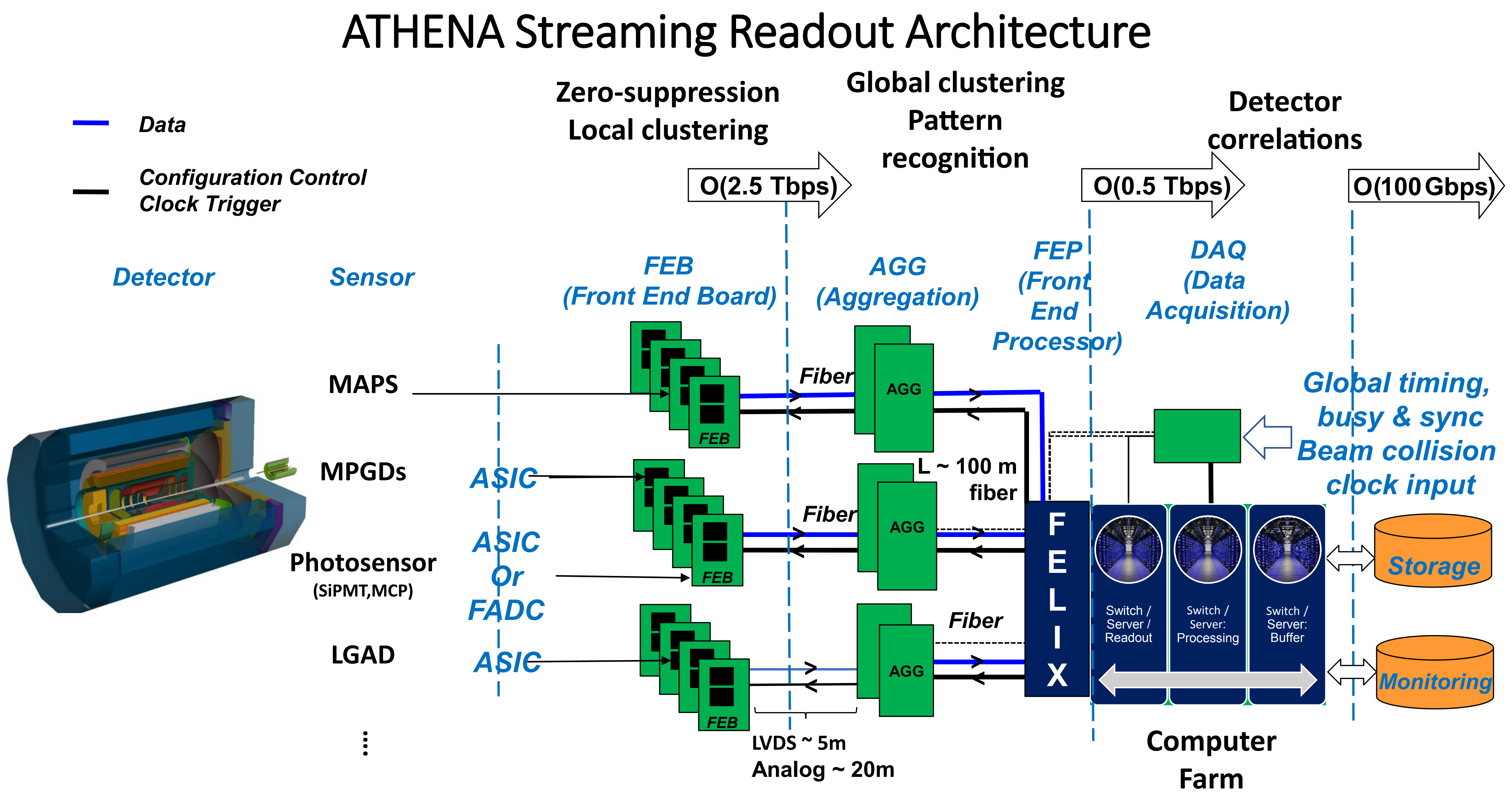

FAR-BACKWARD MATERIAL VS. LABOR
Project Material, $200,000, 4%
Project Labor, $47,097, 1%
In-Kind Material, $1,627,608, 29%
In-Kind Labor, $3,628,367, 66%


FAR-BACKWARD Labor Total (Project, In-Kind)
$900,000
$800,000
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other


FAR-BACKWARD Labor in FTE
8
7
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

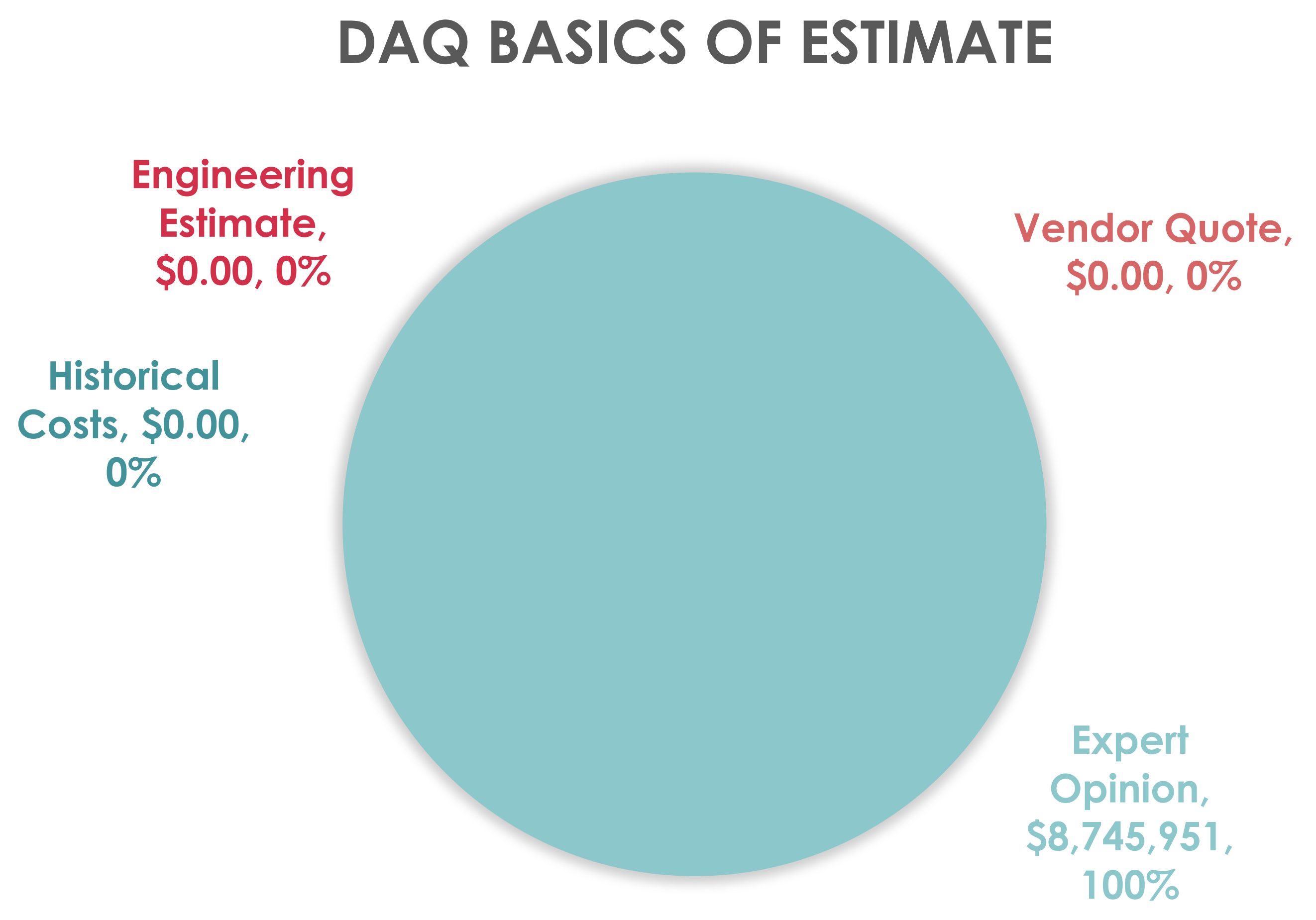
Costing - DAQ

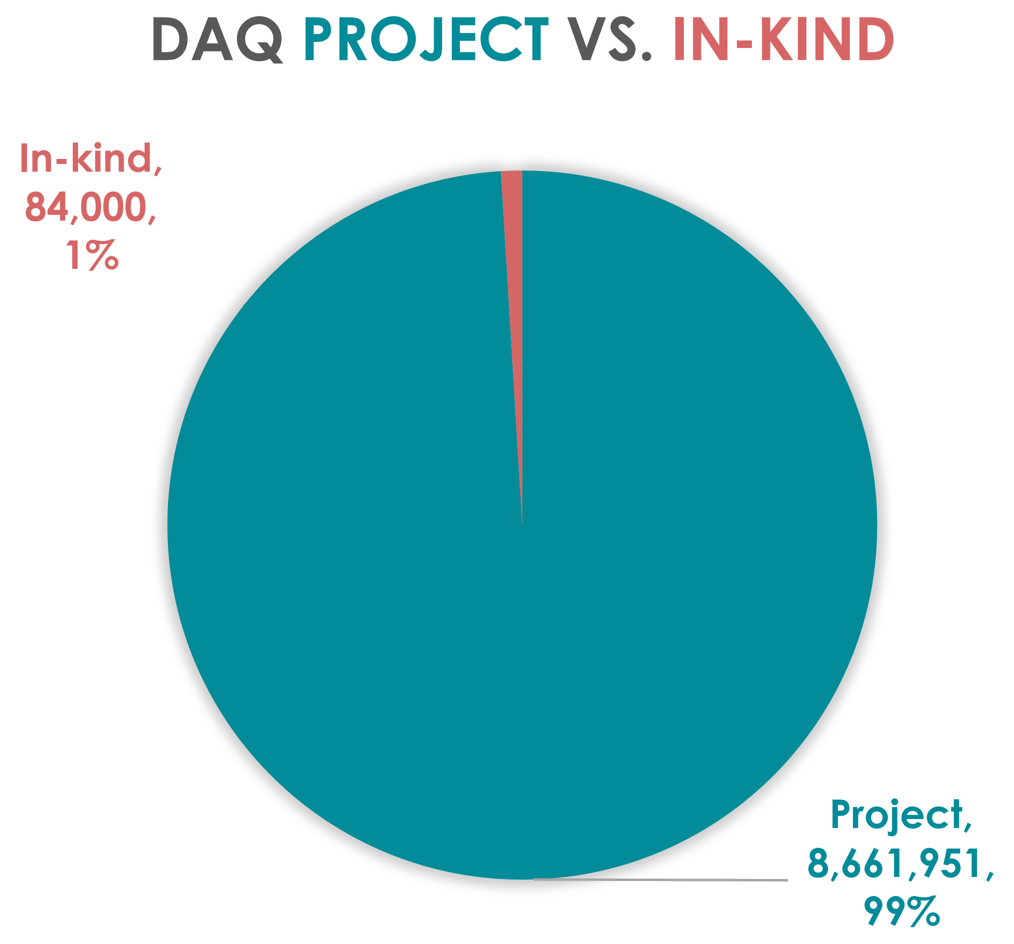
- Proposed DAQ system profits from extensive experience at STAR and other experiments
- Costing includes FELIX cards and DAQ computers (Readout computers / Analysis farm / Transfer computers)
- Labor estimates include the completion of all DAQ components guided by an experienced expert or engineer together with postdocs and students
- Larger portions of expert-level labor required for electronics and infrastructure portions of the system

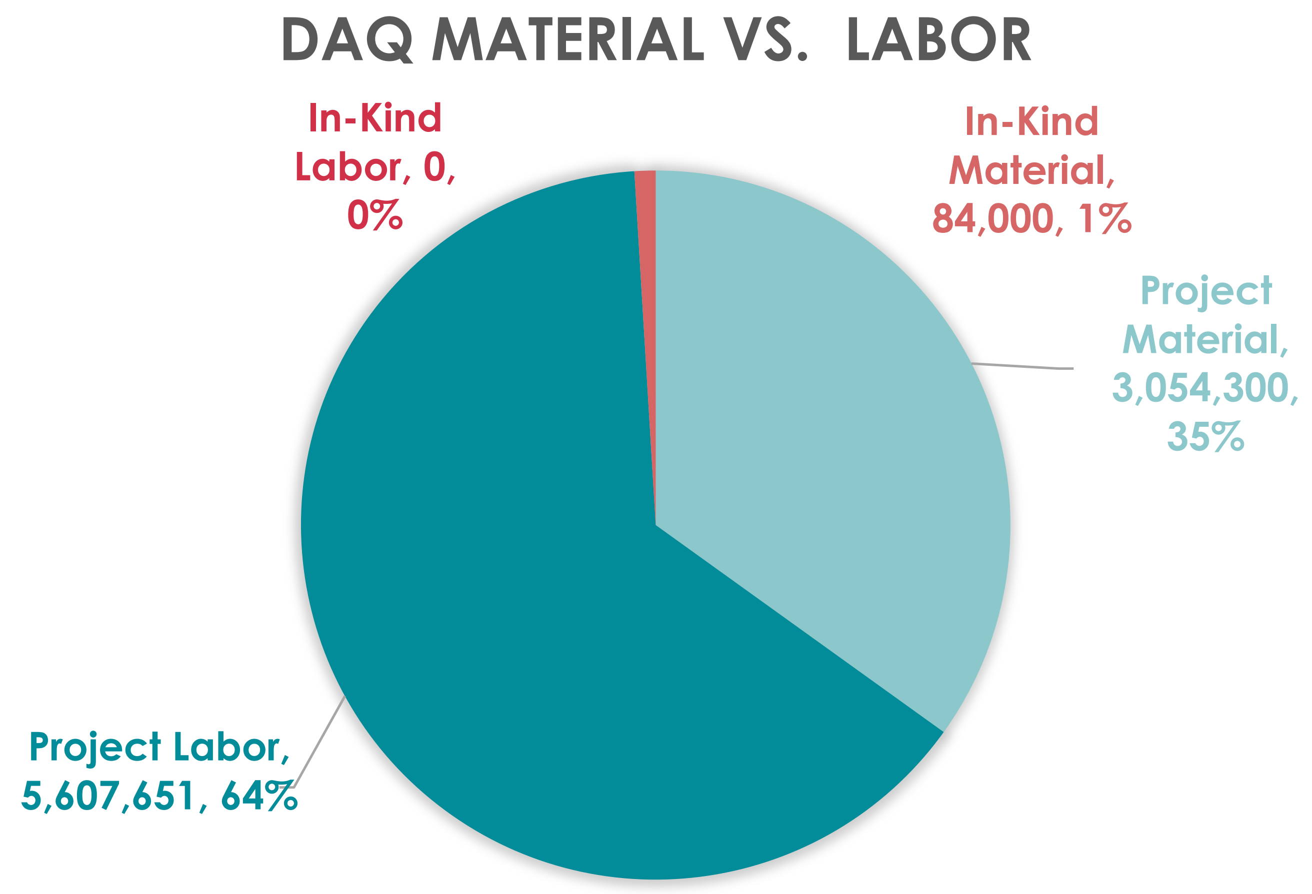


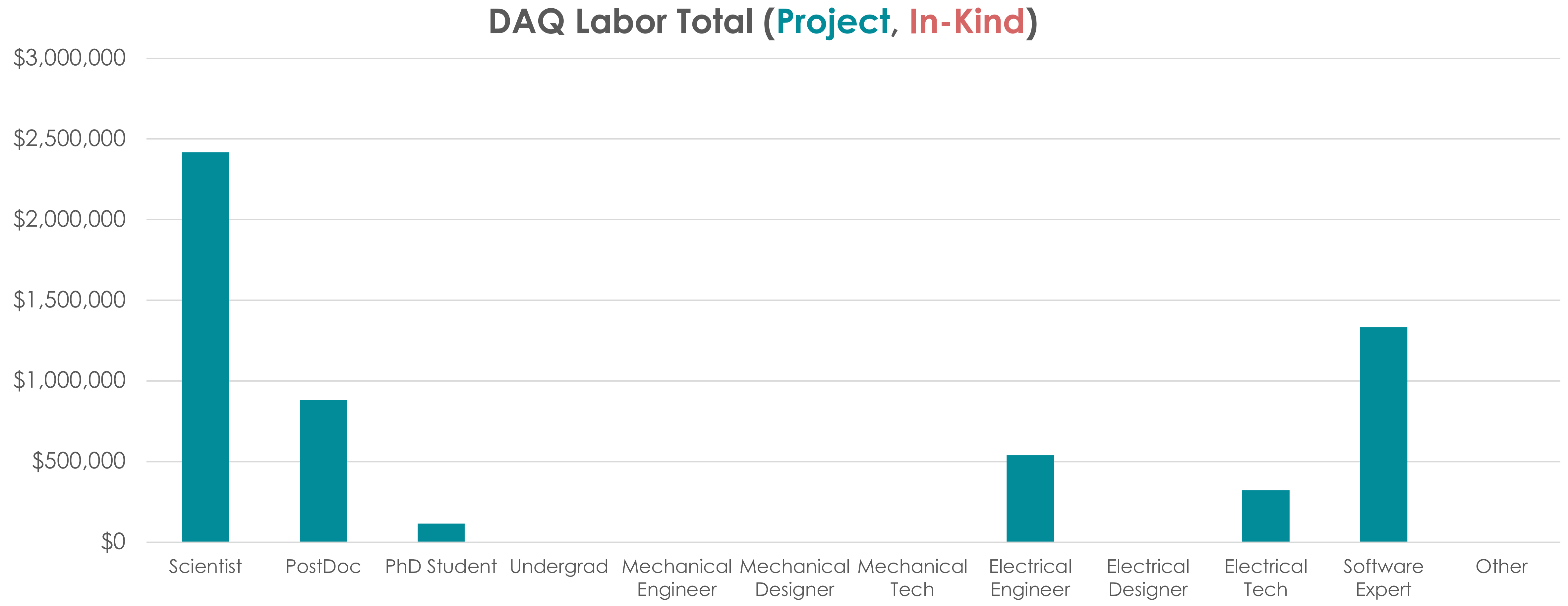
DAQ

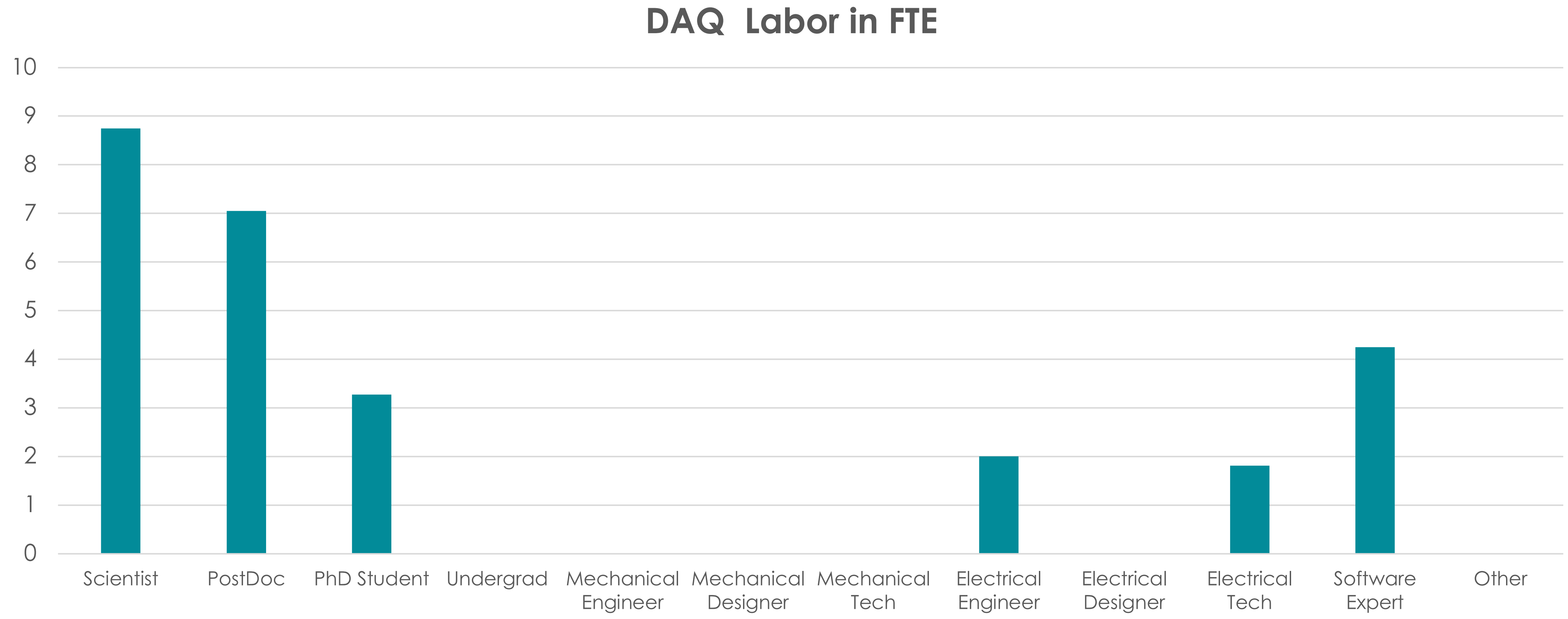
Costing


DAQ BASICS OF ESTIMATE
Engineering Estimate, $0.00, 0%
Vendor Quote, $0.00, 0%
Historical Costs, $0.00, 0%
Expert Opinion, $8,745,951, 100%


DAQ PROJECT VS. IN-KIND
In-kind, 84,000, 1%
Project, 8,661,951, 99%


DAQ MATERIAL VS. LABOR
In-Kind Labor, 0, 0%
In-Kind Material, 84,000, 1%
Project Material, 3,054,300, 35%
Project Labor, 5,607,651, 64%


DAQ Labor Total (Project, In-Kind)
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other


DAQ Labor in FTE
10
9
8
7
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

Costing - Summary

ATHENA

- Costing of ATHENA based on extensive experience from prior detector systems and R&D programs
- Coordinated, best effort to estimate the cost of the ATHENA sub-systems at the present project state of Material In-Kind / Project and Labor In-Kind / Project:

	In-Kind	Project	Total	
Material	$30M	$76M	$106M	64%
Labor	$19M	$40M	$59M	36%
Total	$49M	$116M	$166M	
	30%	70%		

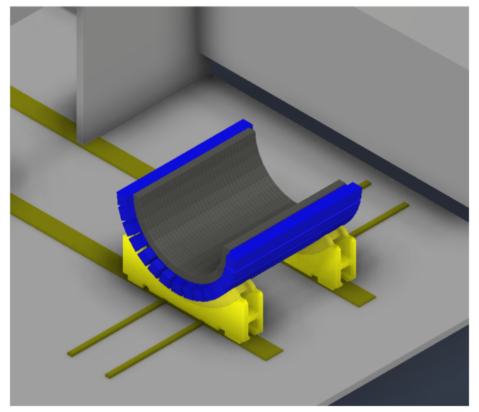
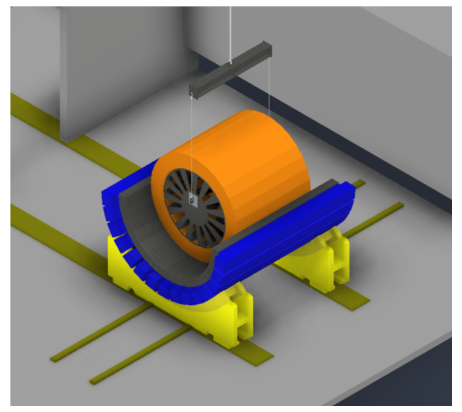
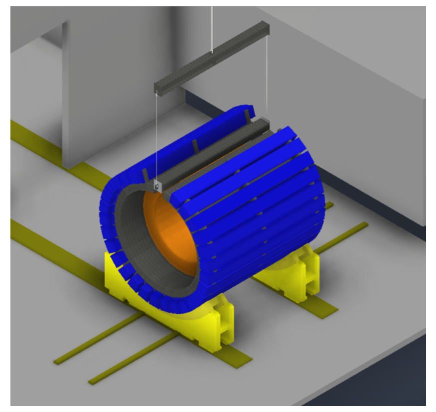
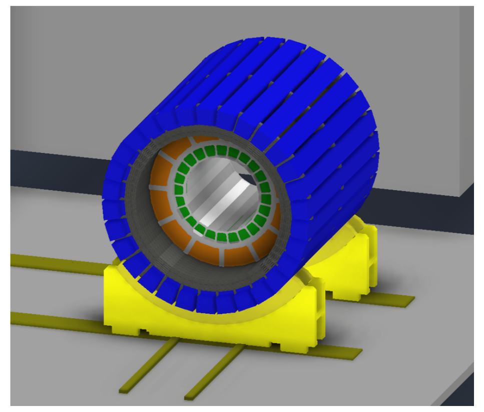
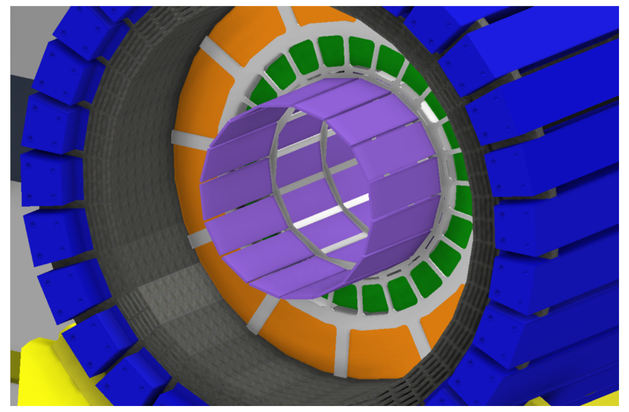
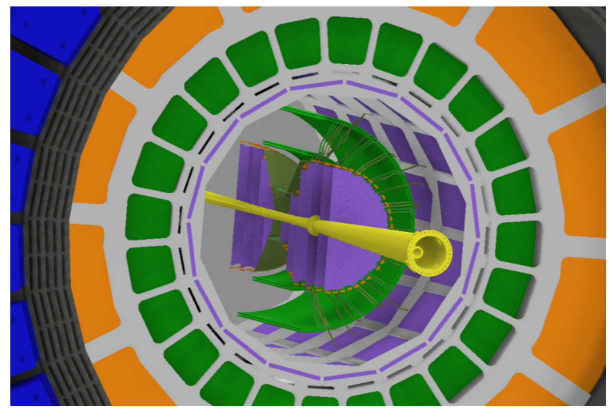
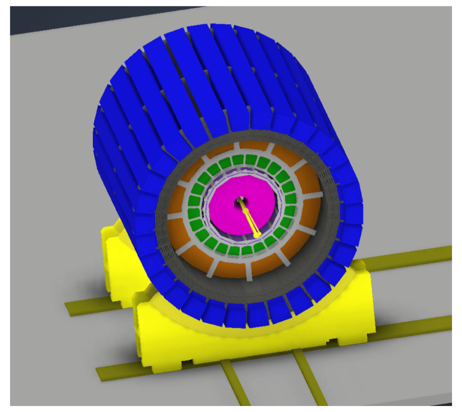
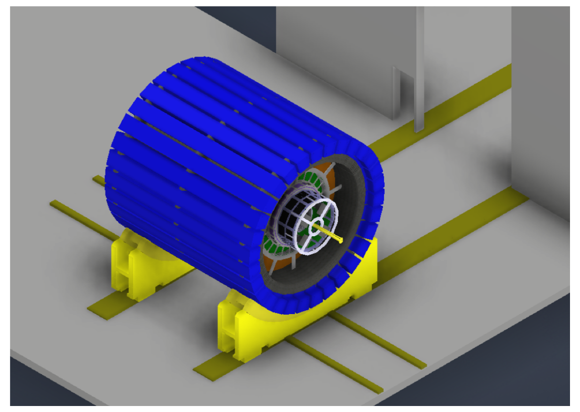
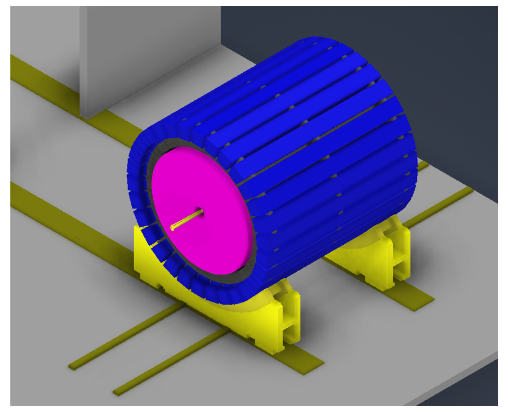
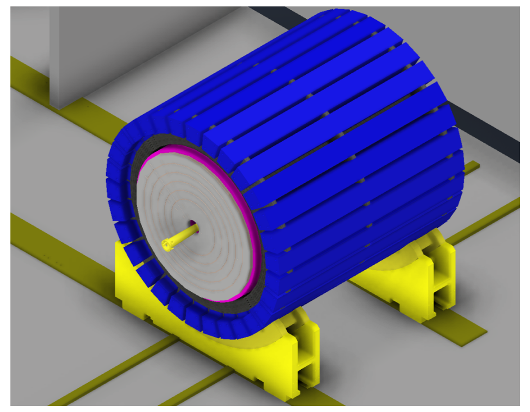
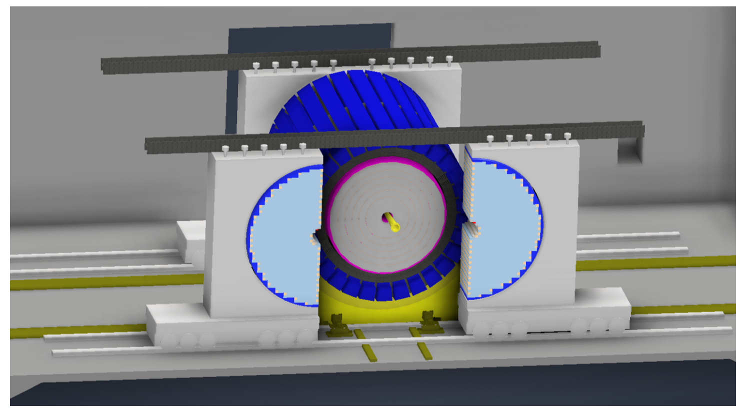
- Guidance provided by EIC project: No contingency included
  - Labor costs: Quoted in US Dollars (USD) using standard BNL labor rates
  - Costing of Global Systems for Detector Management, Magnet, Detector Infrastructure, and Detector Pre-Ops & Commissioning provided by EIC project

Magnet cost:	$23.9M
Vendor visit:	$.5M
Cryo-flex line and cryo can:	$.5M
Labor hours:	$3.8M
Total:	$28.7M

- ATHENA sub-system costing (Construction and R&D) in 2021 USD
- In-Kind contributions are expected to increase with evolution of the EIC project: Lower limit!
- Total for sub-system construction in 2021 USD: $166M
- Total for sub-system R&D in 2021 USD: $25M
- Escalation of sub-system costing based on 3.5% growth rate and combination with R&D, and Global System provided!

Schedule

- GOAL: Completion of ATHENA in 3rd Quarter of 2030 = CD-4Ae (early)!
- Documented installation sequence around solenoid installation
- Central detector: 1) Detector cradle, 2) Lower half of flux return and bHCAL, 3) Solenoid, 4) Upper half of flux return and bHCAL, 5) bECAL, 6) hpDIRC, 7) Barrel Tracker (MM/MAPS)
- Electron endcap: 1) MAPS disks, 2) MPGD disks, 3) pfRICH, 4) Electron Endcap, 7) hpDIRC readout
- Hadron endcap: 1) MAPS disks, 2) MPGD disks, 3) dRICH, 4) μRWell
- Endcap calorimeters: 1) nHCAL, pECAL, and pHCAL are installed on their own cradles
- FarBackward system needs to be ready for accelerator startup!
- FarForward installation contingent on beam conditions / accelerator status!

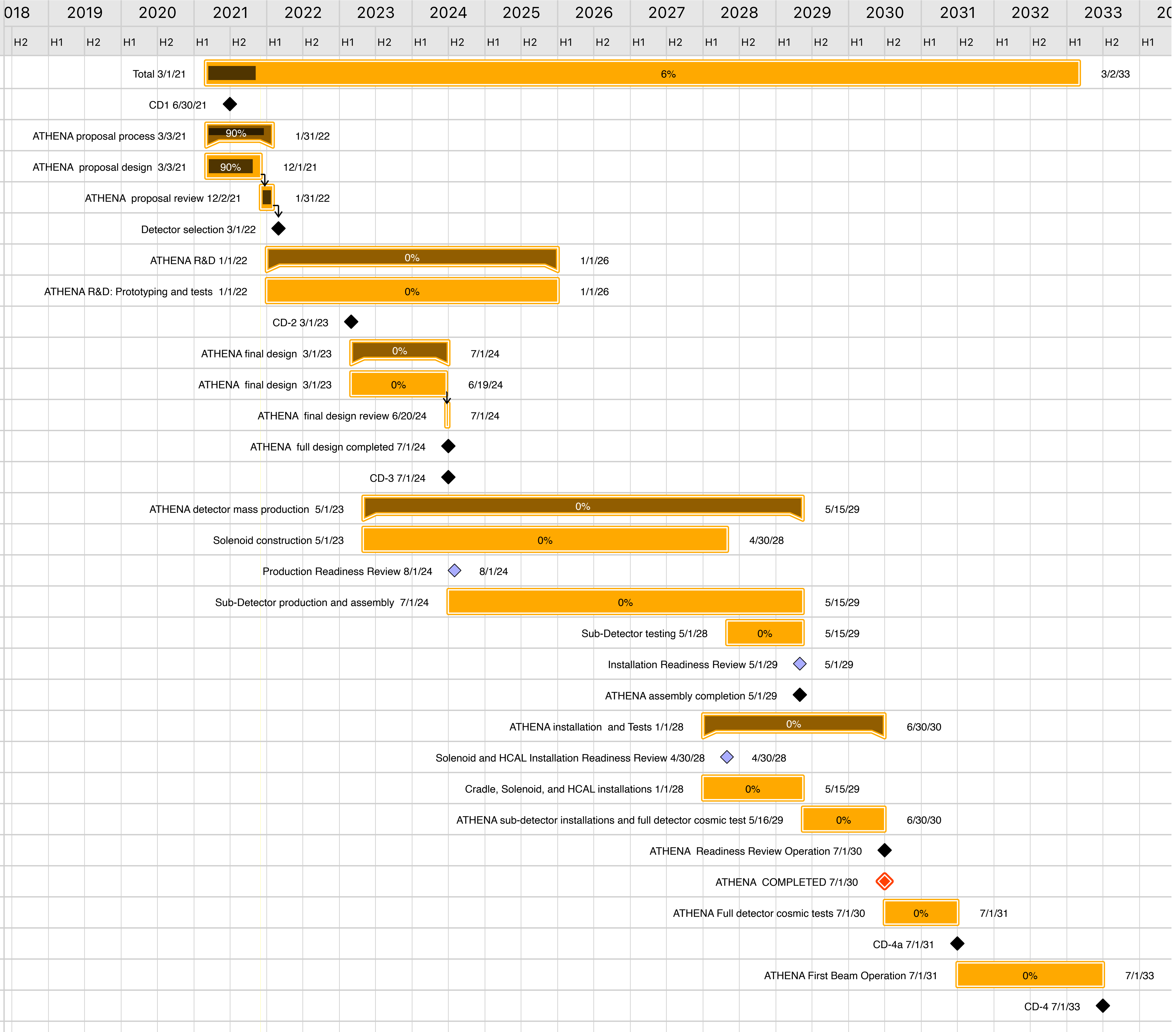












Schedule

ATHENA

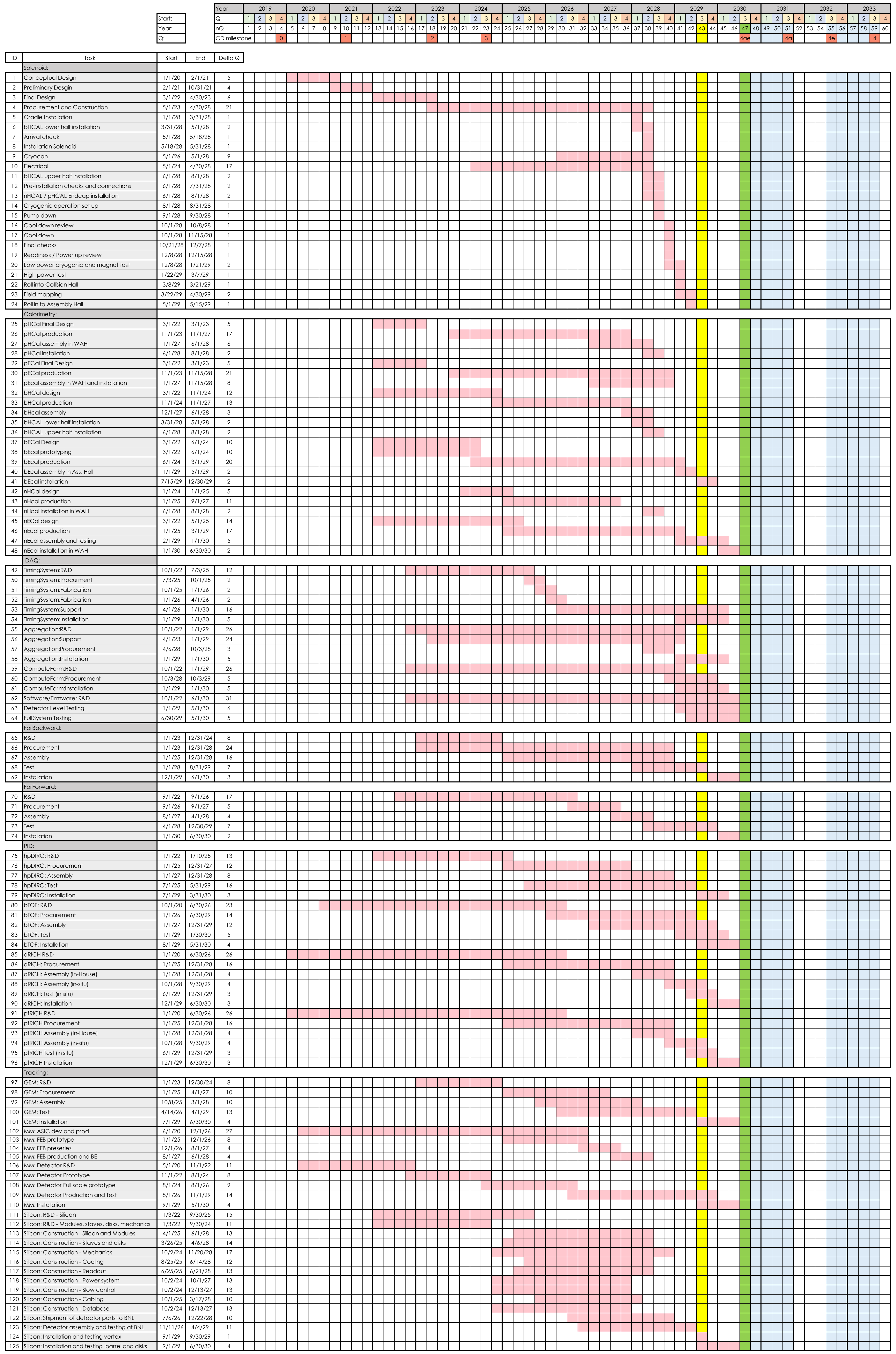
- ATHENA schedule summarized in simplified Gantt chart with major activities and milestones:
  - CD-2
  - CD-3
  - Construction
  - Installation
  - Completion: 3rd Quarter of 2030 = CD-4Ae (early)

#	Name	Start
1	Total	3/1/21
2	CD1	6/30/21
3	**ATHENA proposal process**	3/3/21
4	ATHENA proposal design	3/3/21
5	ATHENA proposal review	12/2/21
6	Detector selection	3/1/22
7	**ATHENA R&D**	1/1/22
8	ATHENA R&D: Prototyping and tests	1/1/22
9	CD-2	3/1/23
10	**ATHENA final design**	3/1/23
11	ATHENA final design	3/1/23
12	ATHENA final design review	6/20/24
13	ATHENA full design completed	7/1/24
14	CD-3	7/1/24
15	**ATHENA detector mass production**	5/1/23
16	Solenoid construction	5/1/23
17	Production Readiness Review	8/1/24
18	Sub-Detector production and assembly	7/1/24
19	Sub-Detector testing	5/1/28
20	Installation Readiness Review	5/1/29
21	ATHENA assembly completion	5/1/29
22	**ATHENA installation and Tests**	1/1/28
23	Solenoid and HCAL Installation Readiness F	4/30/28
24	Cradle, Solenoid, and HCAL installations	1/1/28
25	ATHENA sub-detector installations and full c	5/16/29
26	ATHENA Readiness Review Operation	7/1/30
27	ATHENA COMPLETED	7/1/30
28	ATHENA Full detector cosmic tests	7/1/30
29	CD-4a	7/1/31
30	ATHENA First Beam Operation	7/1/31
31	CD-4	7/1/33



Schedule

- Gantt-chart quarterly layout provided in appendix: 2019-2033
- Sub-systems:
  - Magnet
  - Calorimetry
  - DAQ
  - FarForward
  - FarBackward
  - PID
  - Tracking
- Critical decision (CD) milestones (CD-0 to CD-4) marked in red
- Early (e) scenarios marked as CD-4Ae and CD-4e!
- Start of ATHENA installation after solenoid installation marked in yellow: 3rd Quarter 2029
- ATHENA completion marked in green: 3rd Quarter 2030 = CD-4Ae
- Period between 4 (4A) and 4e (4Ae): Schedule contingency marked in blue!



ATHENA

Magnet

Calorimetry

DAQ

FarForward

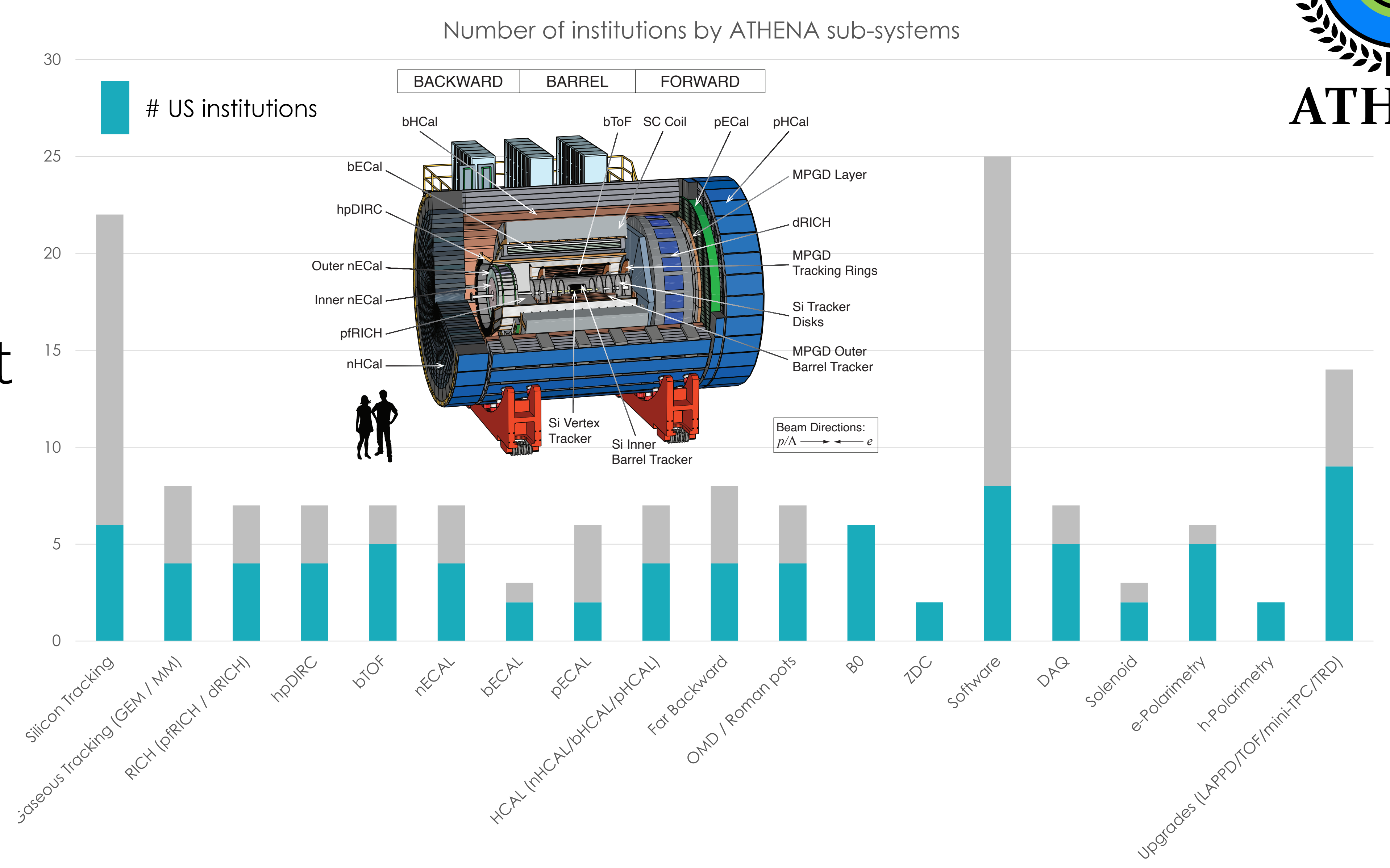
FarBackward

PID

Tracking

Conclusions

- ATHENA institutions cover a broad scientific background: Nucleon/nuclear structure at RHIC/JLab & HERA/COMPASS, Relativistic Heavy-Ion Physics at RHIC/LHC, HEP (LHC, FNAL, Belle II)
- ATHENA provides at its core significant experience in all detector areas with strong US and non-US institutional participation!



- Growth opportunities for new institutions, particularly for young scientists!
- Coordinated, best effort to estimate the cost of the ATHENA sub-systems at the present project state:

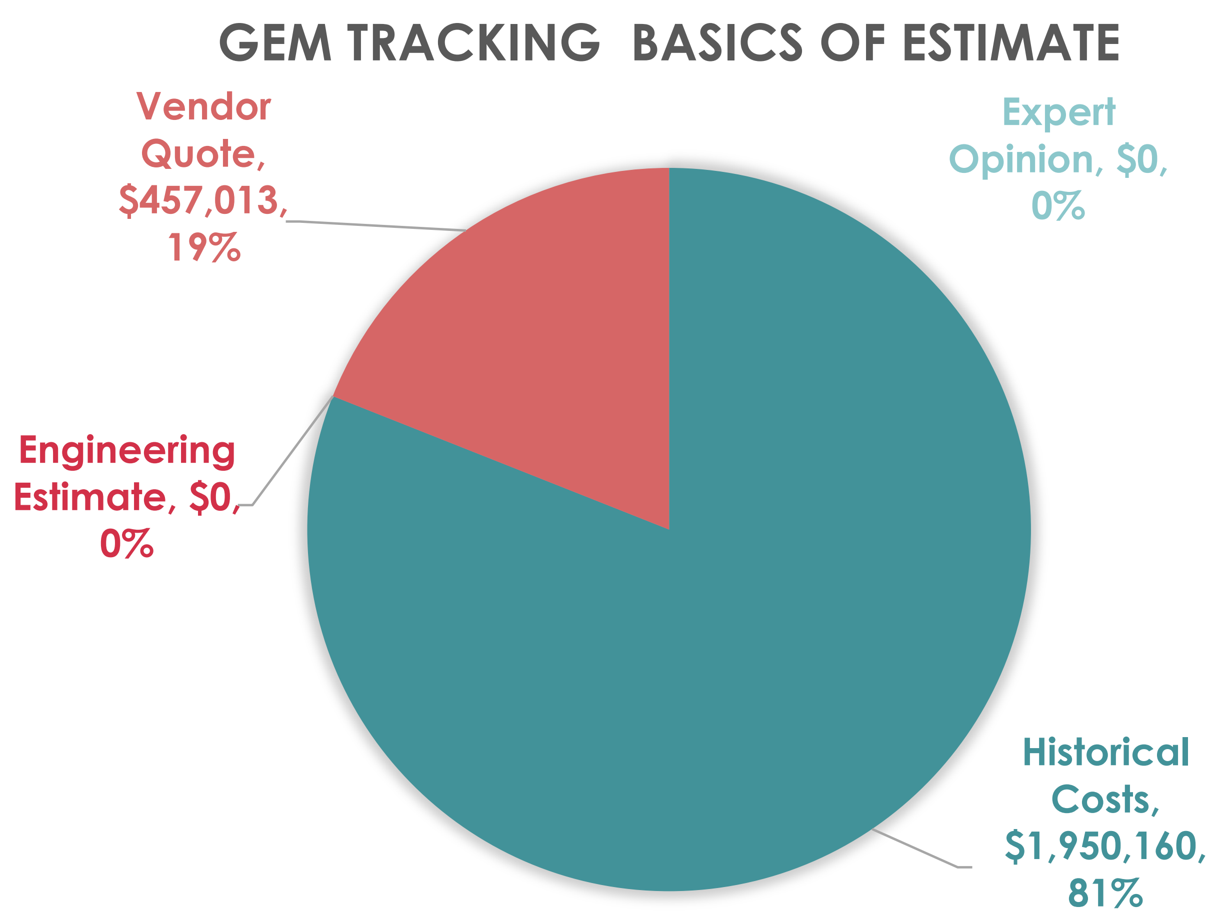
	In-Kind	Project	Total	
Material	$30M	$76M	$106M	64%
Labor	$19M	$40M	$59M	36%
Total	$49M	$116M	$166M	
	30%	70%		

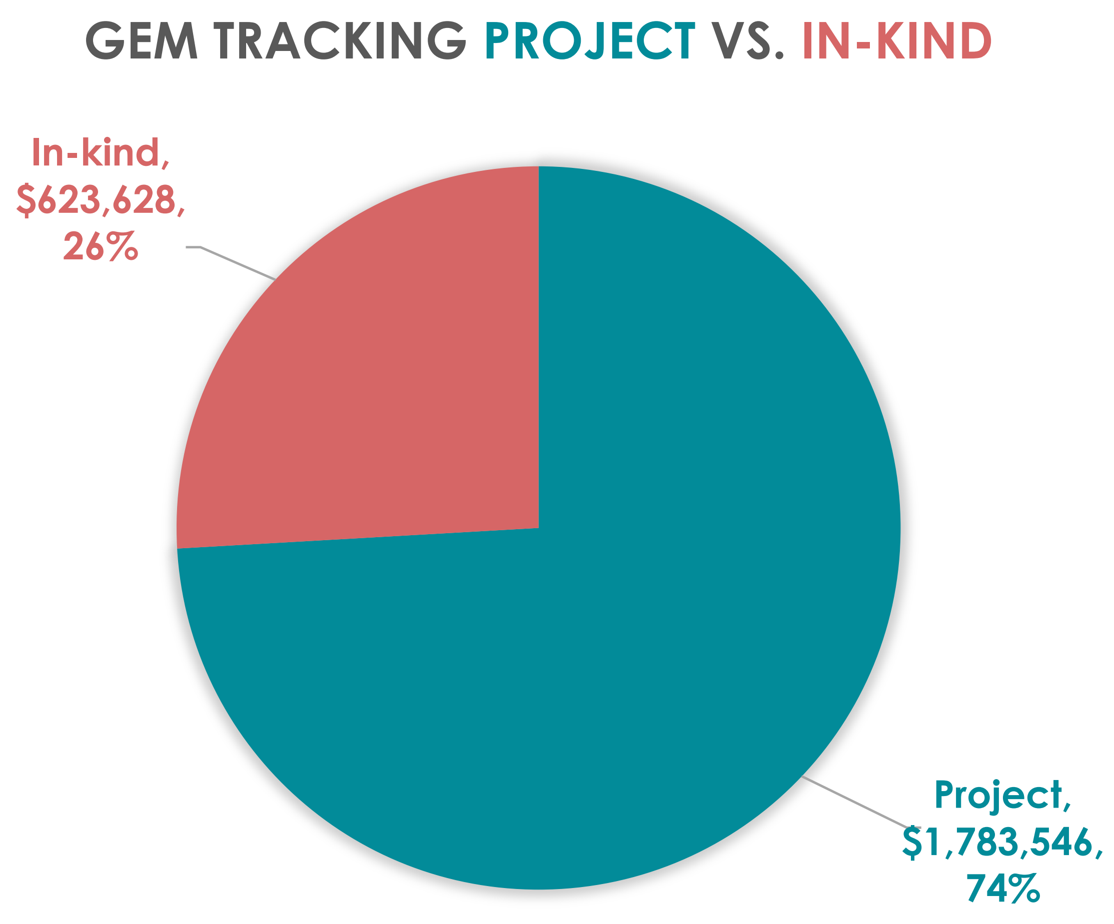
- In-Kind contributions are expected to increase with evolution of the EIC project: Lower limit!
- Total in 2021 USD for sub-system construction (R&D): $166M ($25M)
- Completion of ATHENA detector by CD-4A early!

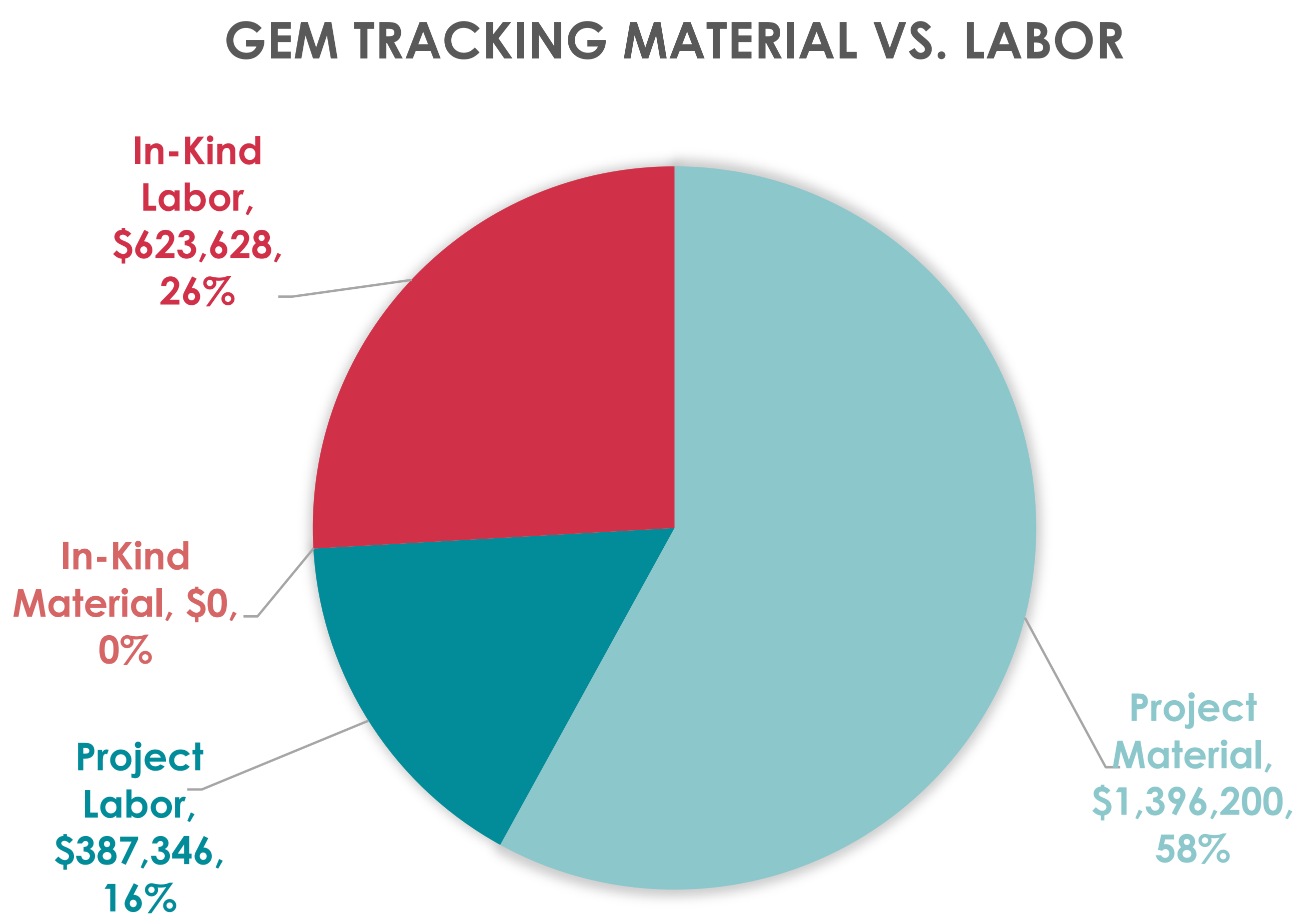
Thank you to the EIC Project Team for providing guidance and support!

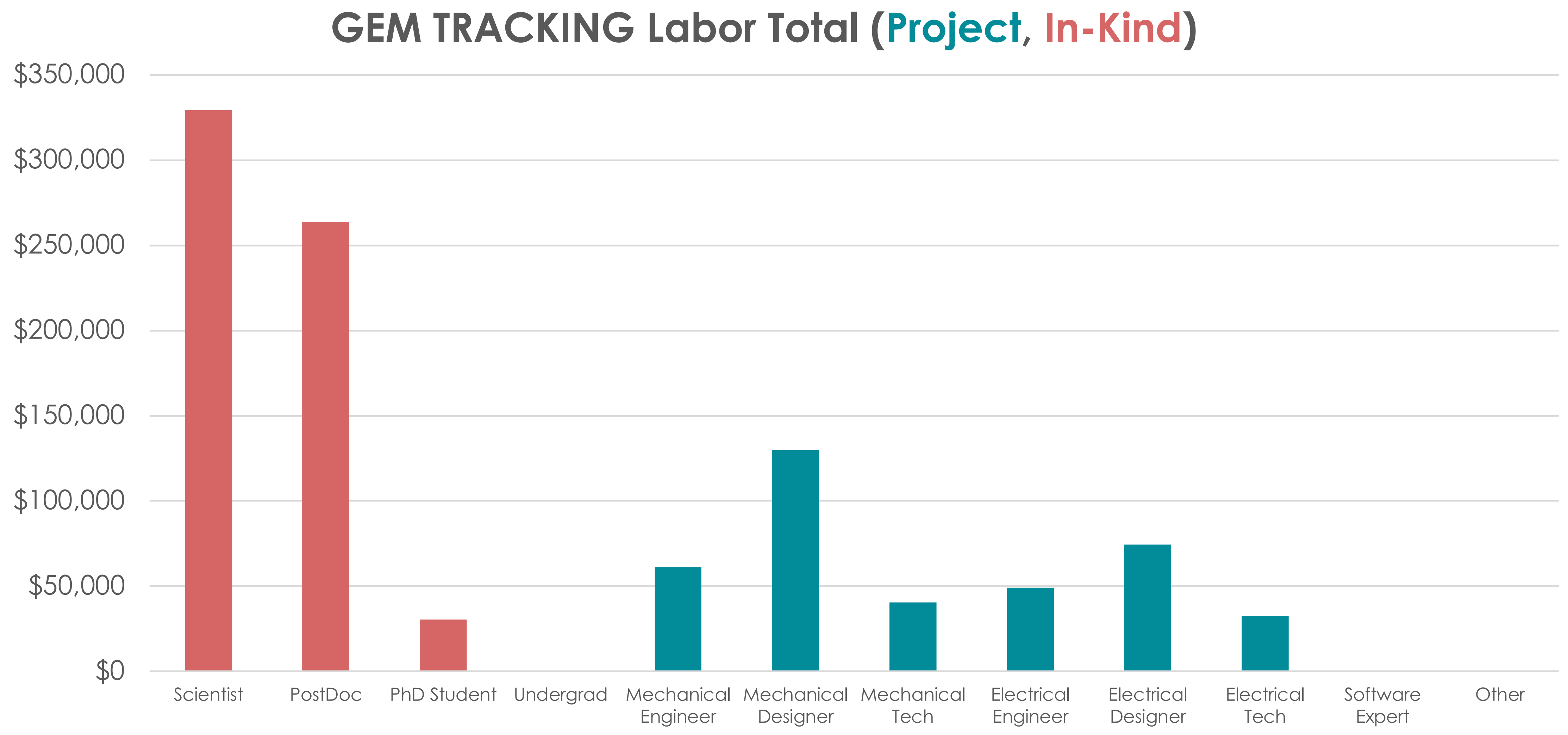
Happy Holidays!

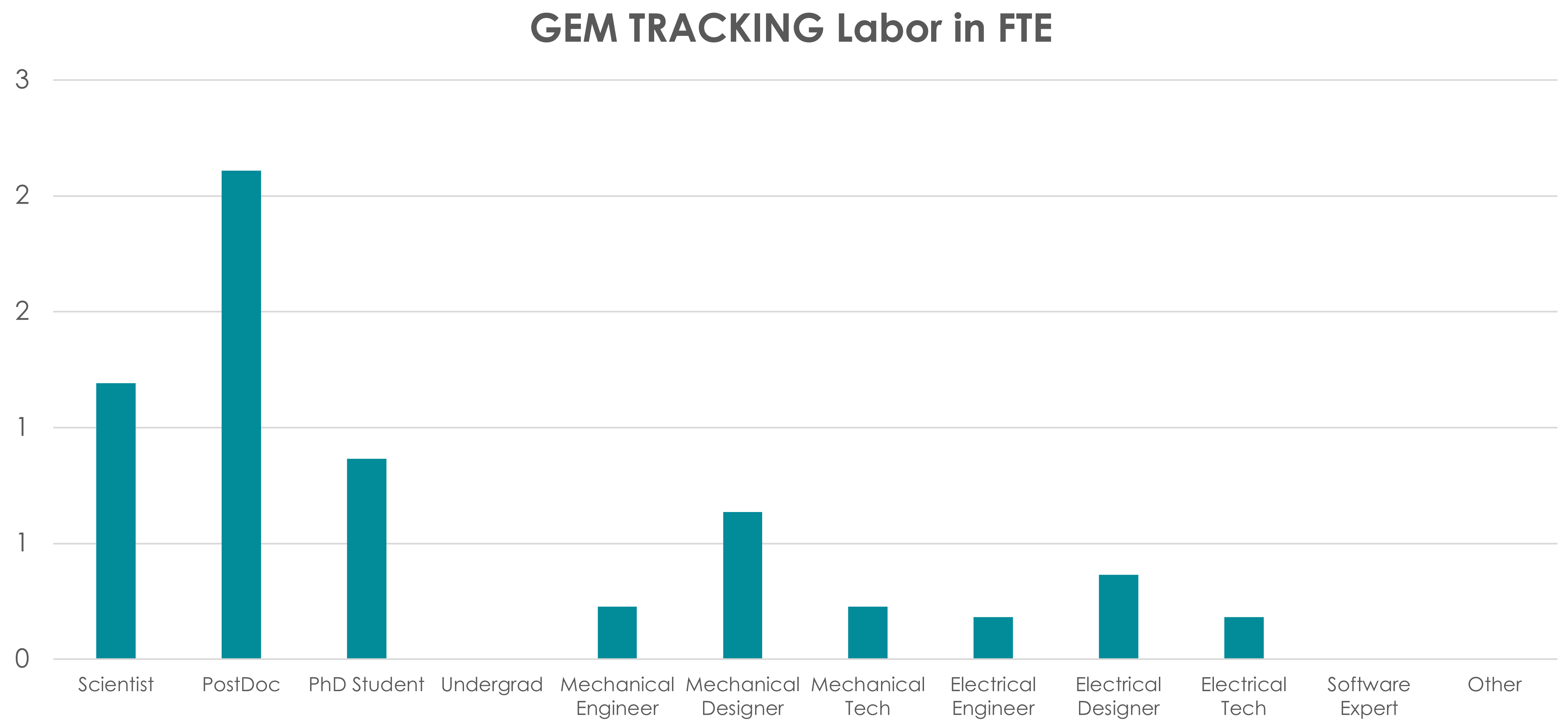
Backup


GEM TRACKING BASICS OF ESTIMATE
Vendor Quote, $457,013, 19%
Expert Opinion, $0, 0%
Engineering Estimate, $0, 0%
Historical Costs, $1,950,160, 81%

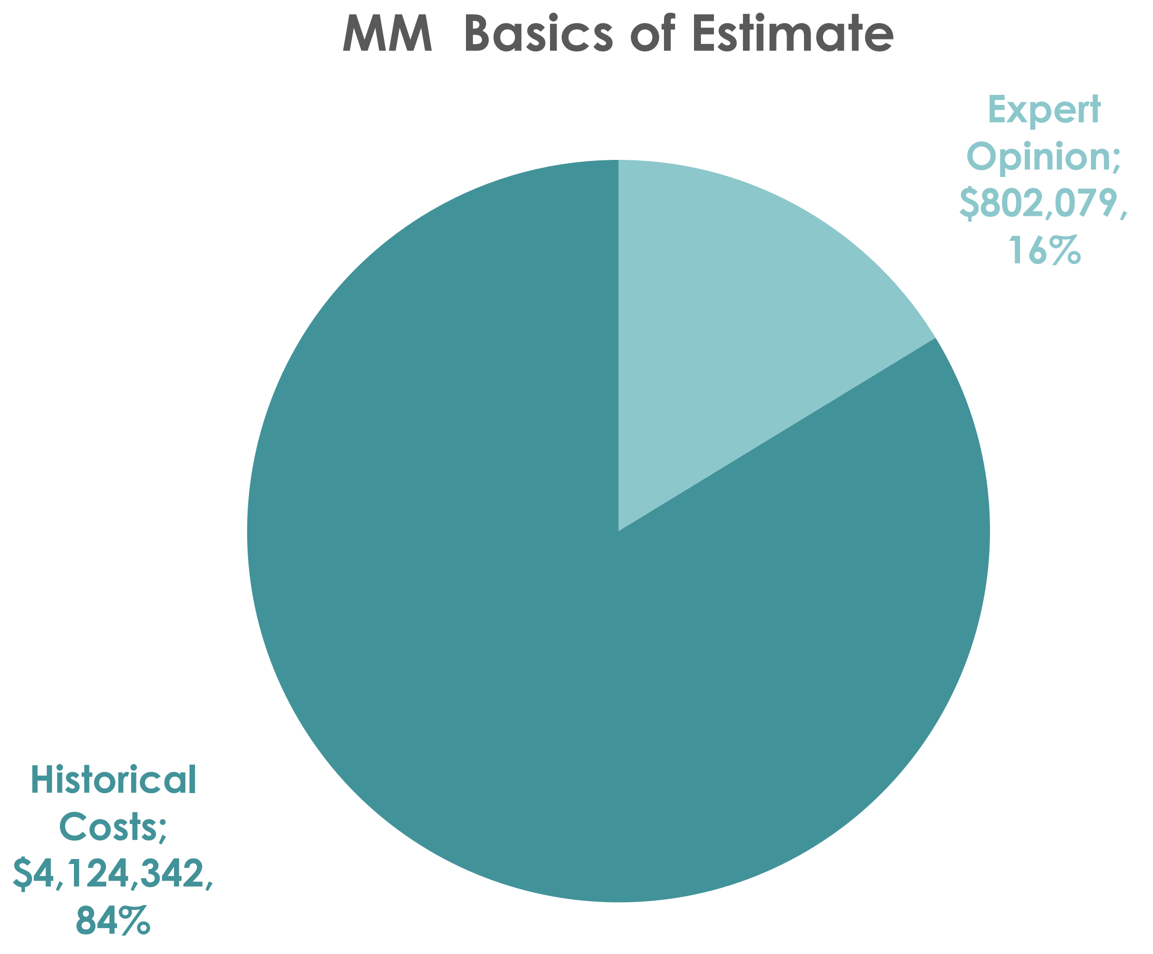

GEM TRACKING PROJECT VS. IN-KIND
In-kind, $623,628, 26%
Project, $1,783,546, 74%

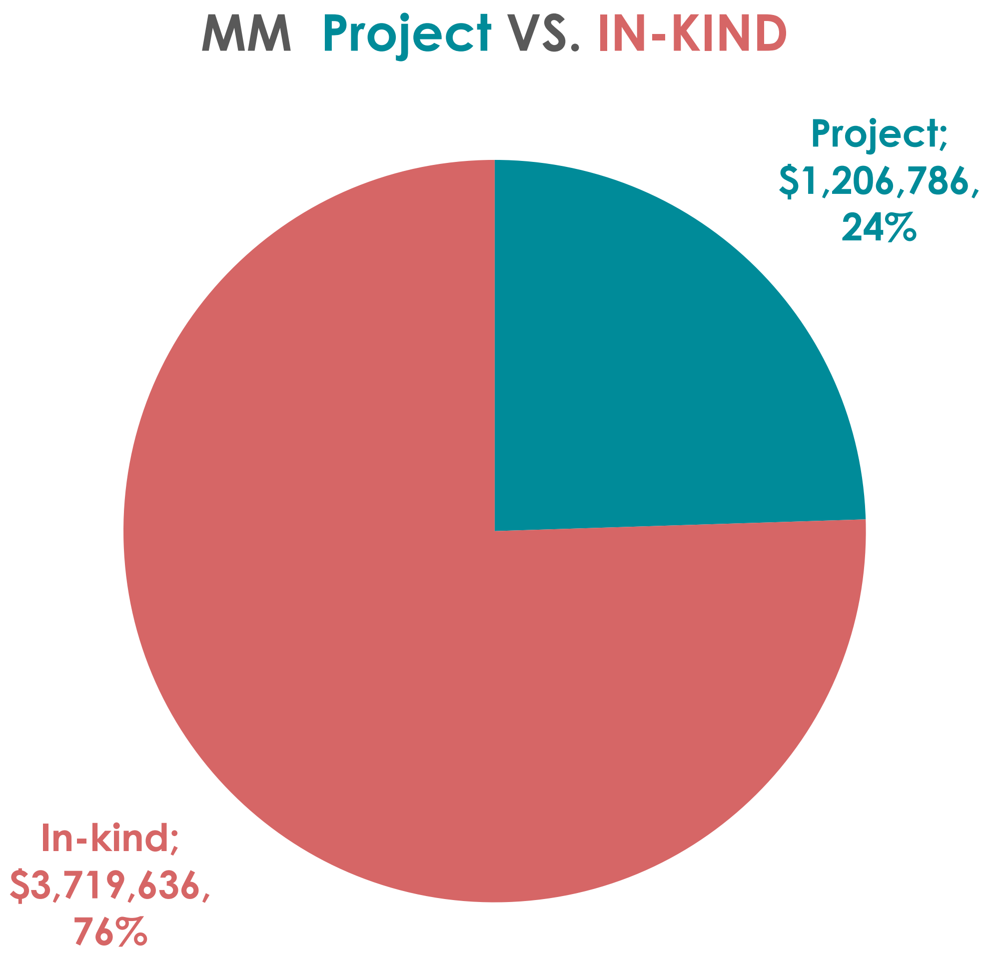

GEM TRACKING MATERIAL VS. LABOR
In-Kind Labor, $623,628, 26%
In-Kind Material, $0, 0%
Project Labor, $387,346, 16%
Project Material, $1,396,200, 58%

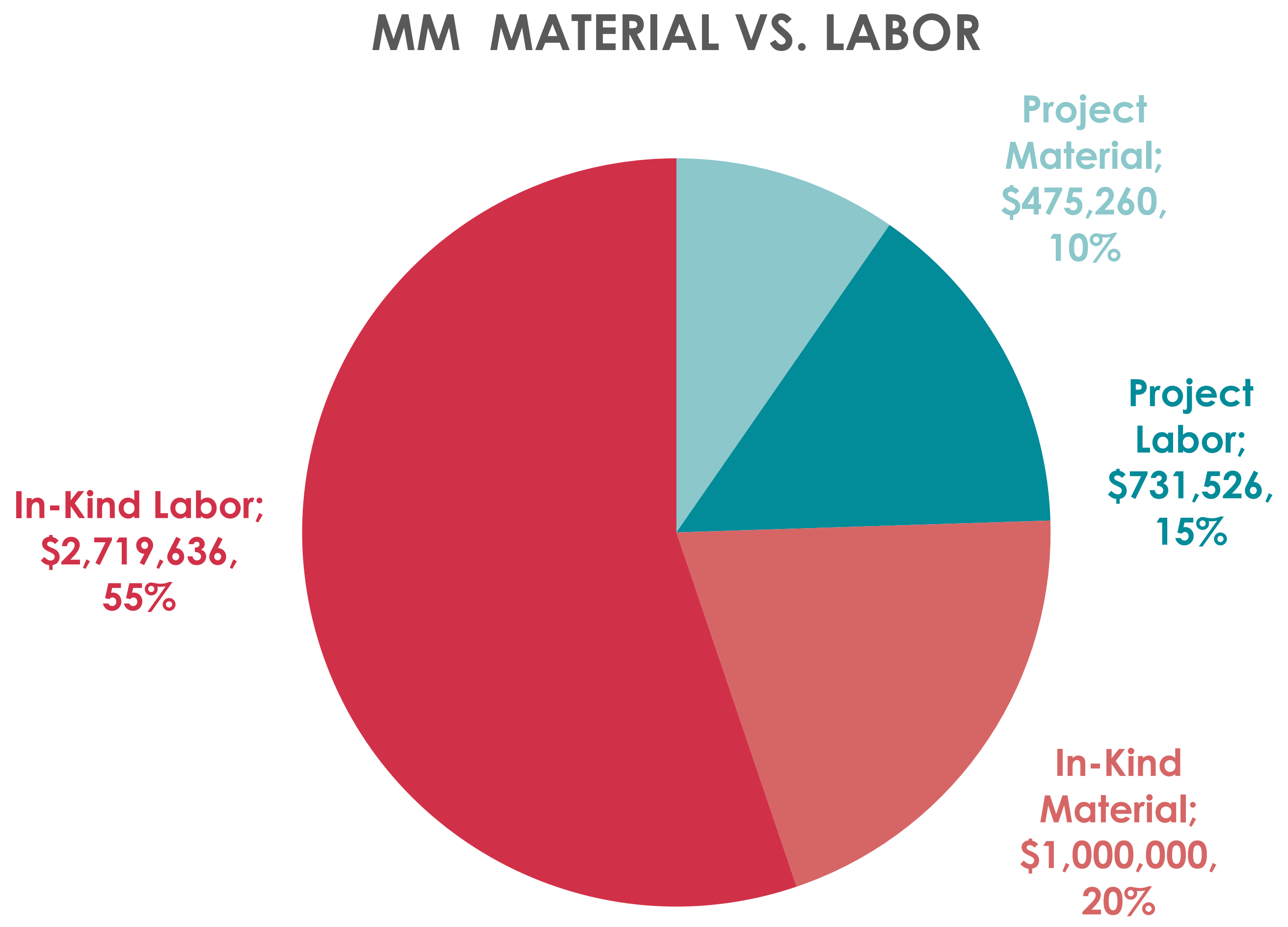

GEM TRACKING Labor Total (Project, In-Kind)
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

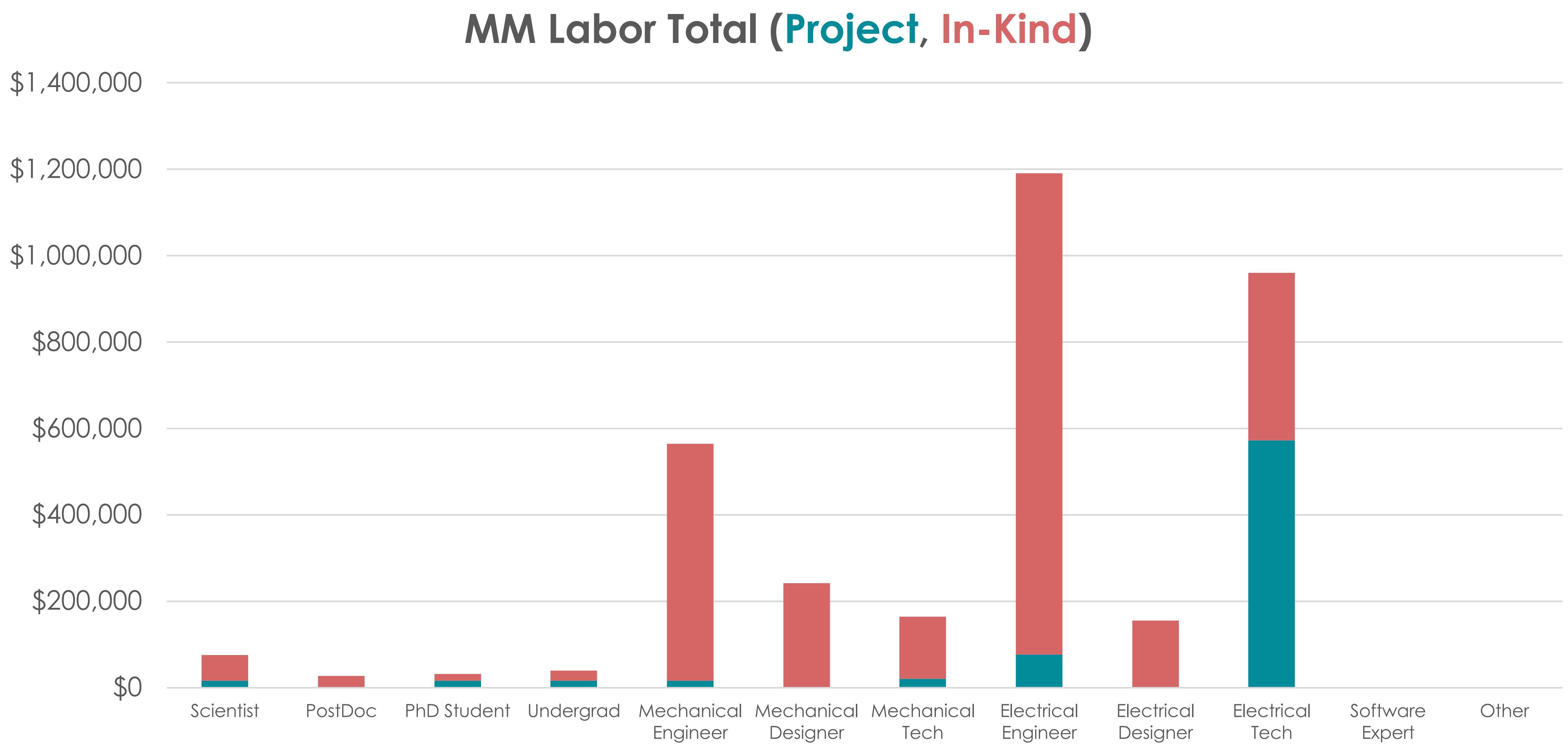

GEM TRACKING Labor in FTE
3
2
2
1
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

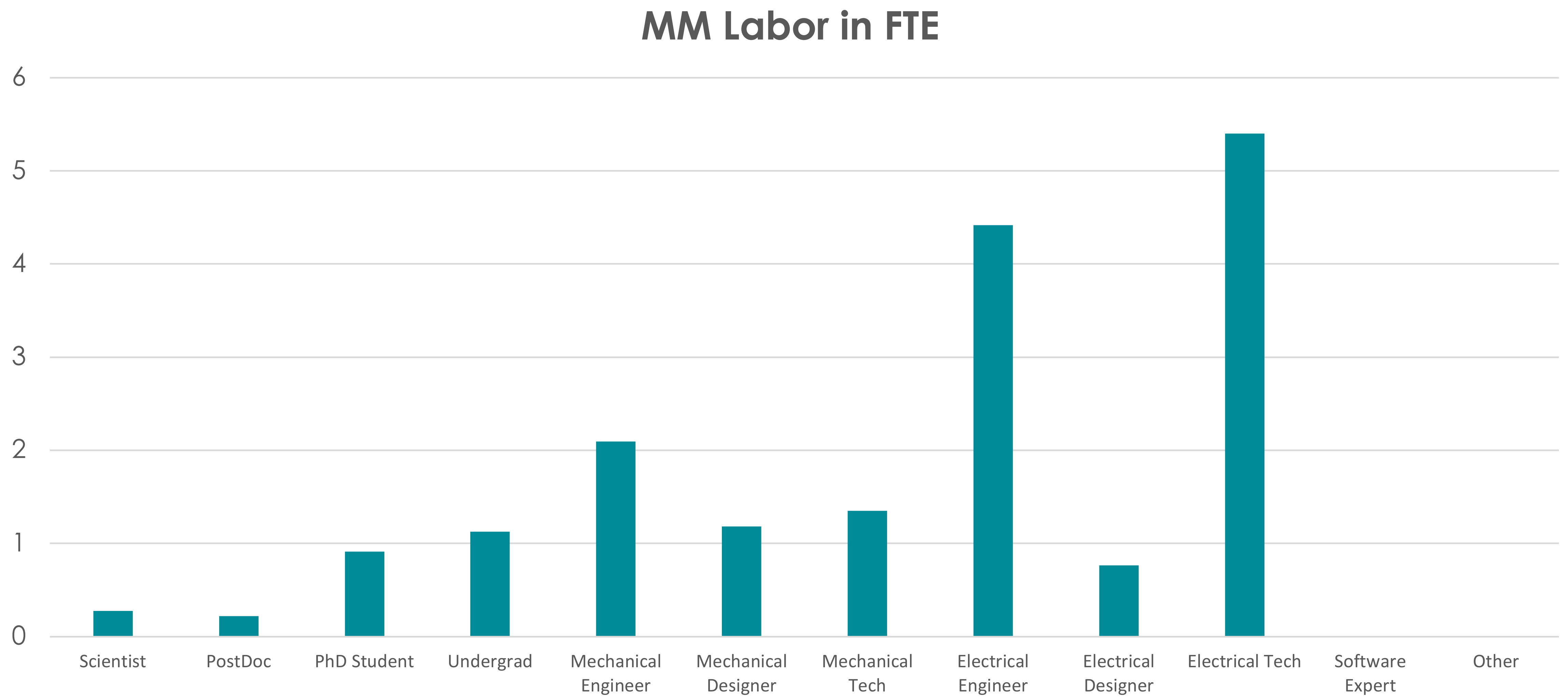
Backup


MM Basics of Estimate
Expert Opinion; $802,079, 16%
Historical Costs; $4,124,342, 84%

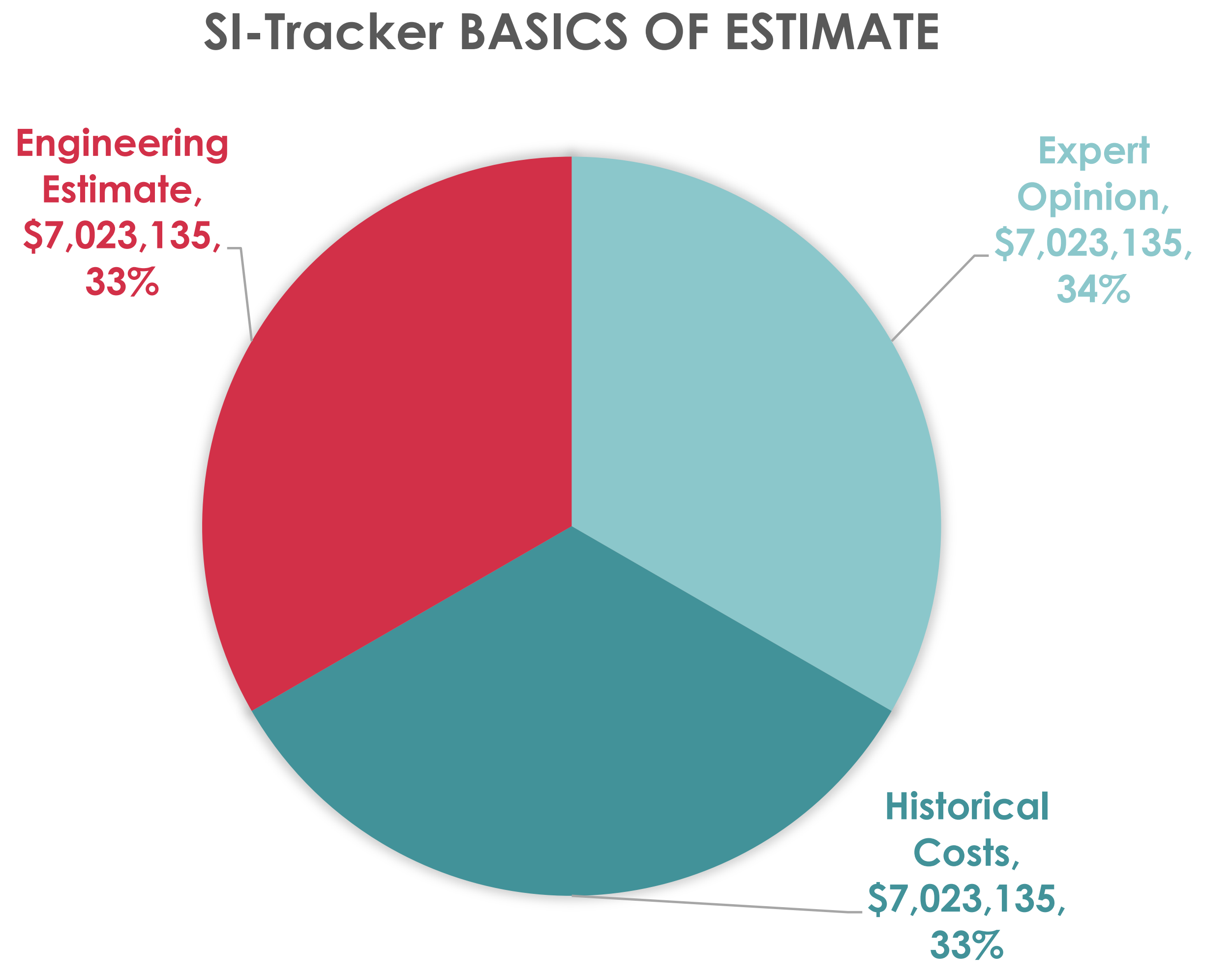

MM Project VS. IN-KIND
Project; $1,206,786, 24%
In-kind; $3,719,636, 76%


MM MATERIAL VS. LABOR
Project Material; $475,260, 10%
Project Labor; $731,526, 15%
In-Kind Labor; $2,719,636, 55%
In-Kind Material; $1,000,000, 20%

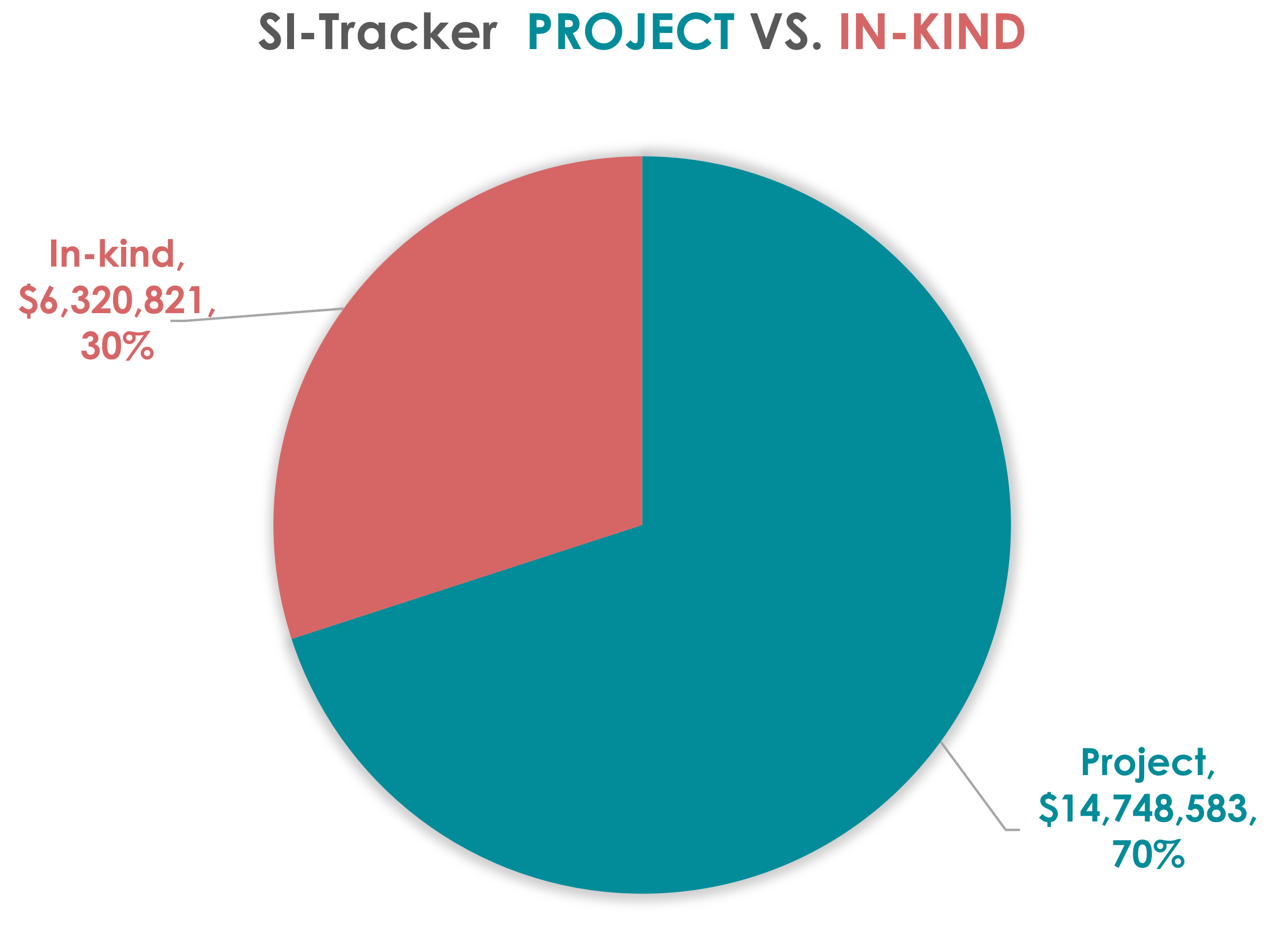

MM Labor Total (Project, In-Kind)
$1,400,000
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other


MM Labor in FTE
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

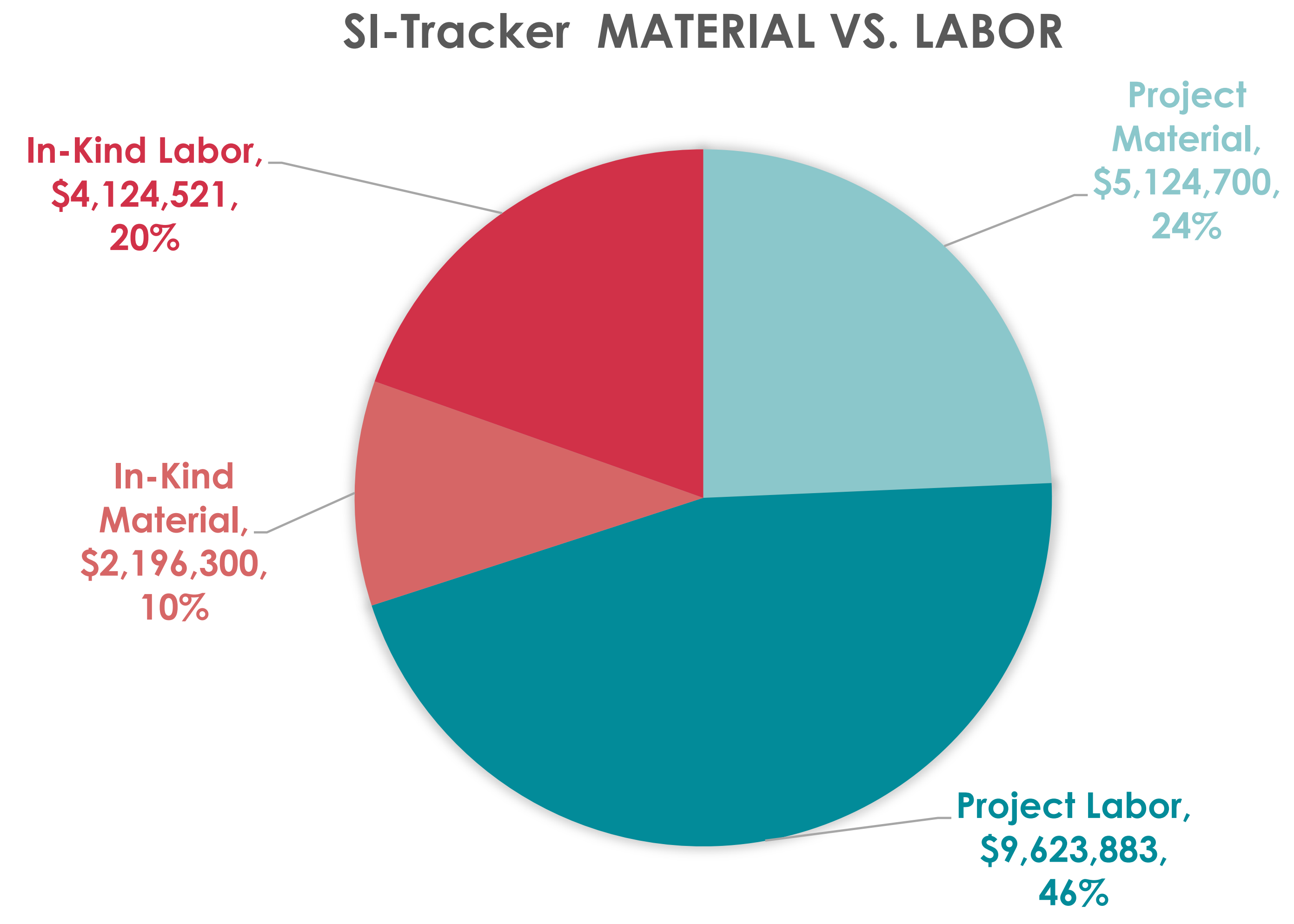
Backup



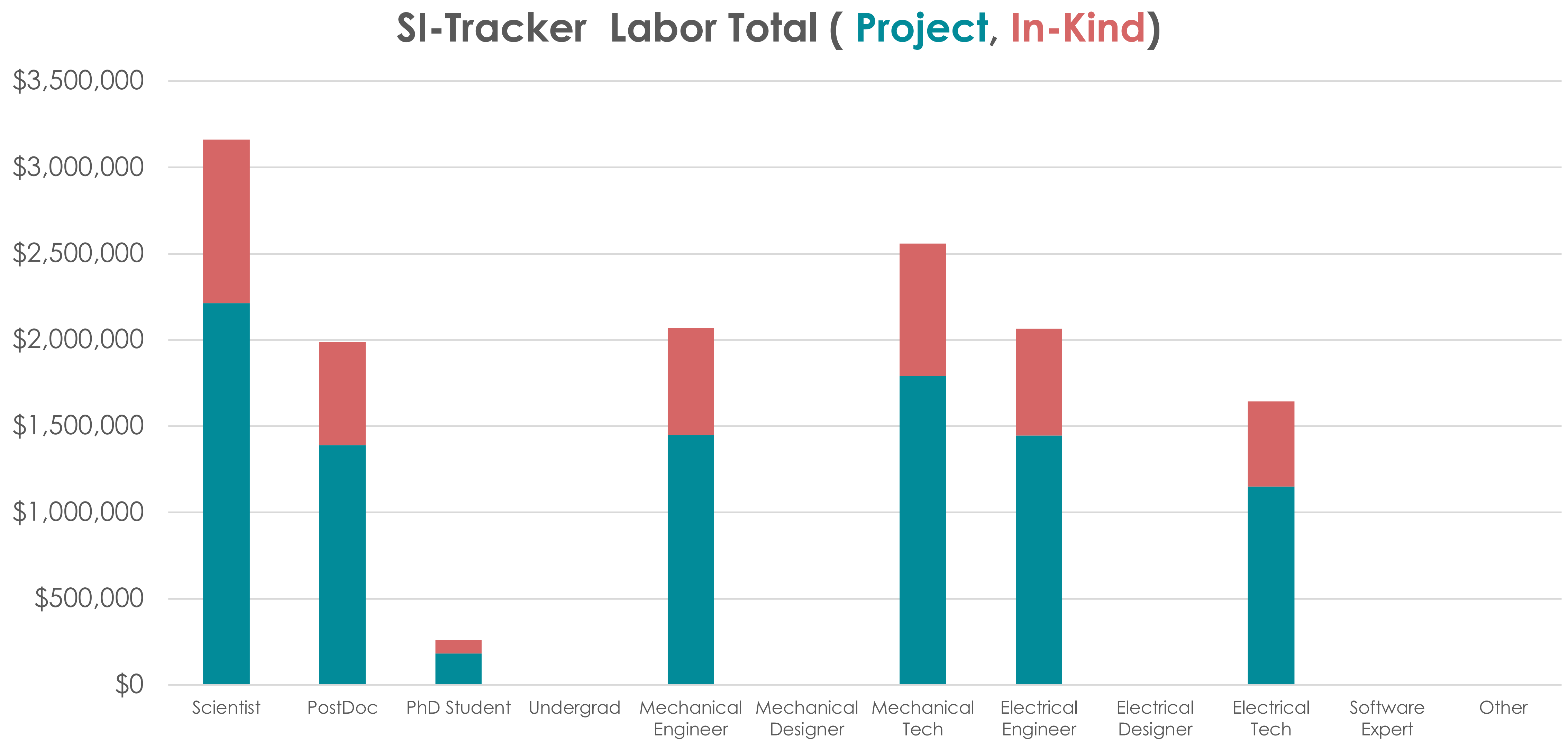
SI-Tracker BASICS OF ESTIMATE
Engineering Estimate, $7,023,135, 33%
Expert Opinion, $7,023,135, 34%
Historical Costs, $7,023,135, 33%



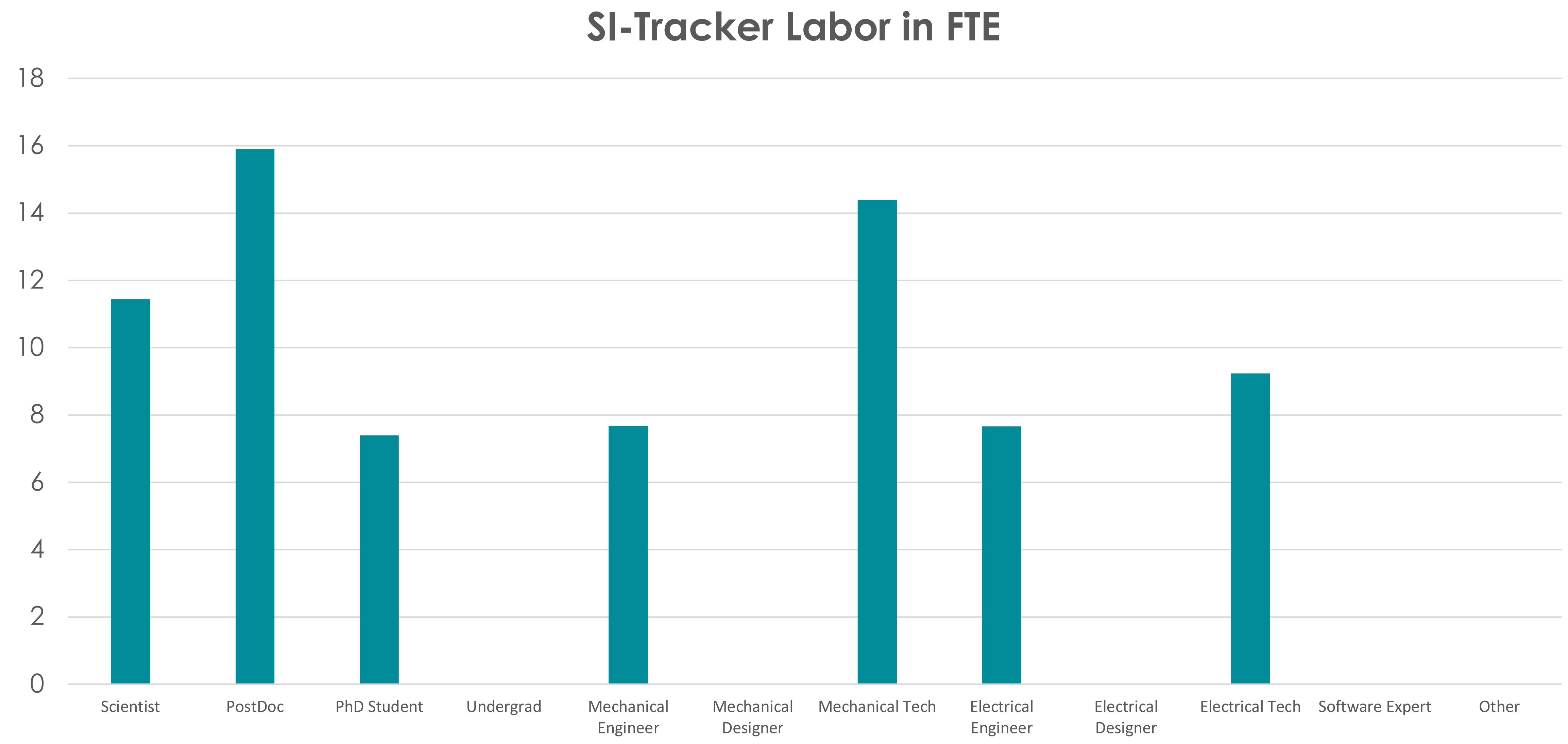
SI-Tracker PROJECT VS. IN-KIND
In-kind, $6,320,821, 30%
Project, $14,748,583, 70%



SI-Tracker MATERIAL VS. LABOR
In-Kind Labor, $4,124,521, 20%
Project Material, $5,124,700, 24%
In-Kind Material, $2,196,300, 10%
Project Labor, $9,623,883, 46%

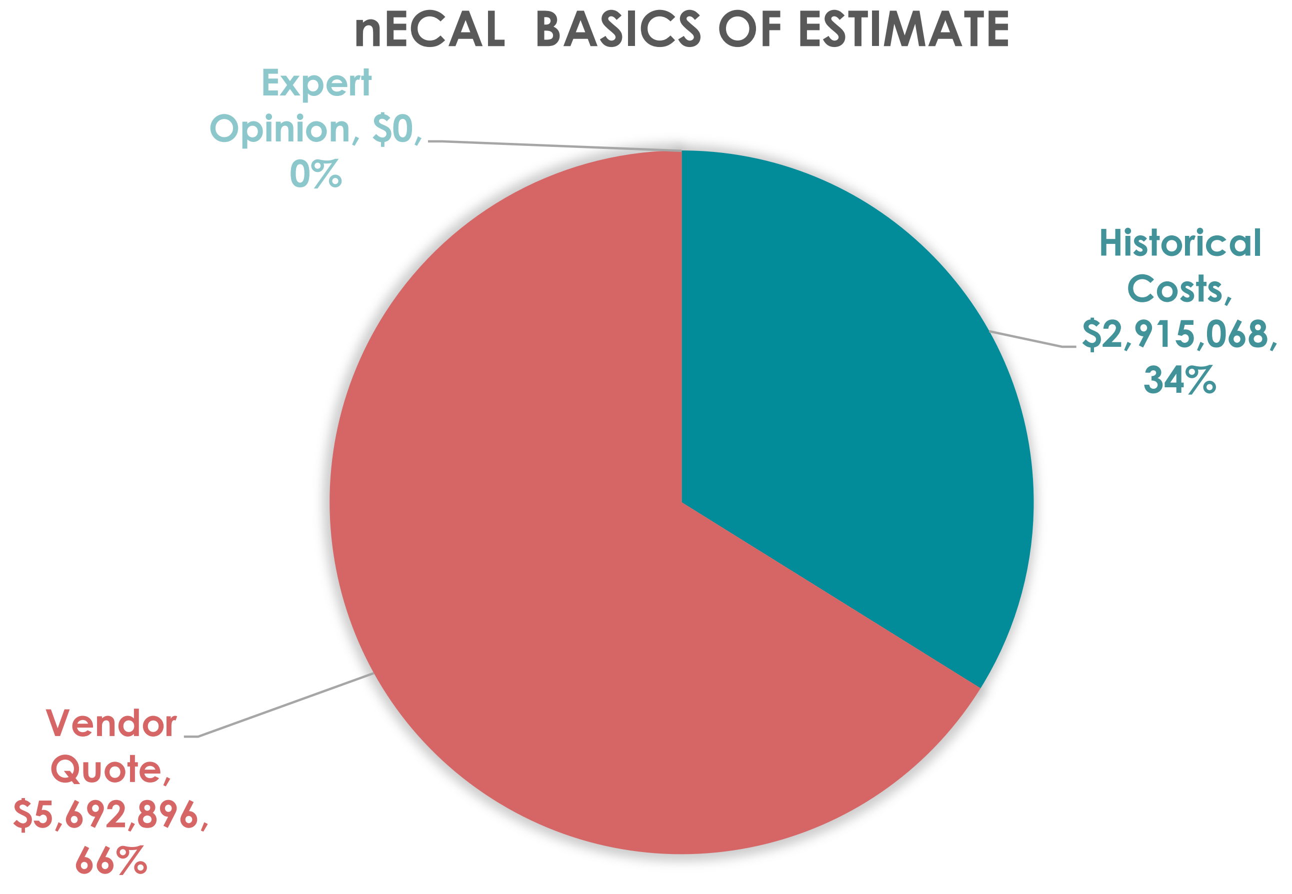


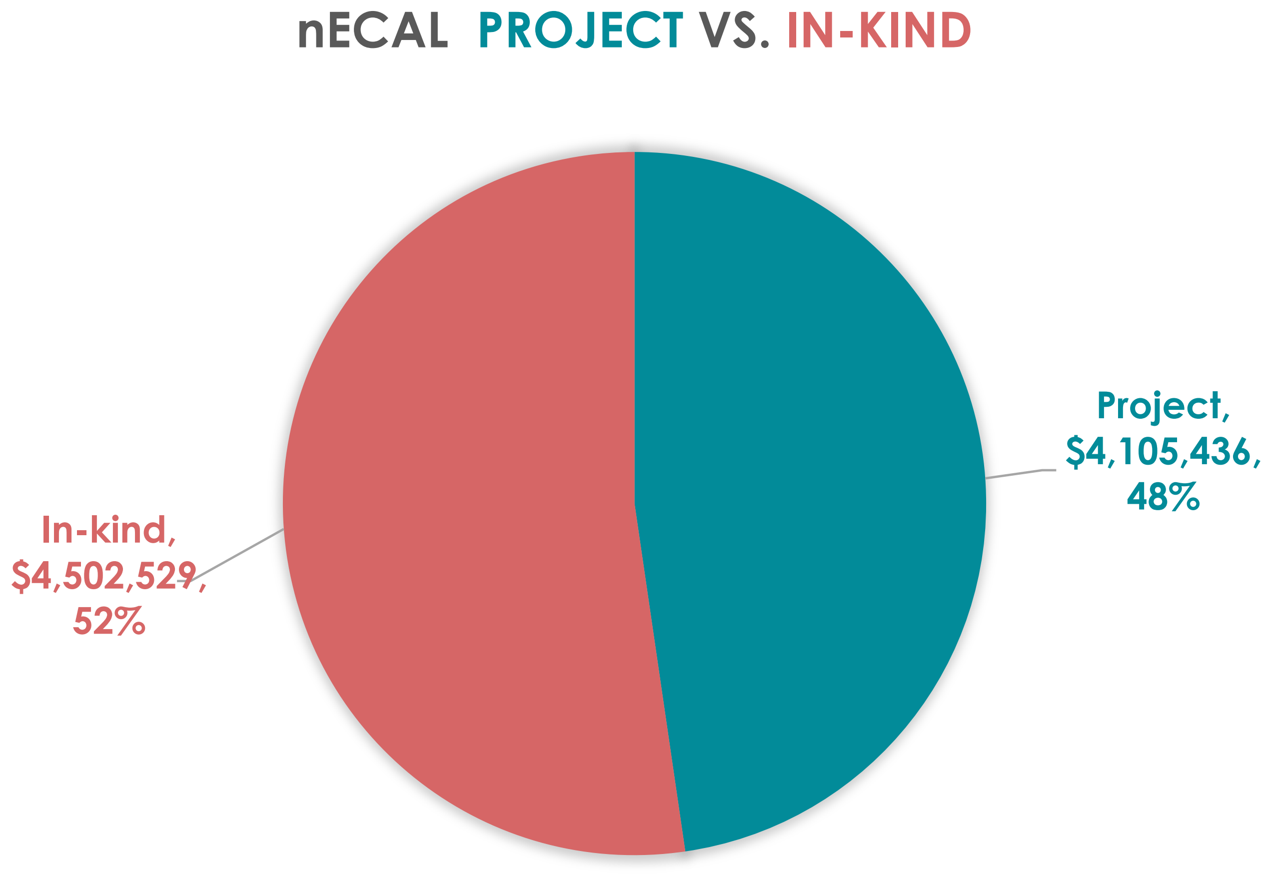
SI-Tracker Labor Total (Project, In-Kind)
$3,500,000
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

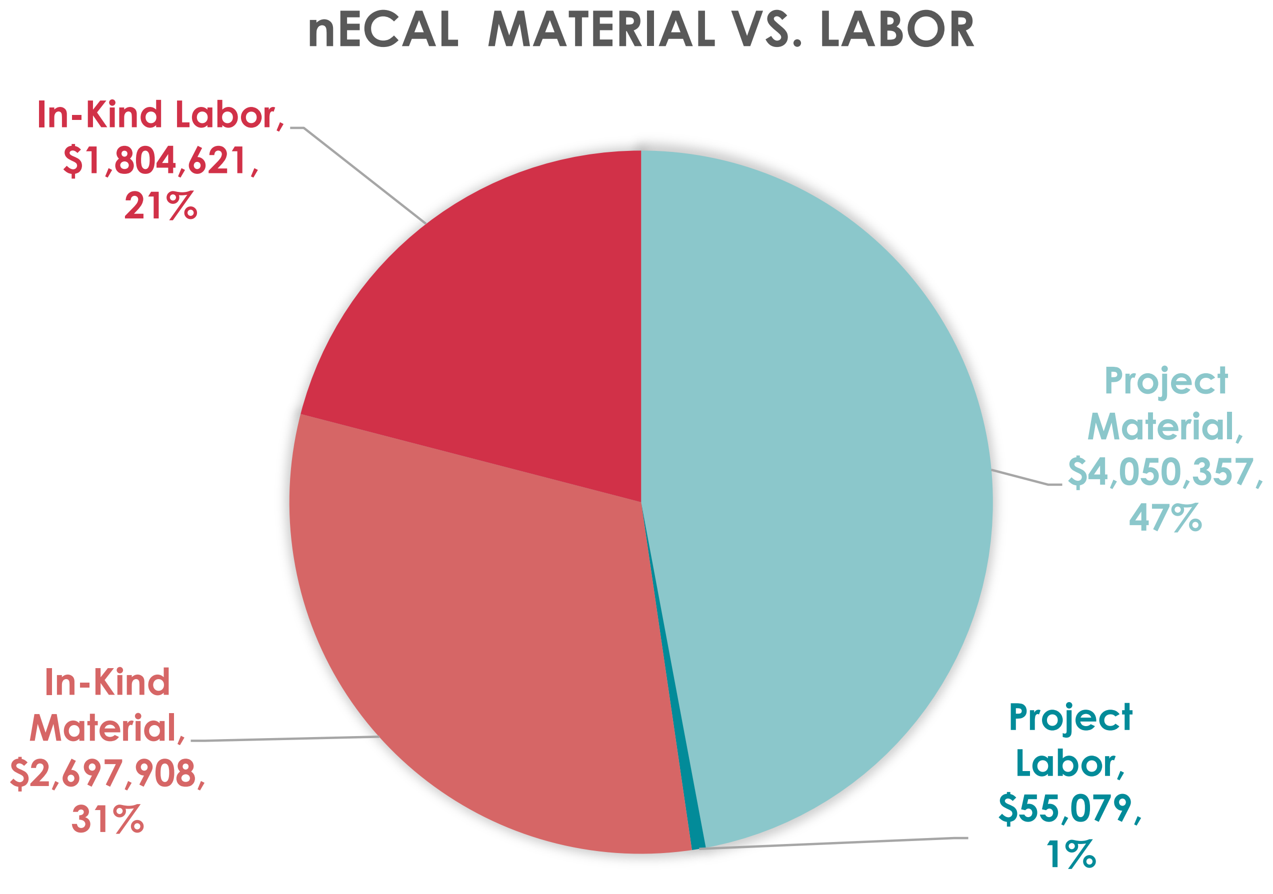


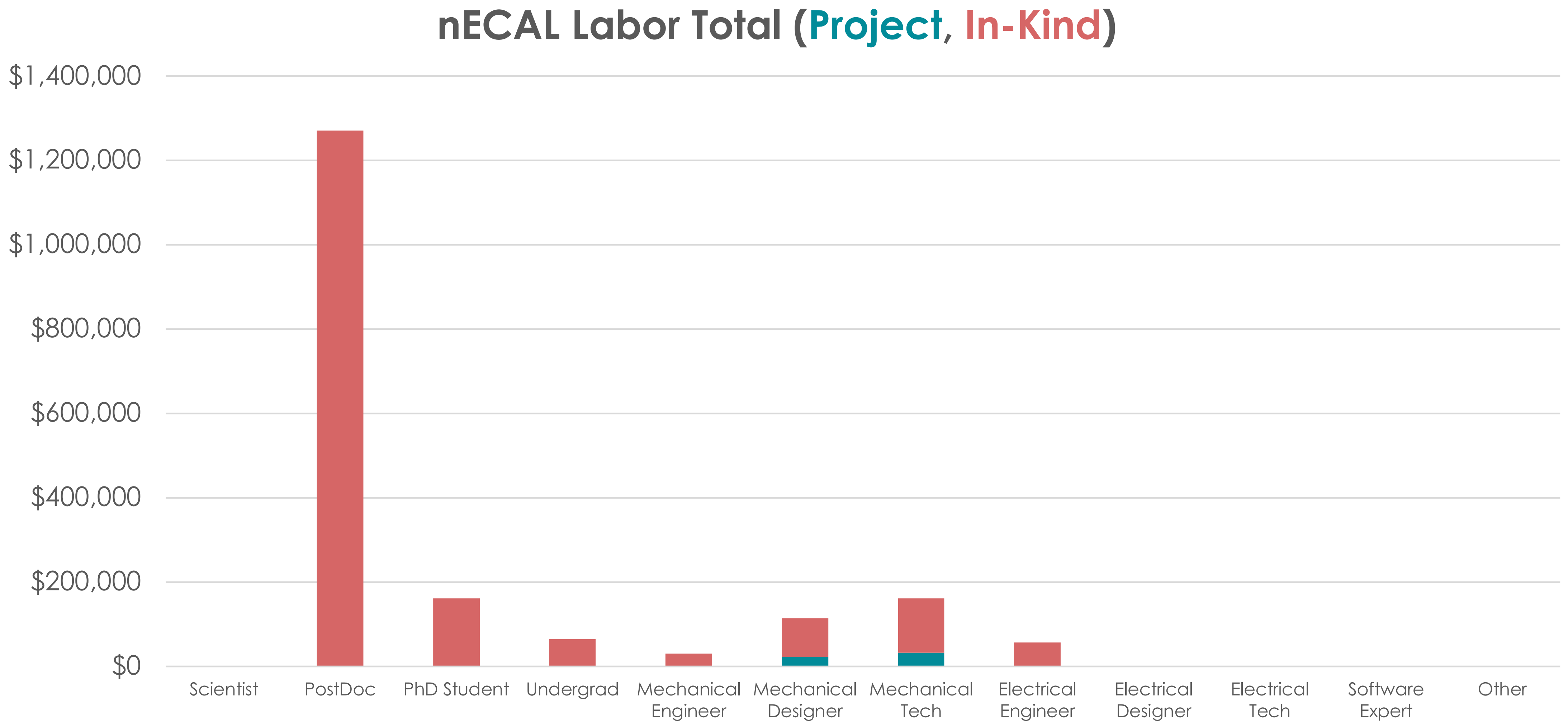
SI-Tracker Labor in FTE
18
16
14
12
10
8
6
4
2
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

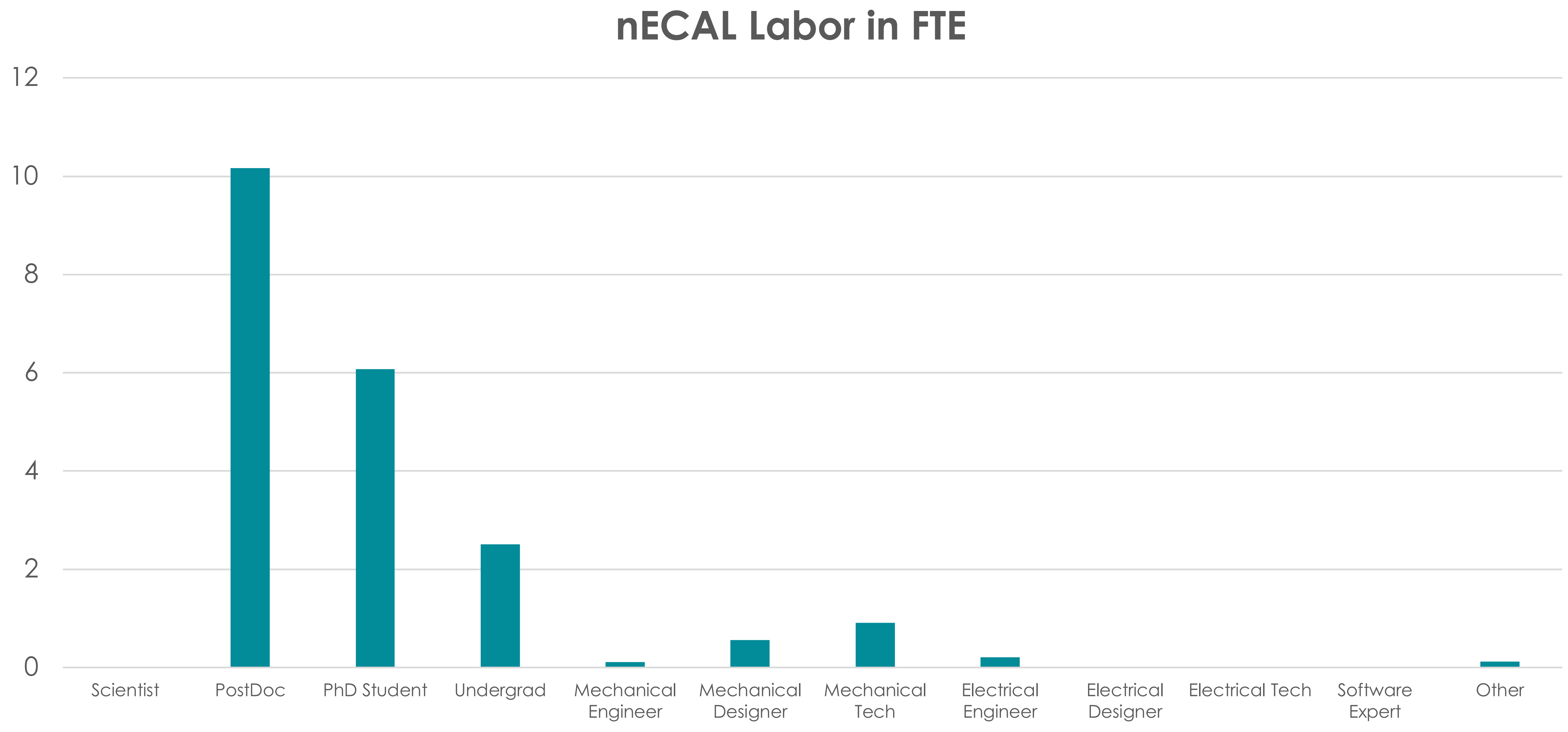
Backup


nECAL BASICS OF ESTIMATE
Expert Opinion, $0, 0%
Historical Costs, $2,915,068, 34%
Vendor Quote, $5,692,896, 66%

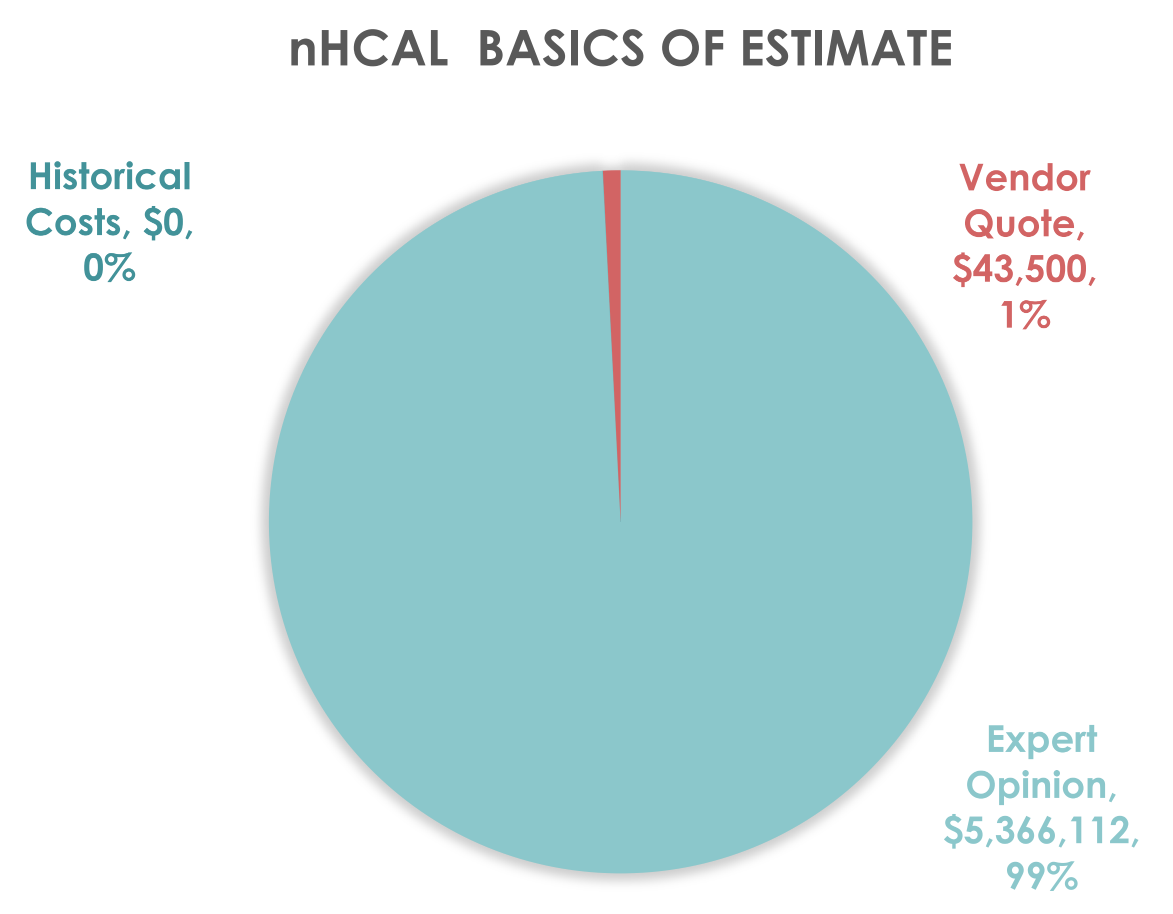

nECAL PROJECT VS. IN-KIND
Project, $4,105,436, 48%
In-kind, $4,502,529, 52%


nECAL MATERIAL VS. LABOR
In-Kind Labor, $1,804,621, 21%
Project Material, $4,050,357, 47%
In-Kind Material, $2,697,908, 31%
Project Labor, $55,079, 1%

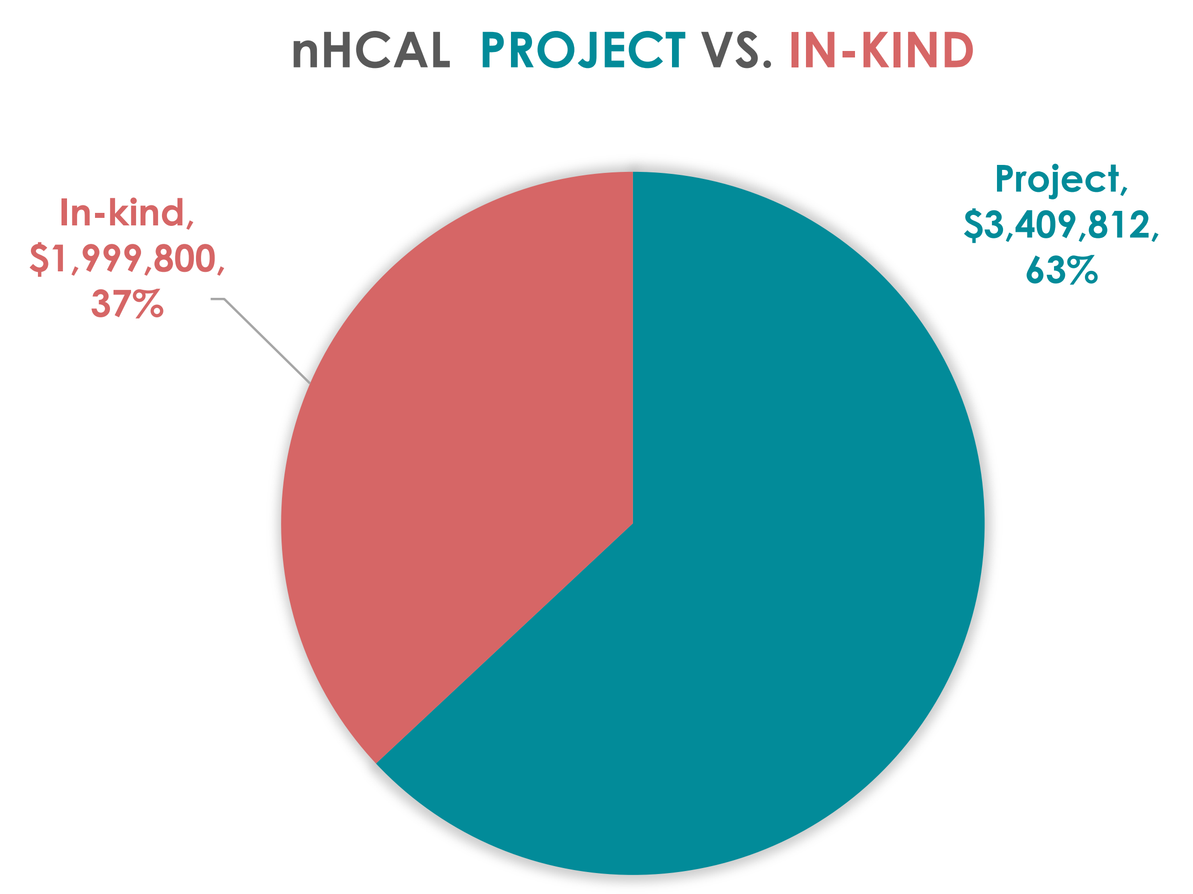

nECAL Labor Total (Project, In-Kind)
$1,400,000
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other


nECAL Labor in FTE
12
10
8
6
4
2
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

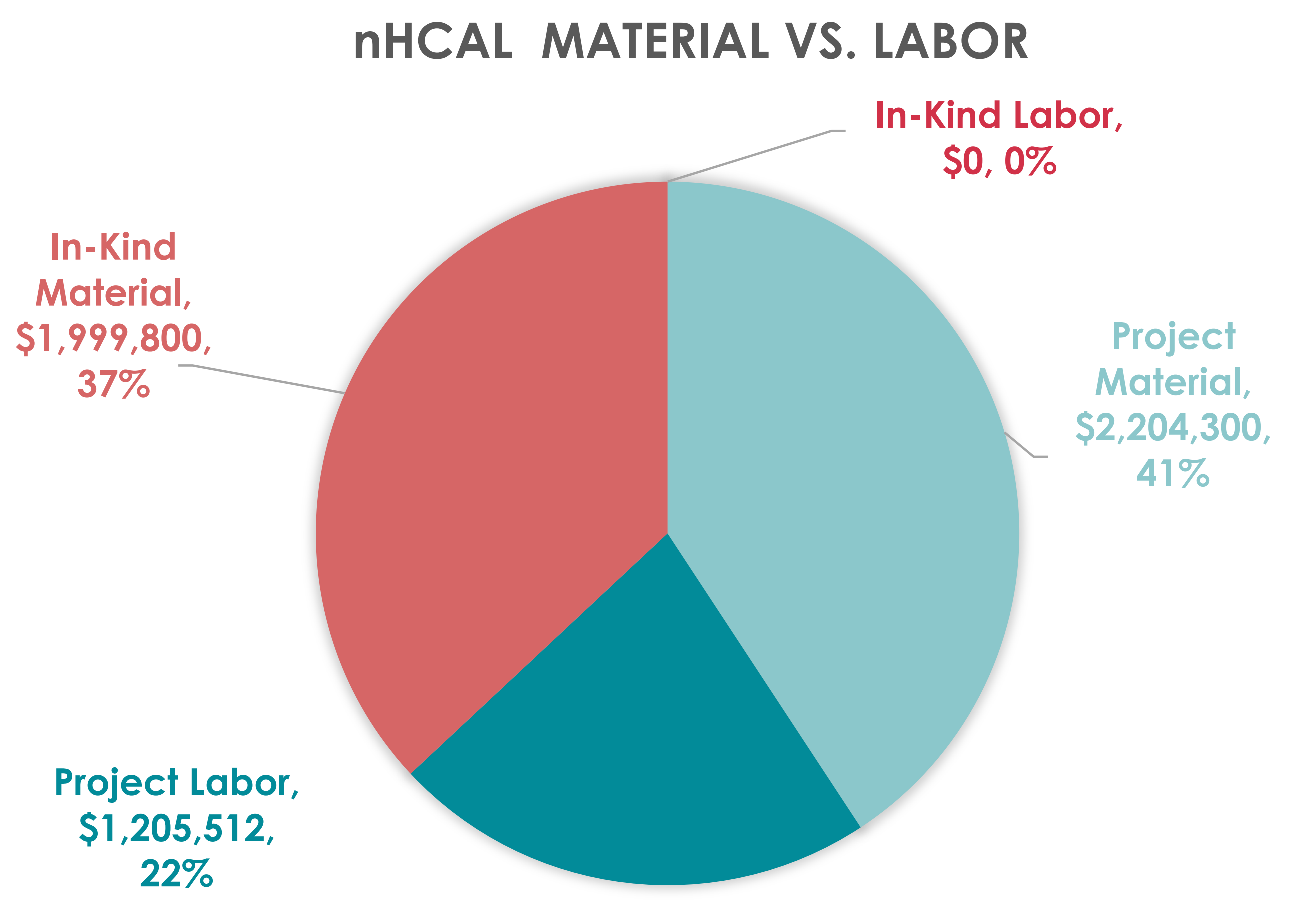
Backup



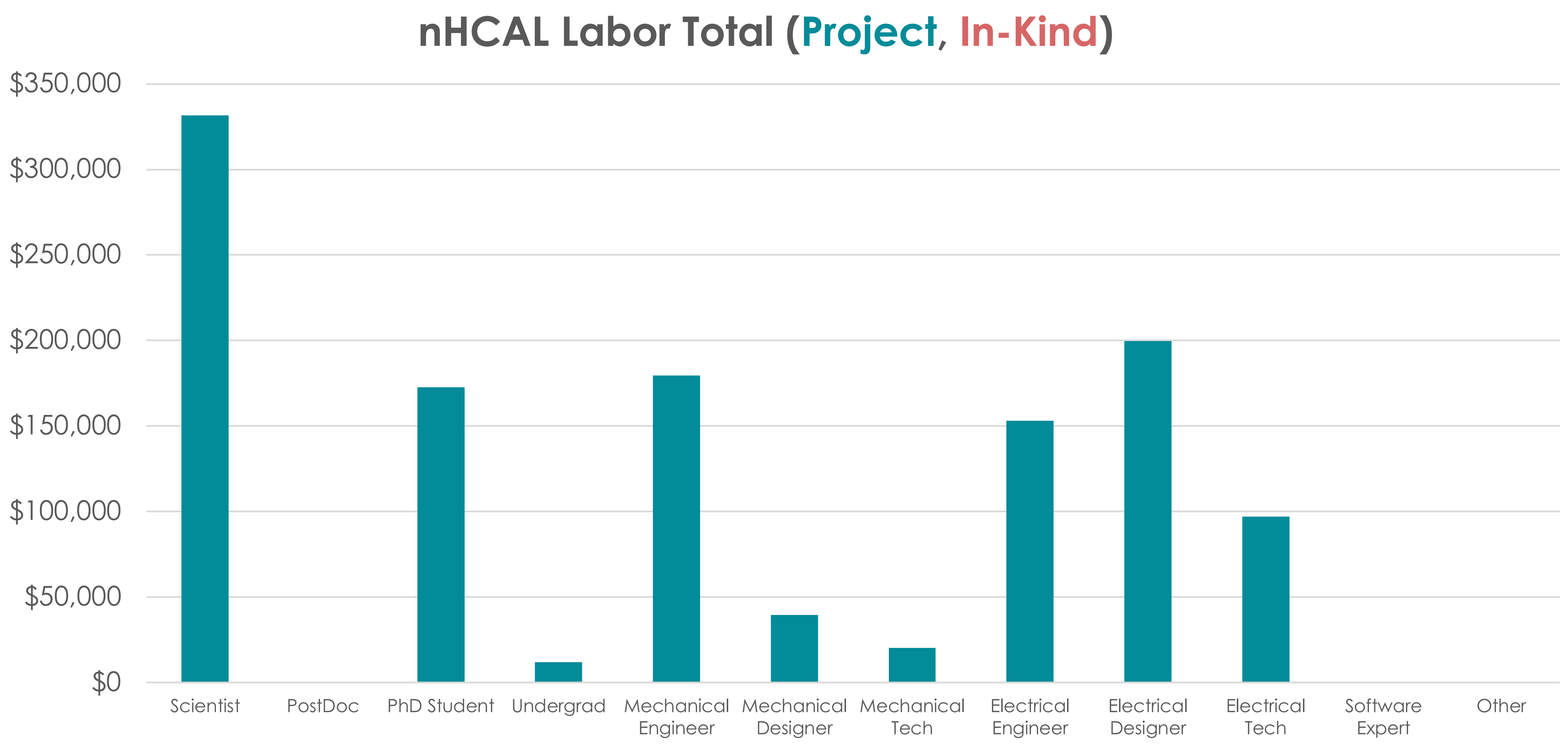
nHCAL BASICS OF ESTIMATE
Historical Costs, $0, 0%
Vendor Quote, $43,500, 1%
Expert Opinion, $5,366,112, 99%



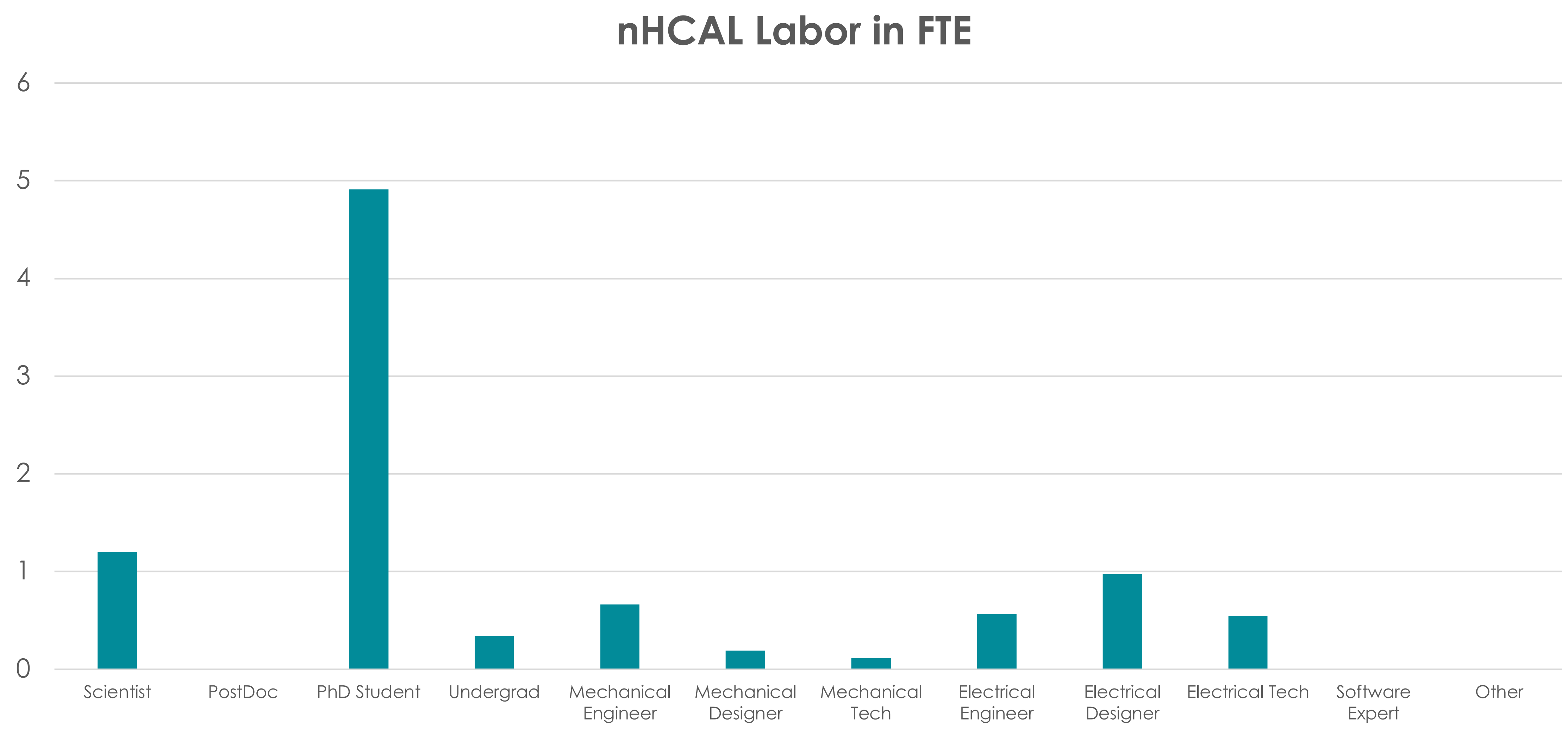
nHCAL PROJECT VS. IN-KIND
In-kind, $1,999,800, 37%
Project, $3,409,812, 63%



nHCAL MATERIAL VS. LABOR
In-Kind Labor, $0, 0%
In-Kind Material, $1,999,800, 37%
Project Material, $2,204,300, 41%
Project Labor, $1,205,512, 22%

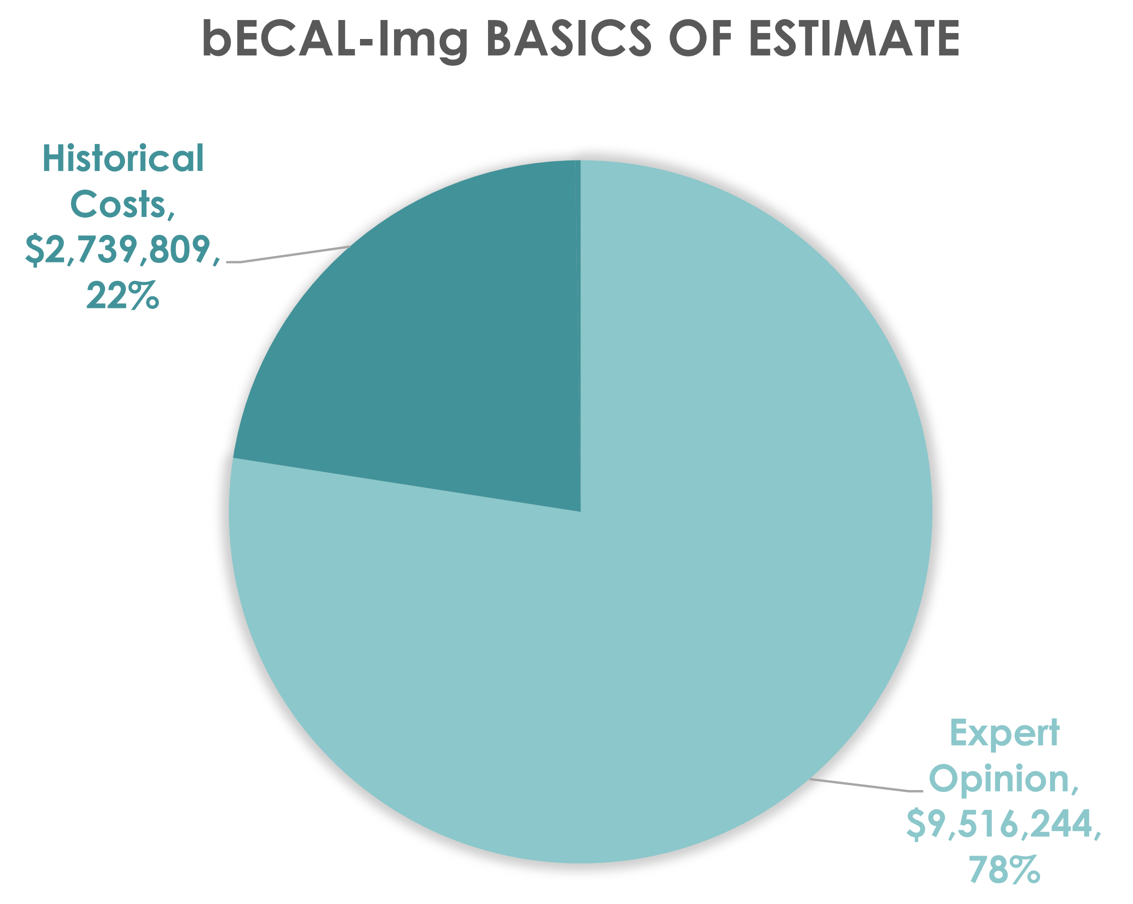


nHCAL Labor Total (Project, In-Kind)
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

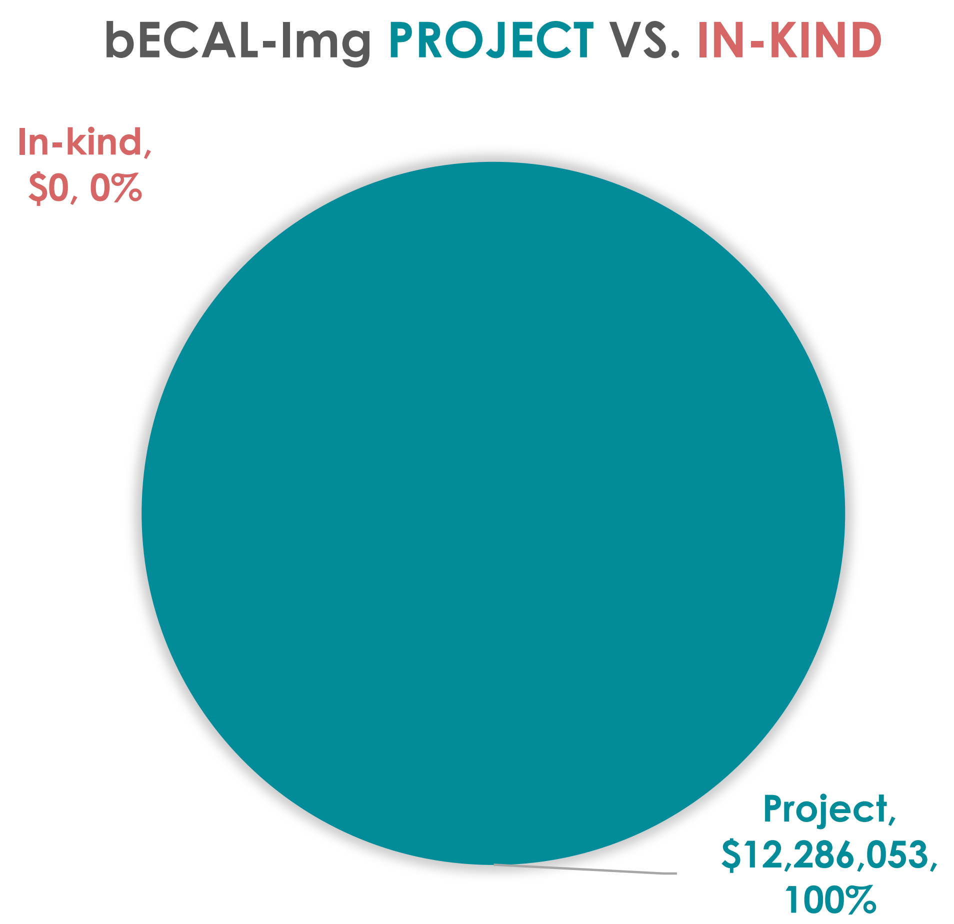


nHCAL Labor in FTE
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

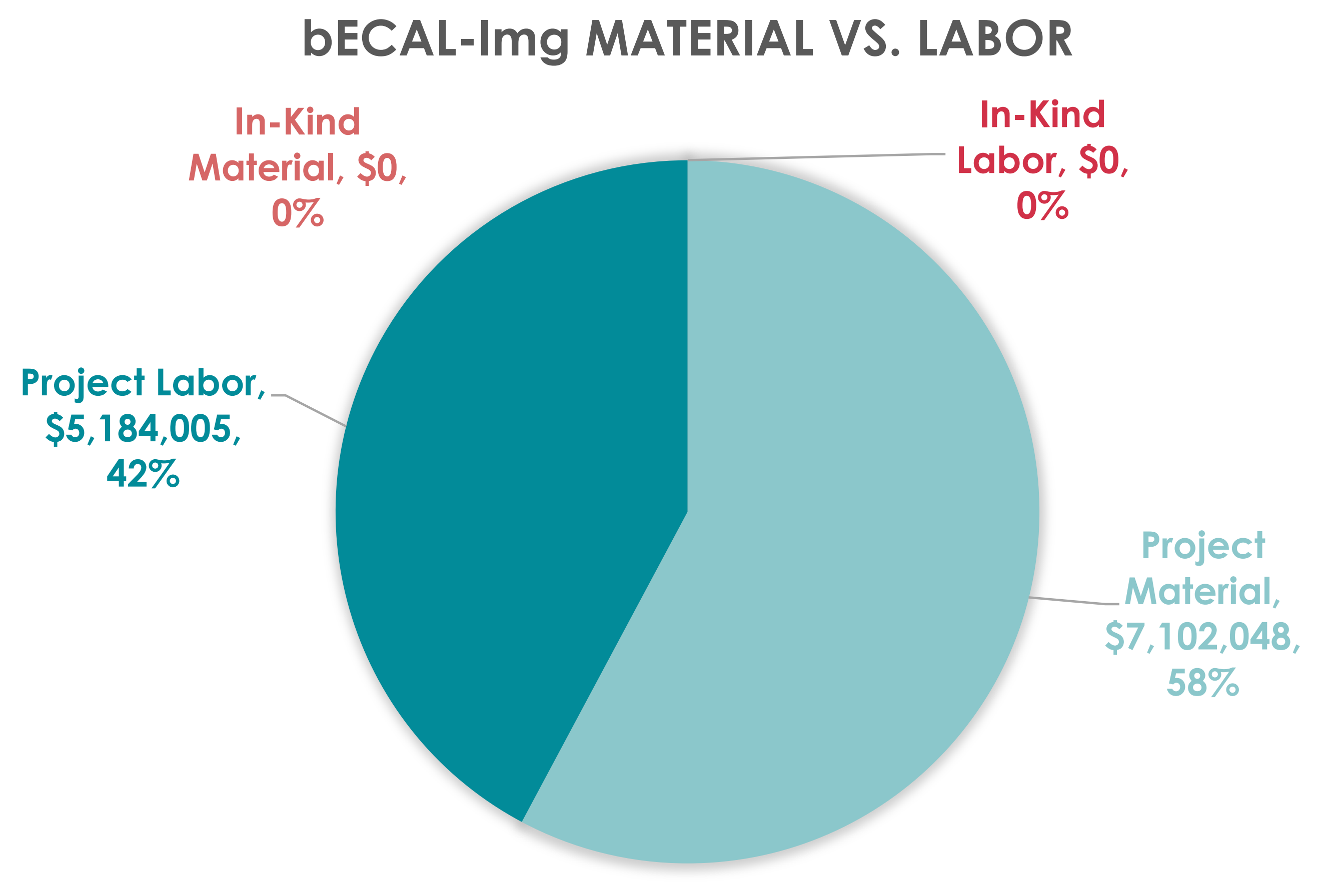
Backup



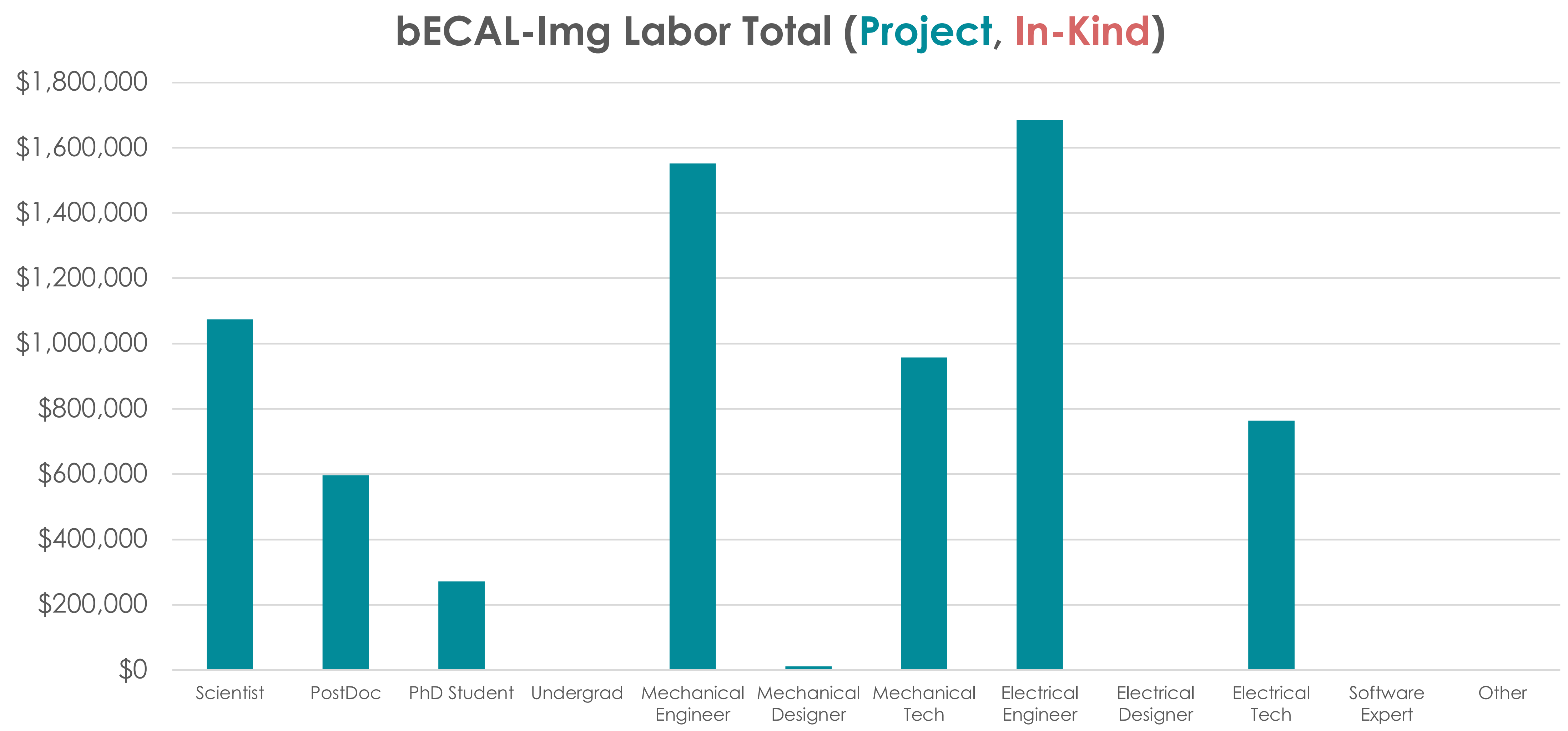
bECAL-Img BASICS OF ESTIMATE
Historical Costs, $2,739,809, 22%
Expert Opinion, $9,516,244, 78%



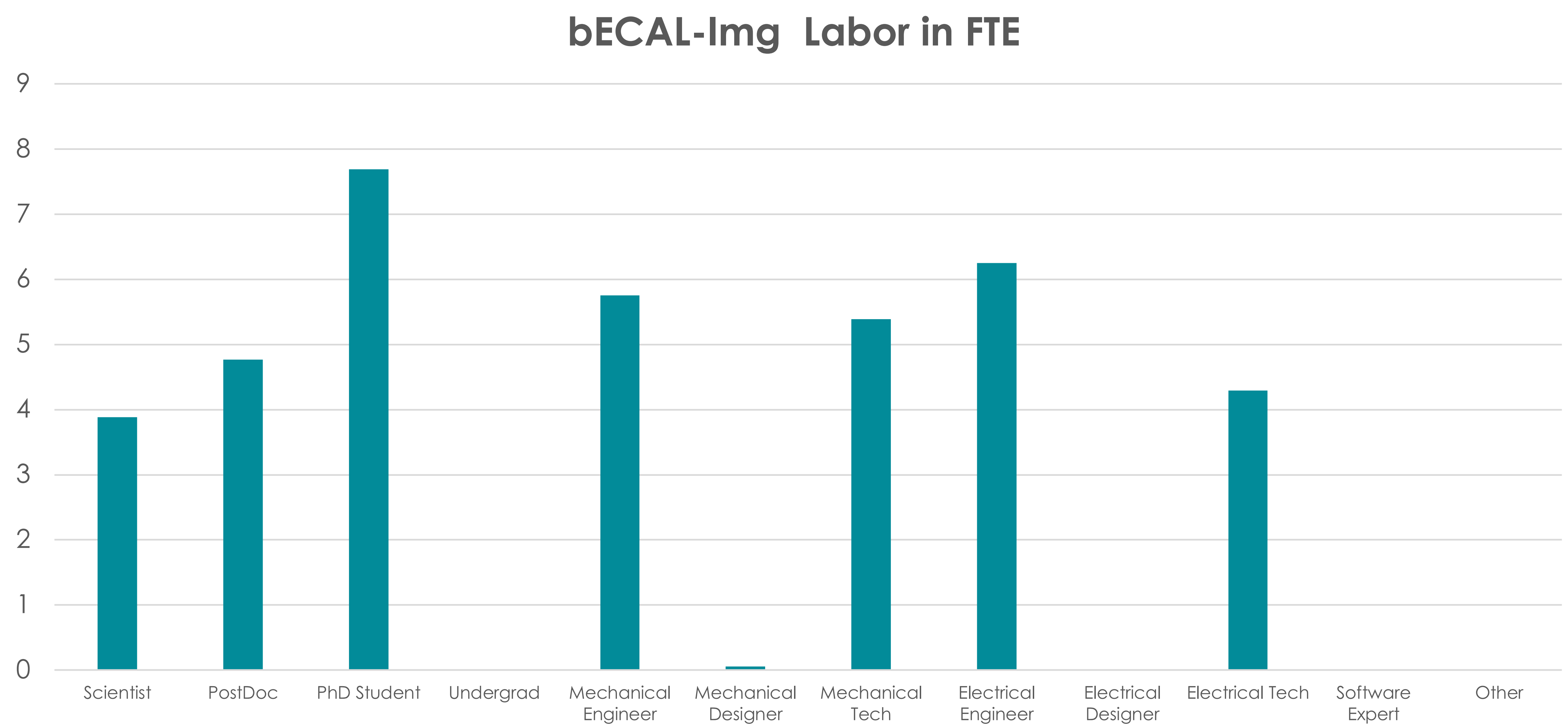
bECAL-Img PROJECT VS. IN-KIND
In-kind, $0, 0%
Project, $12,286,053, 100%



bECAL-Img MATERIAL VS. LABOR
In-Kind Material, $0, 0%
In-Kind Labor, $0, 0%
Project Labor, $5,184,005, 42%
Project Material, $7,102,048, 58%

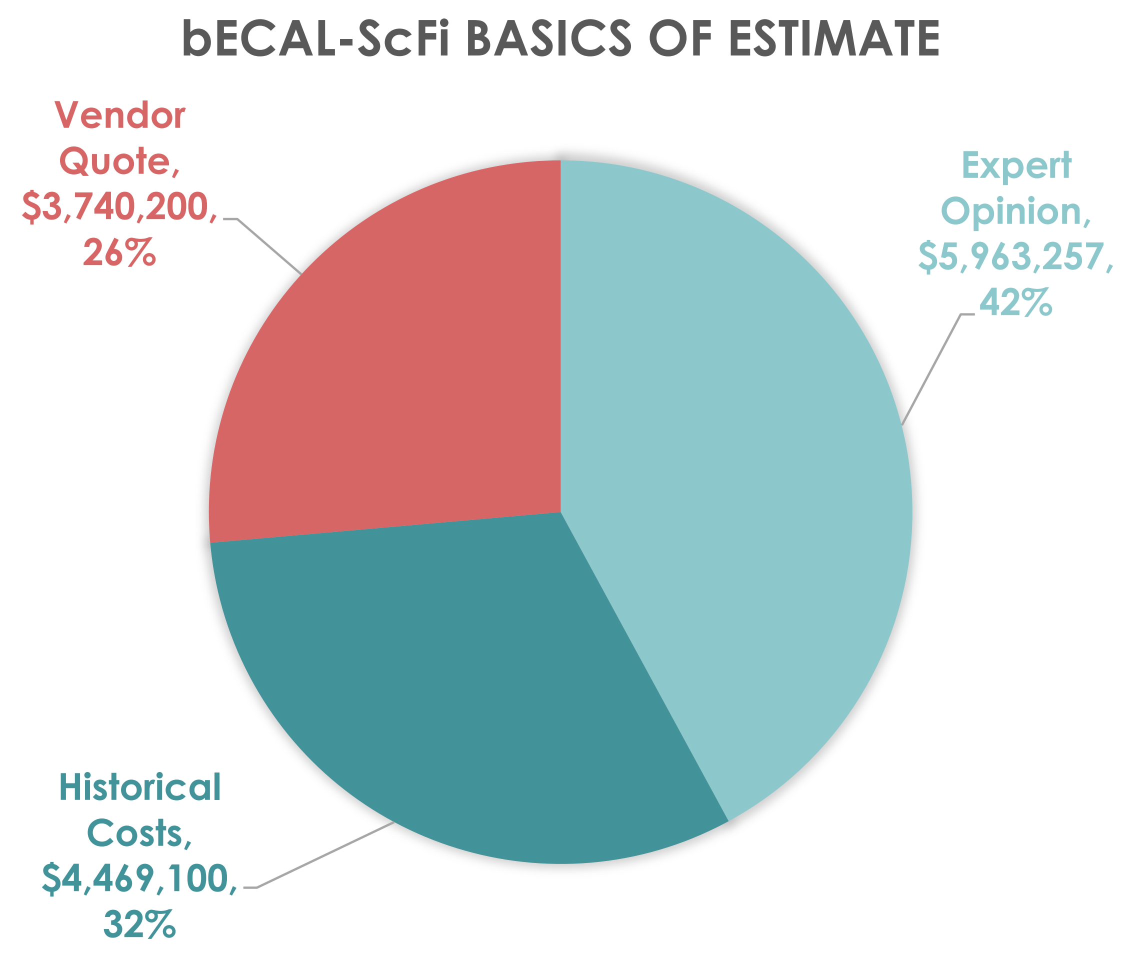


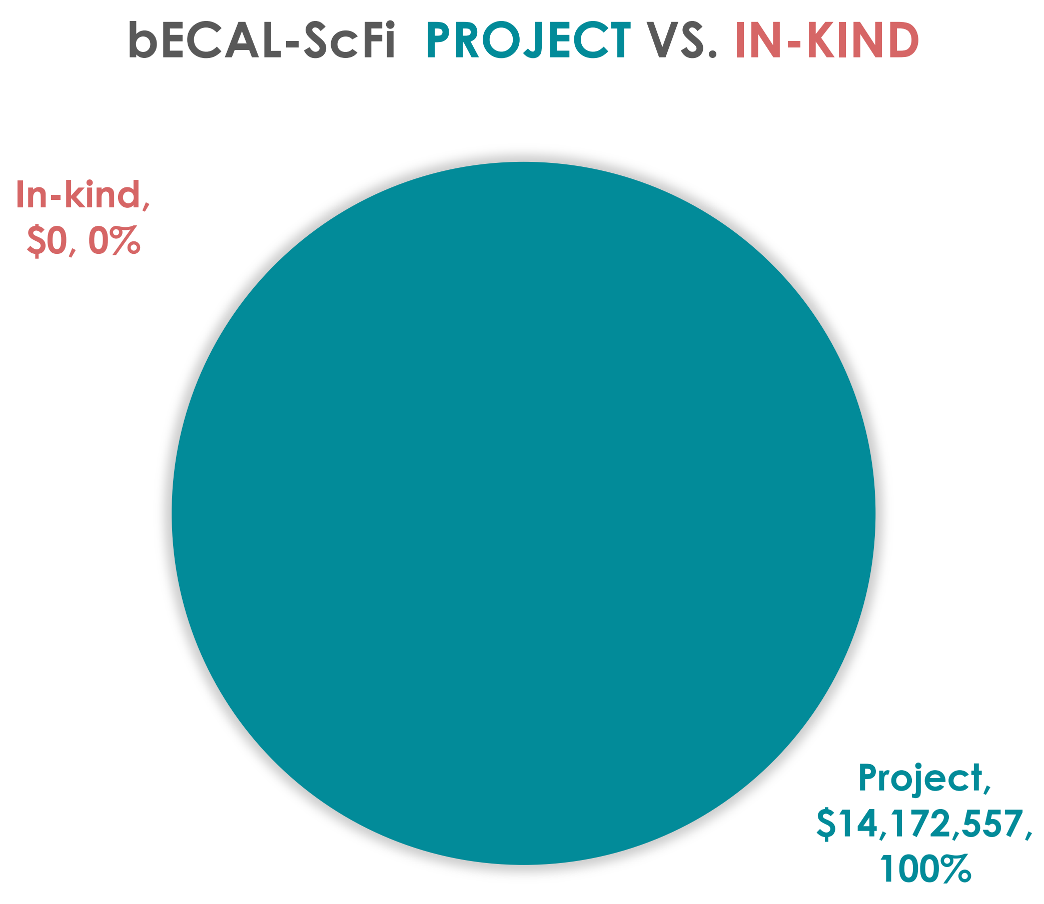
bECAL-Img Labor Total (Project, In-Kind)
$1,800,000
$1,600,000
$1,400,000
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

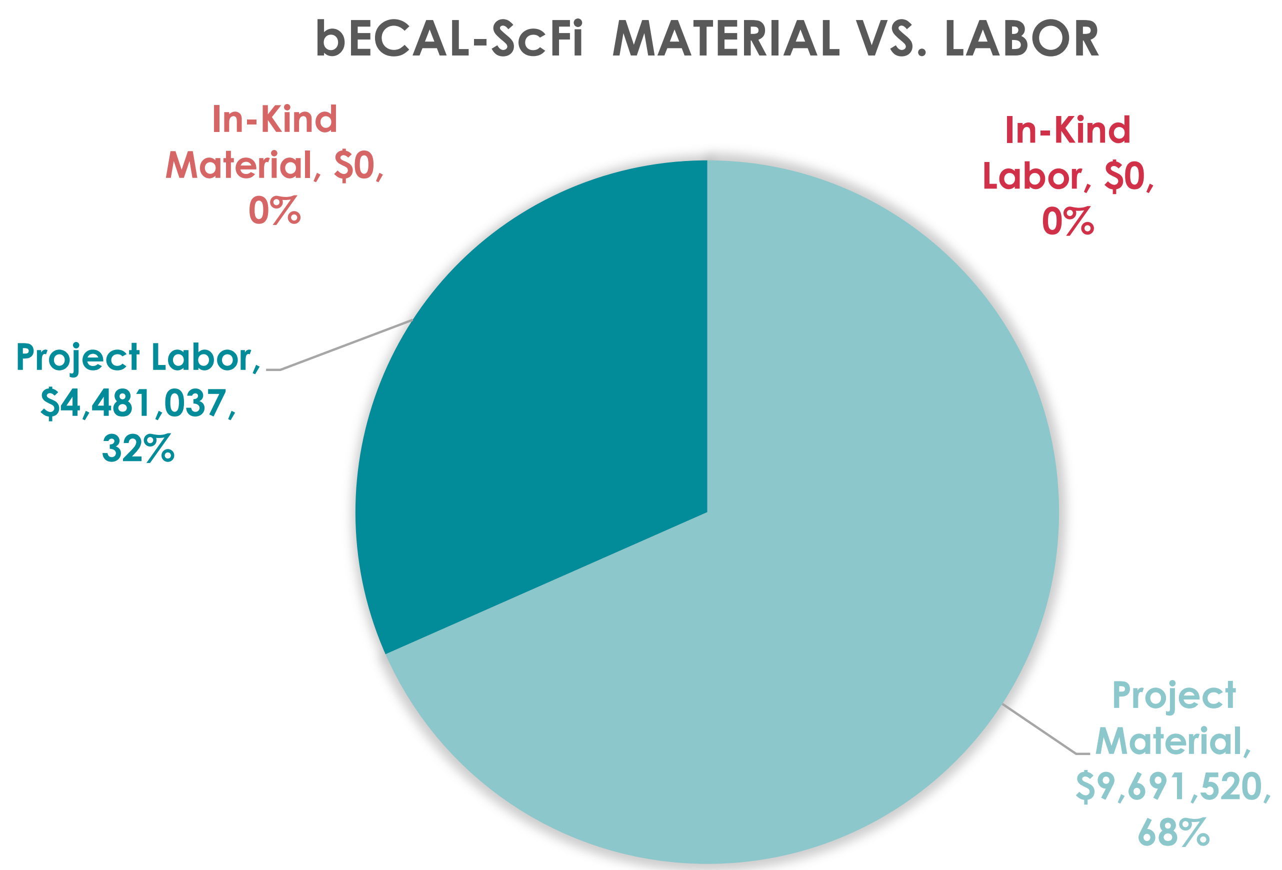


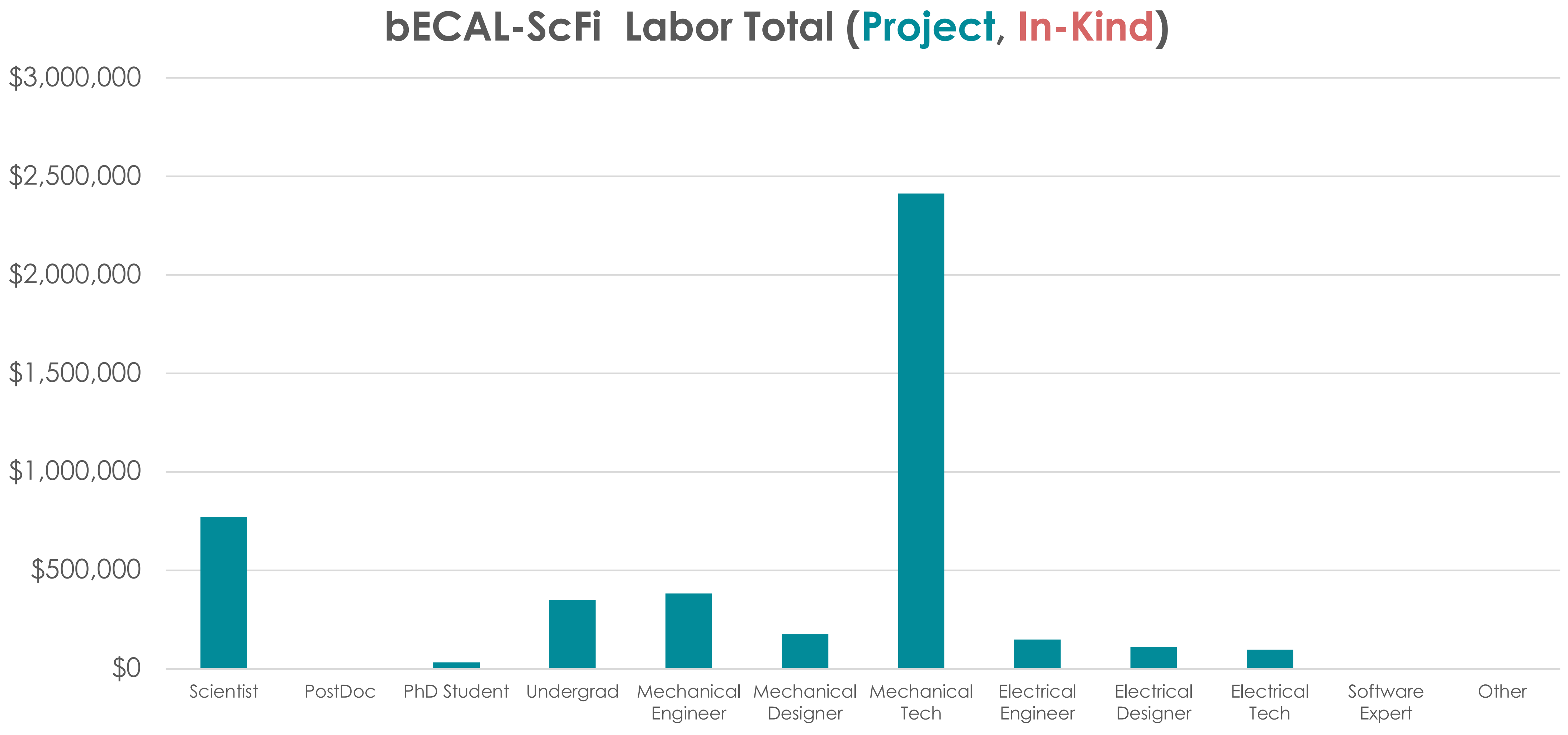
bECAL-Img Labor in FTE
9
8
7
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

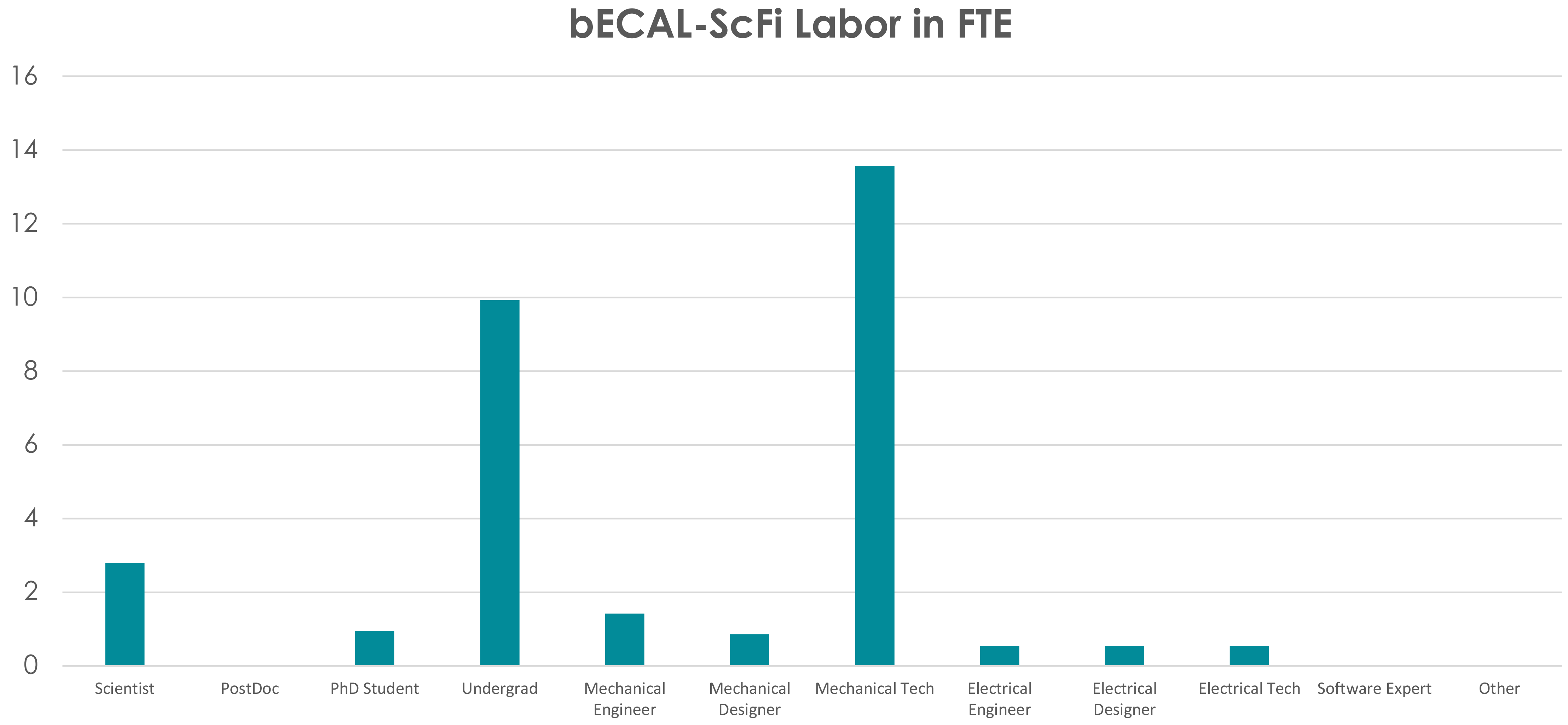
Backup


bECAL-ScFi BASICS OF ESTIMATE
Vendor Quote, $3,740,200, 26%
Expert Opinion, $5,963,257, 42%
Historical Costs, $4,469,100, 32%

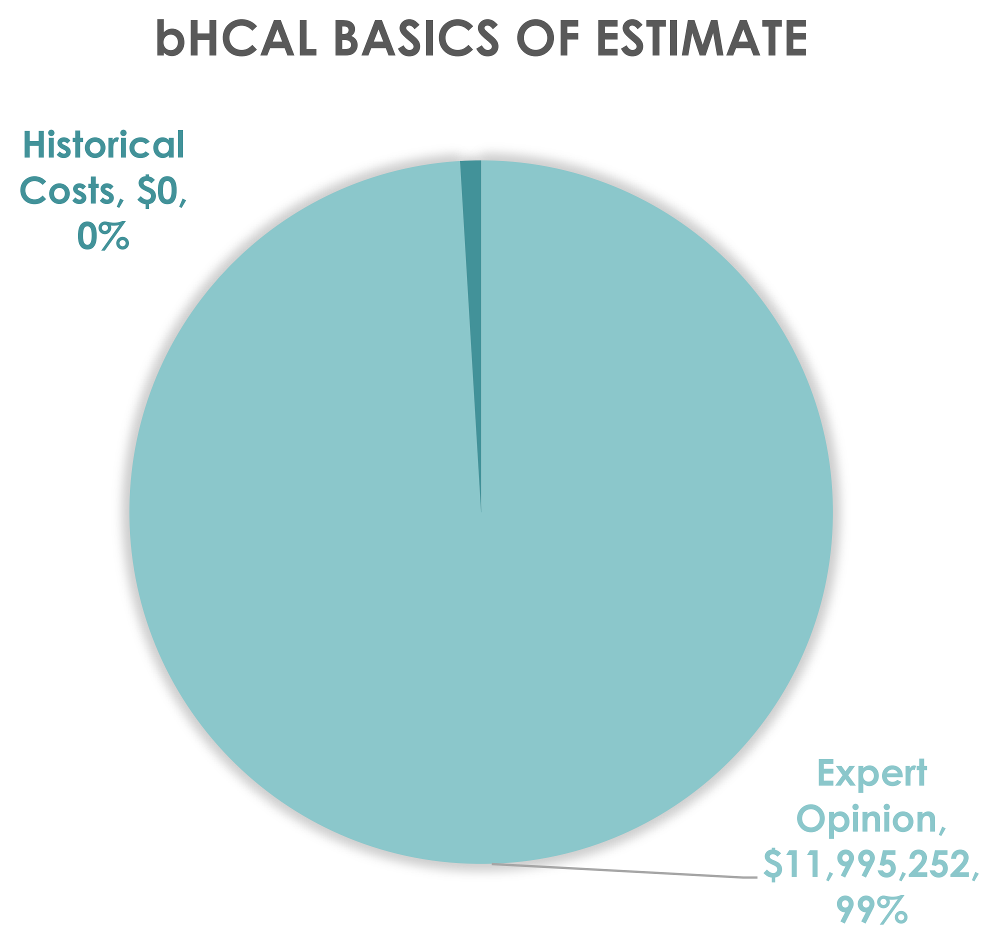

bECAL-ScFi PROJECT VS. IN-KIND
In-kind, $0, 0%
Project, $14,172,557, 100%


bECAL-ScFi MATERIAL VS. LABOR
In-Kind Material, $0, 0%
In-Kind Labor, $0, 0%
Project Labor, $4,481,037, 32%
Project Material, $9,691,520, 68%

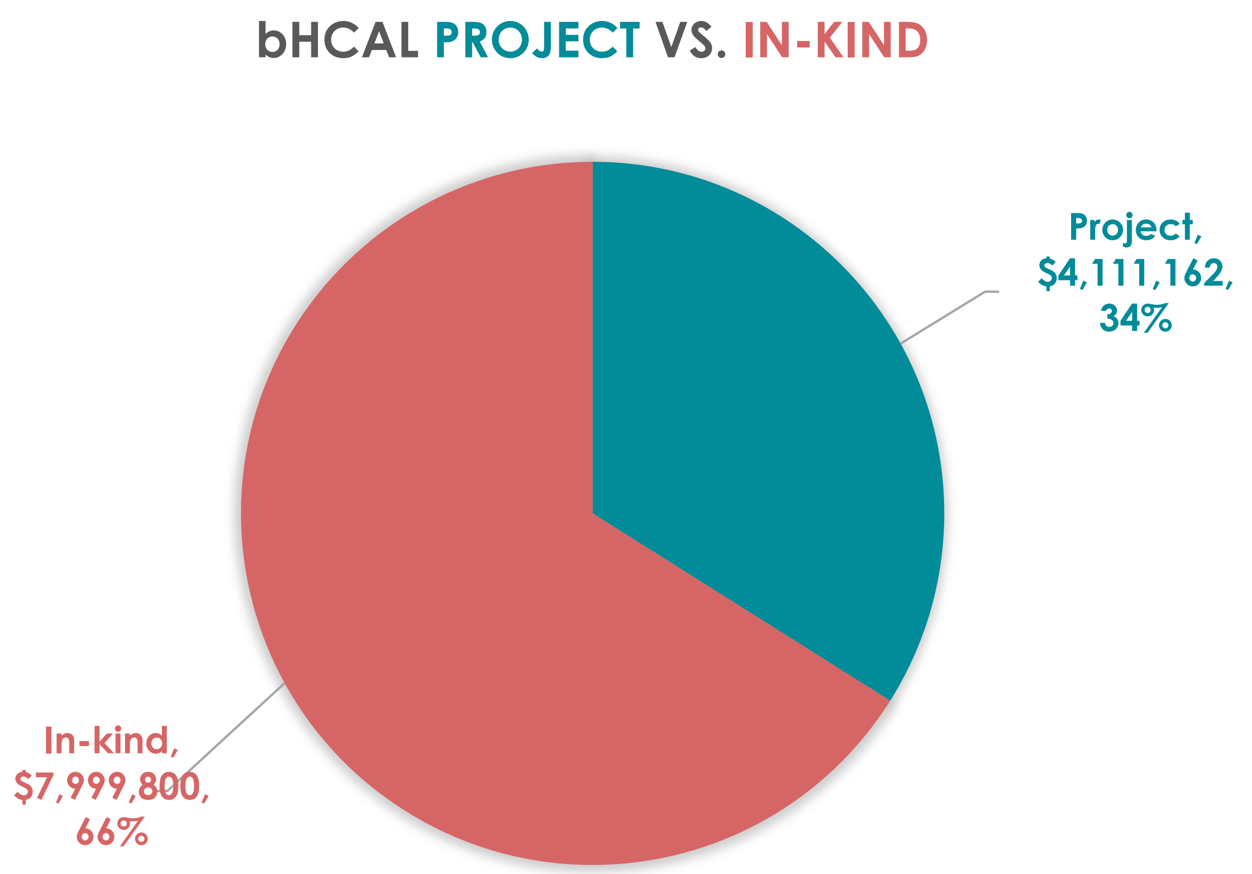

bECAL-ScFi Labor Total (Project, In-Kind)
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other


bECAL-ScFi Labor in FTE
16
14
12
10
8
6
4
2
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

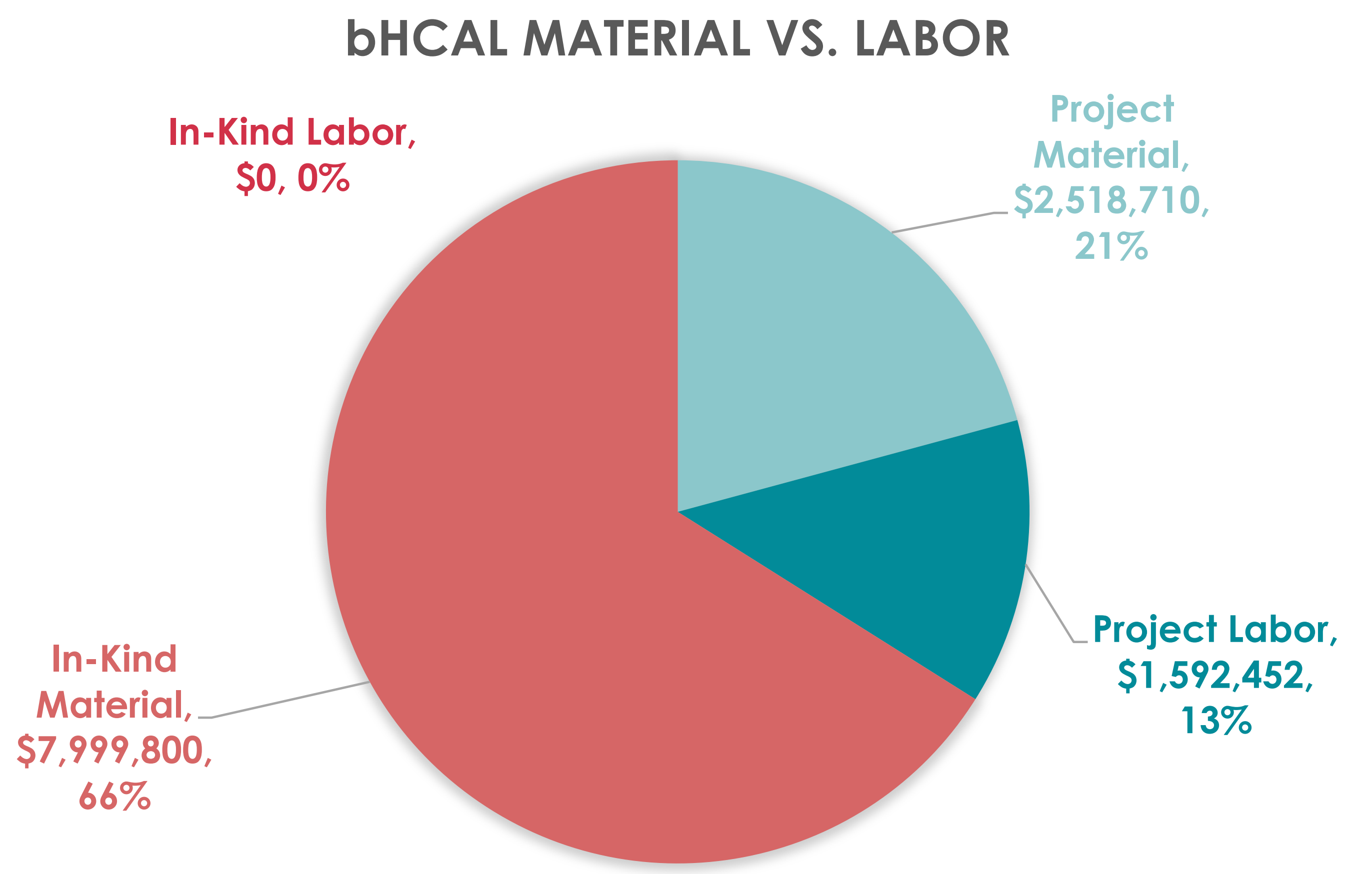
Backup



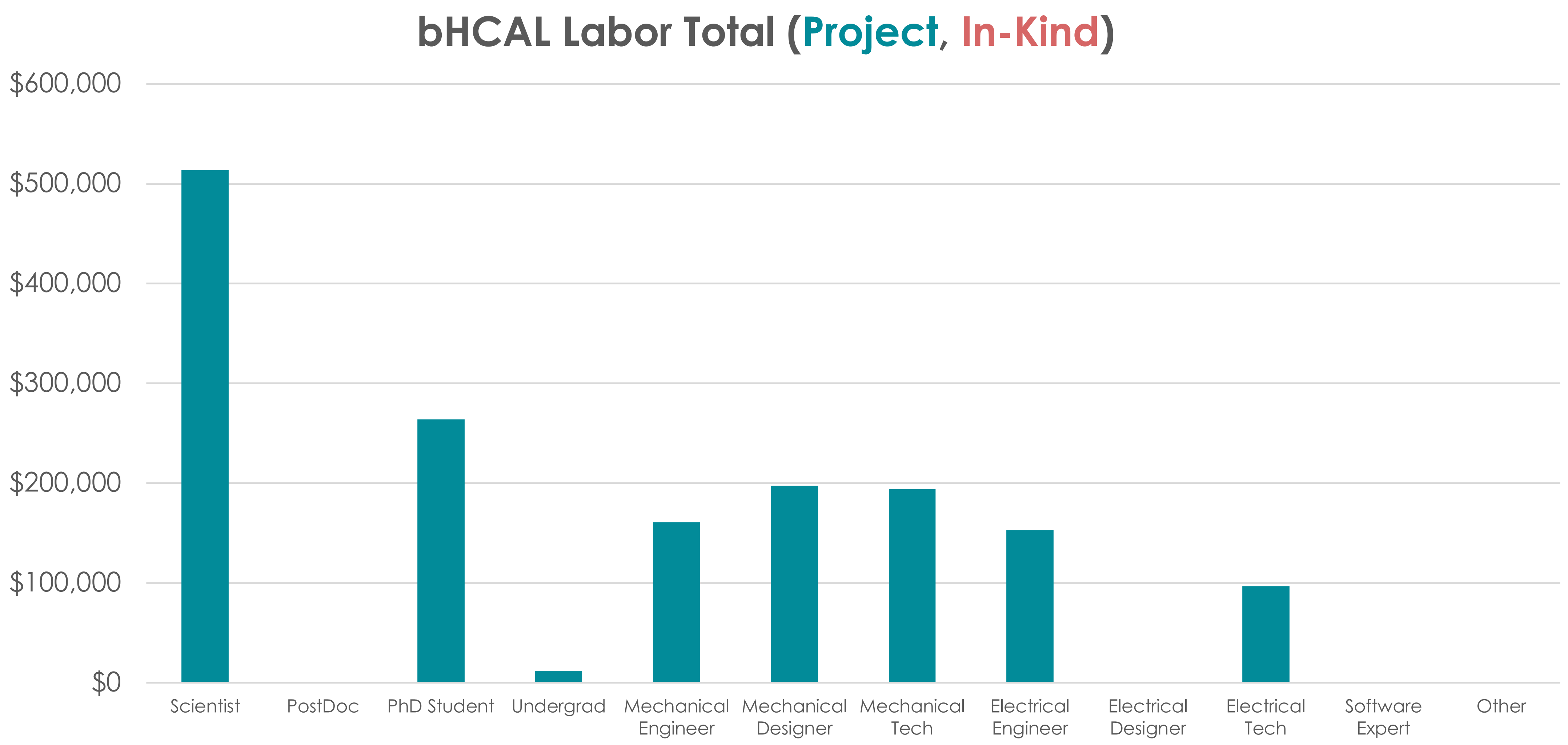
bHCAL BASICS OF ESTIMATE
Historical Costs, $0, 0%
Expert Opinion, $11,995,252, 99%



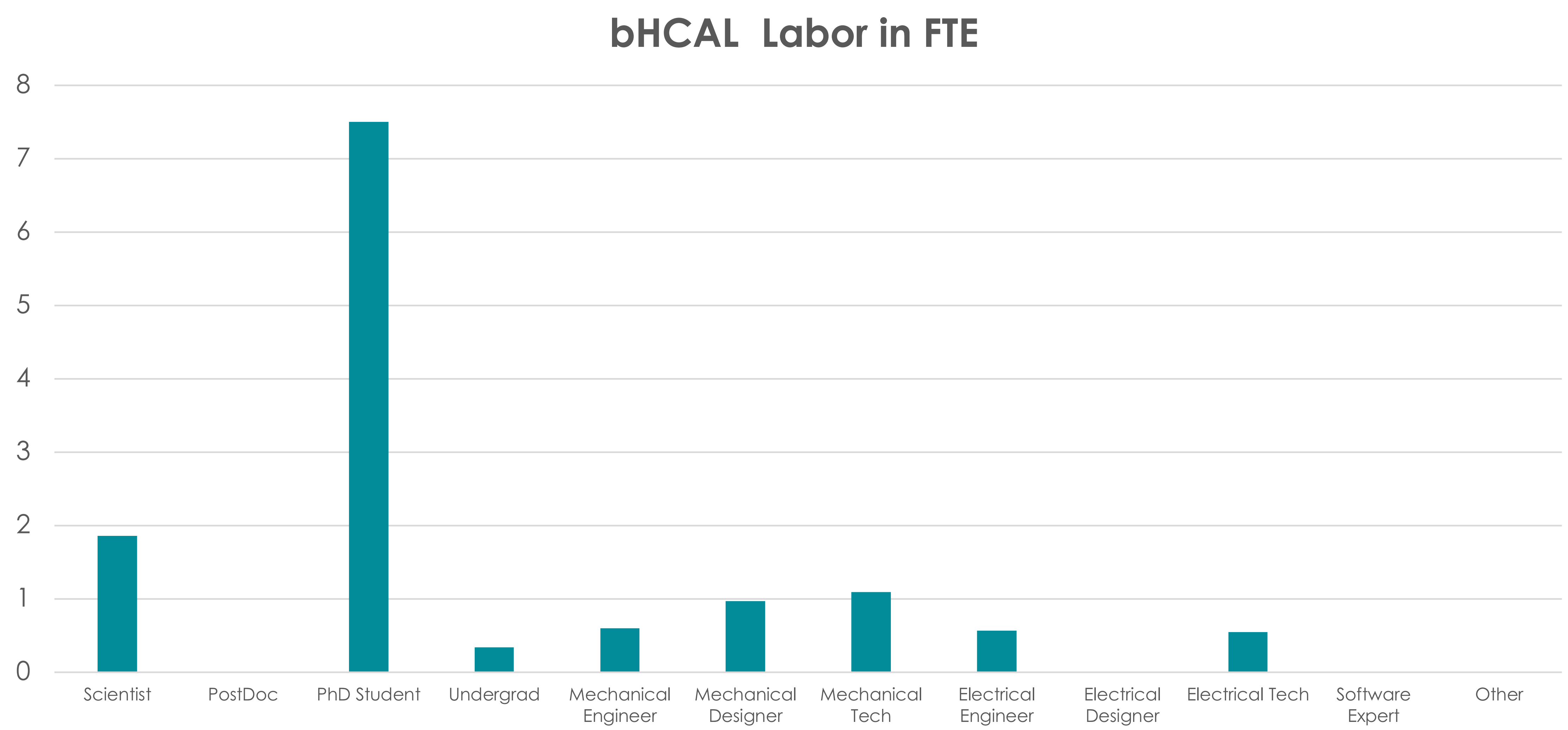
bHCAL PROJECT VS. IN-KIND
Project, $4,111,162, 34%
In-kind, $7,999,800, 66%



bHCAL MATERIAL VS. LABOR
In-Kind Labor, $0, 0%
Project Material, $2,518,710, 21%
Project Labor, $1,592,452, 13%
In-Kind Material, $7,999,800, 66%

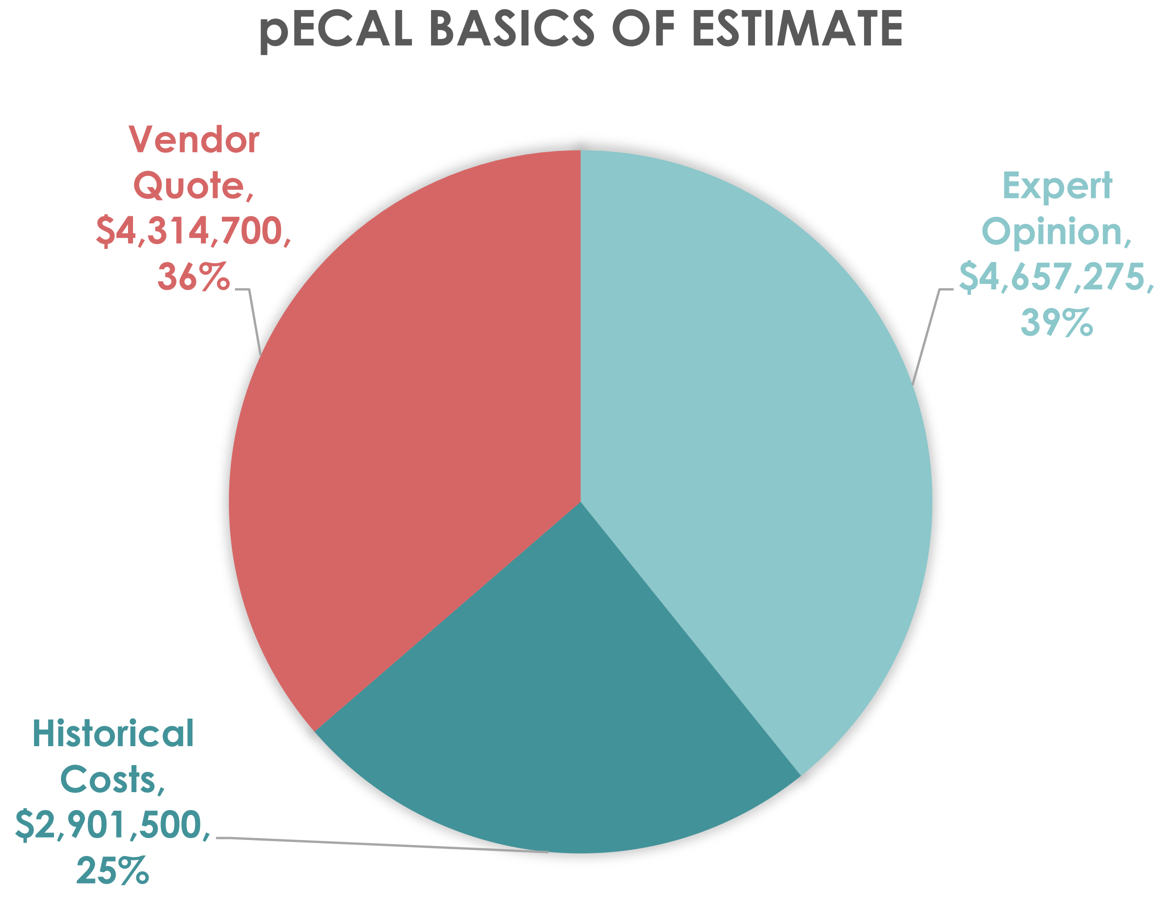


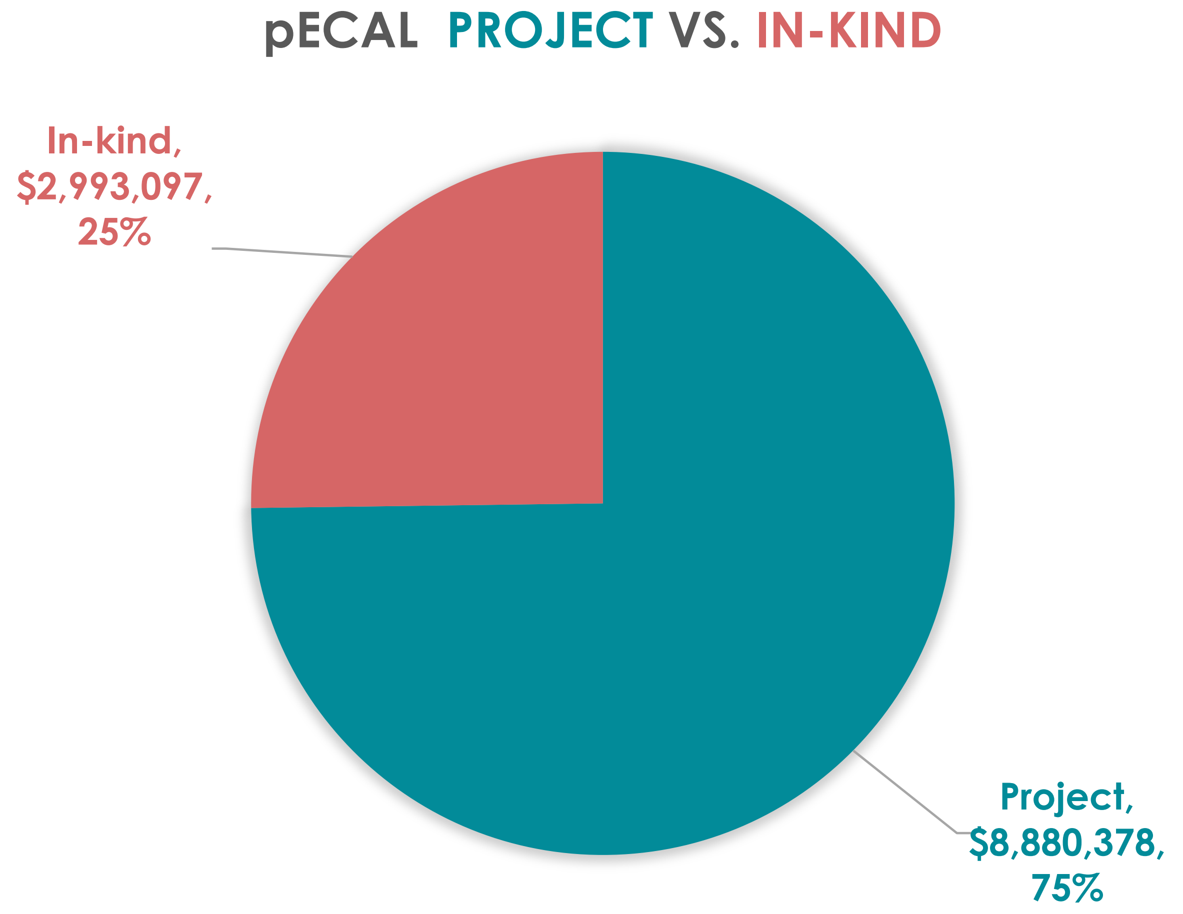
bHCAL Labor Total (Project, In-Kind)
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

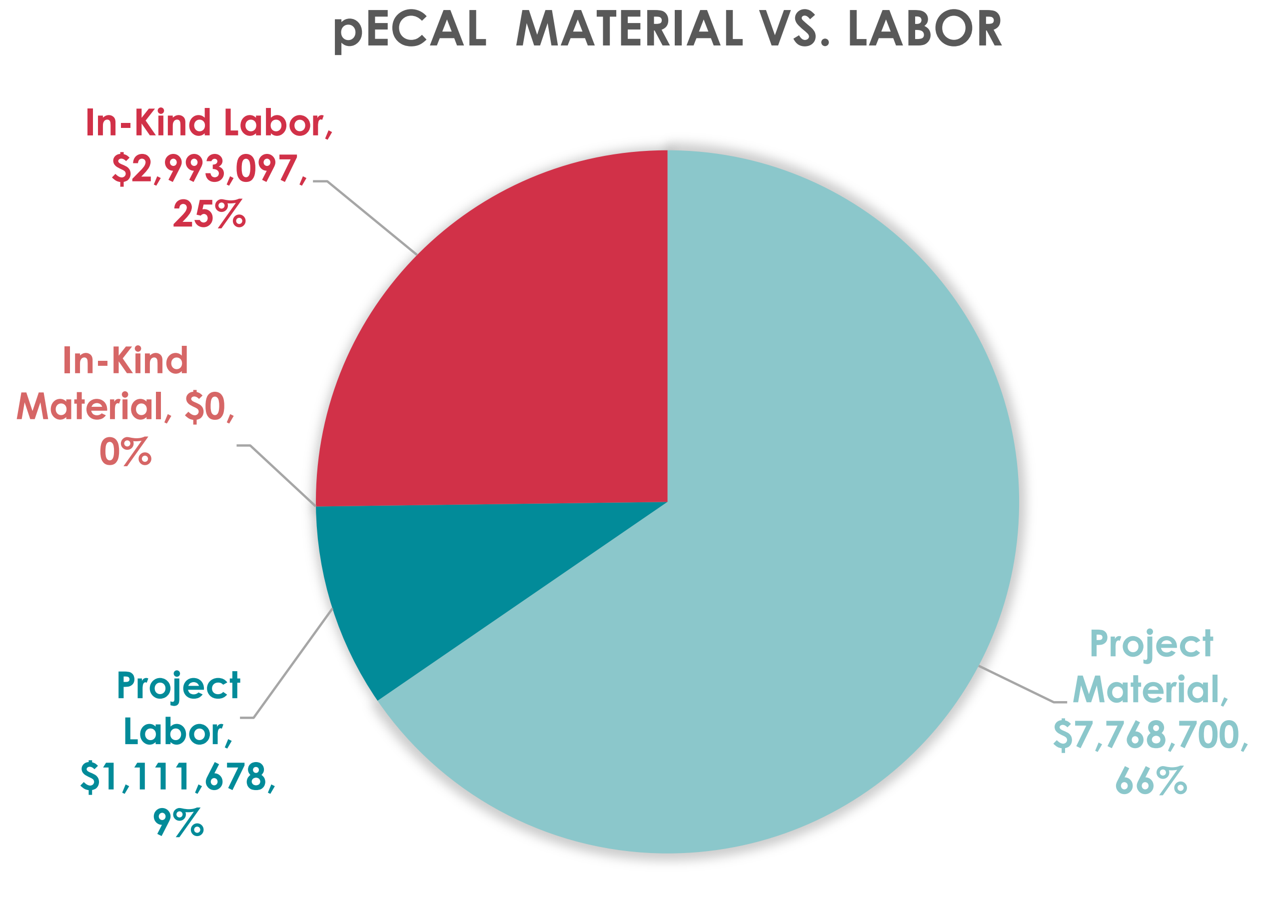


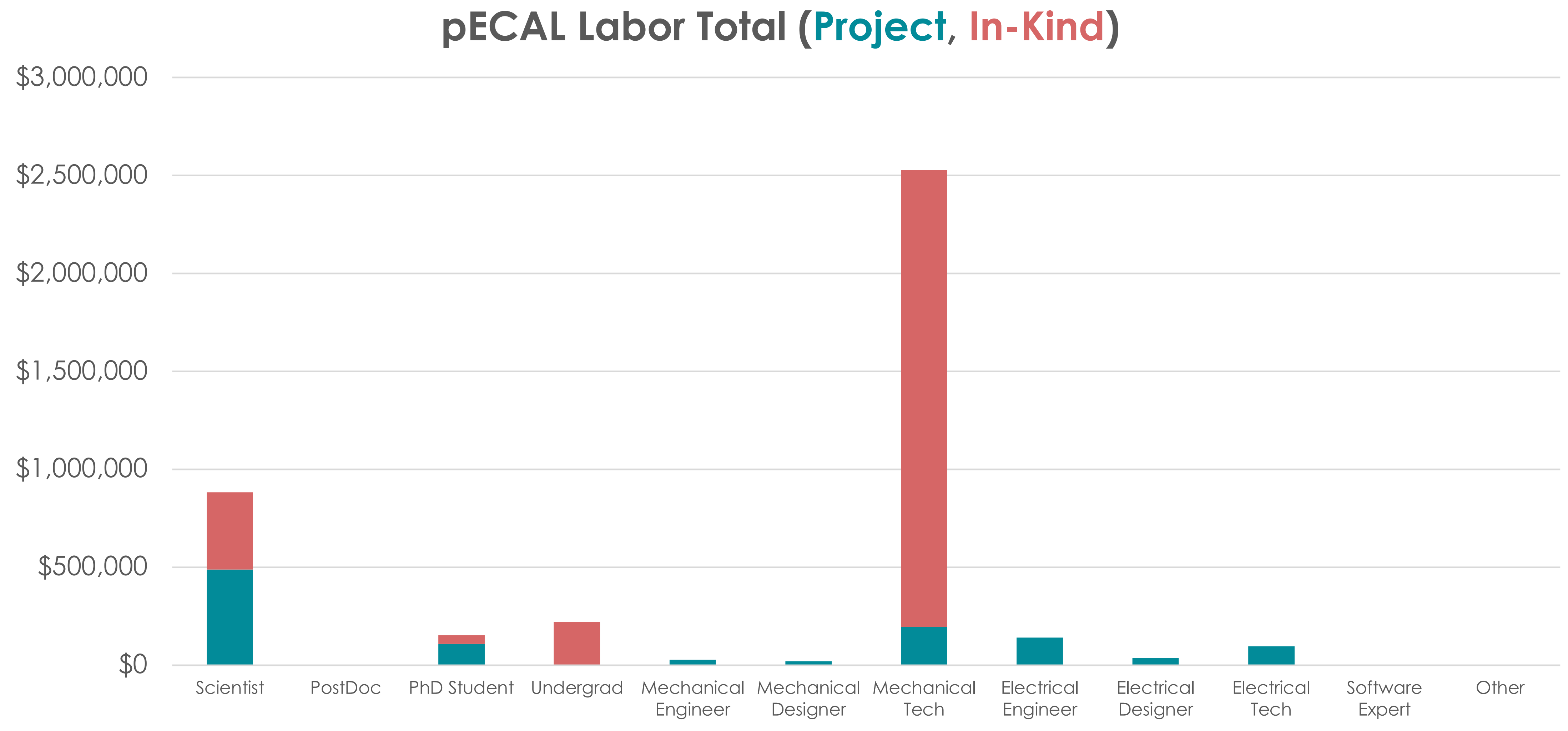
bHCAL Labor in FTE
8
7
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

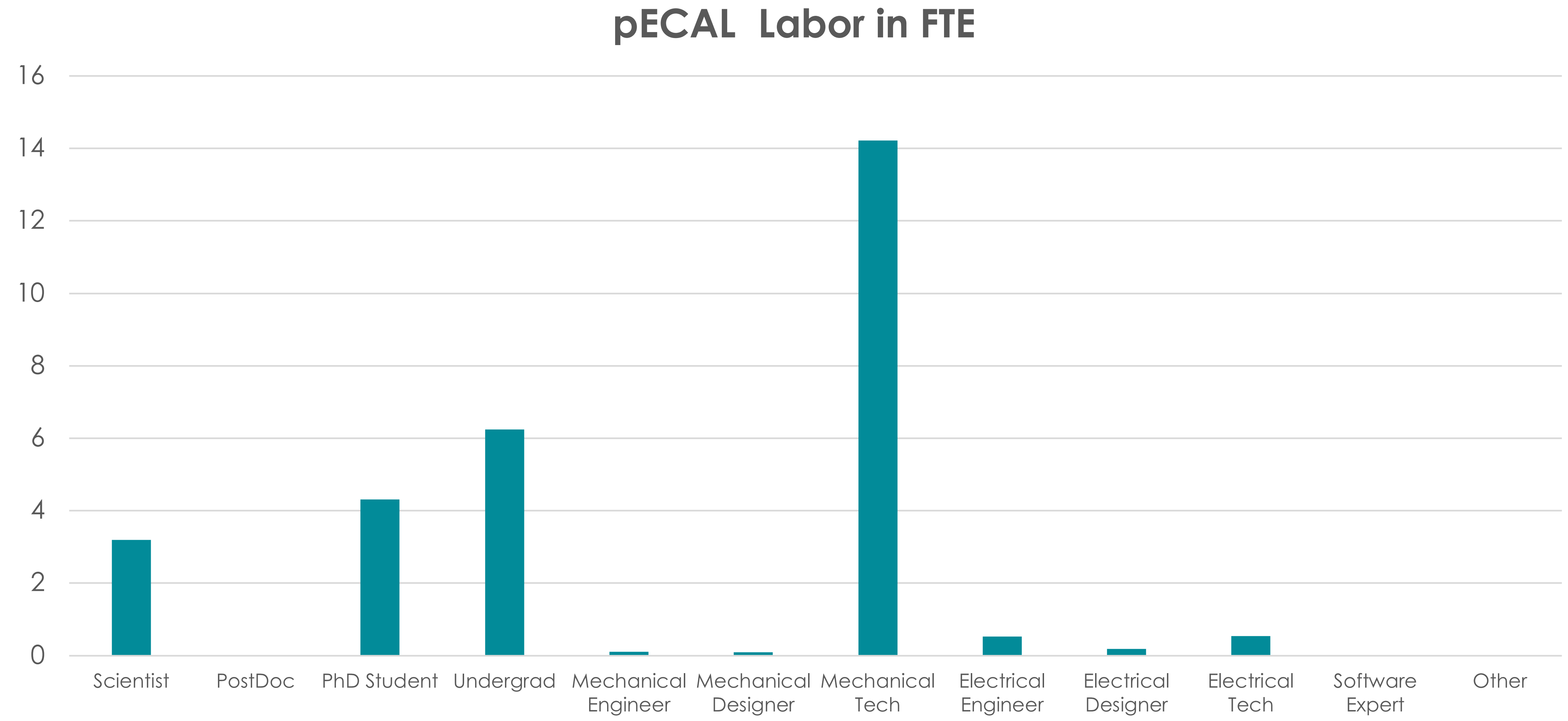
Backup


pECAL BASICS OF ESTIMATE
Vendor Quote, $4,314,700, 36%
Expert Opinion, $4,657,275, 39%
Historical Costs, $2,901,500, 25%

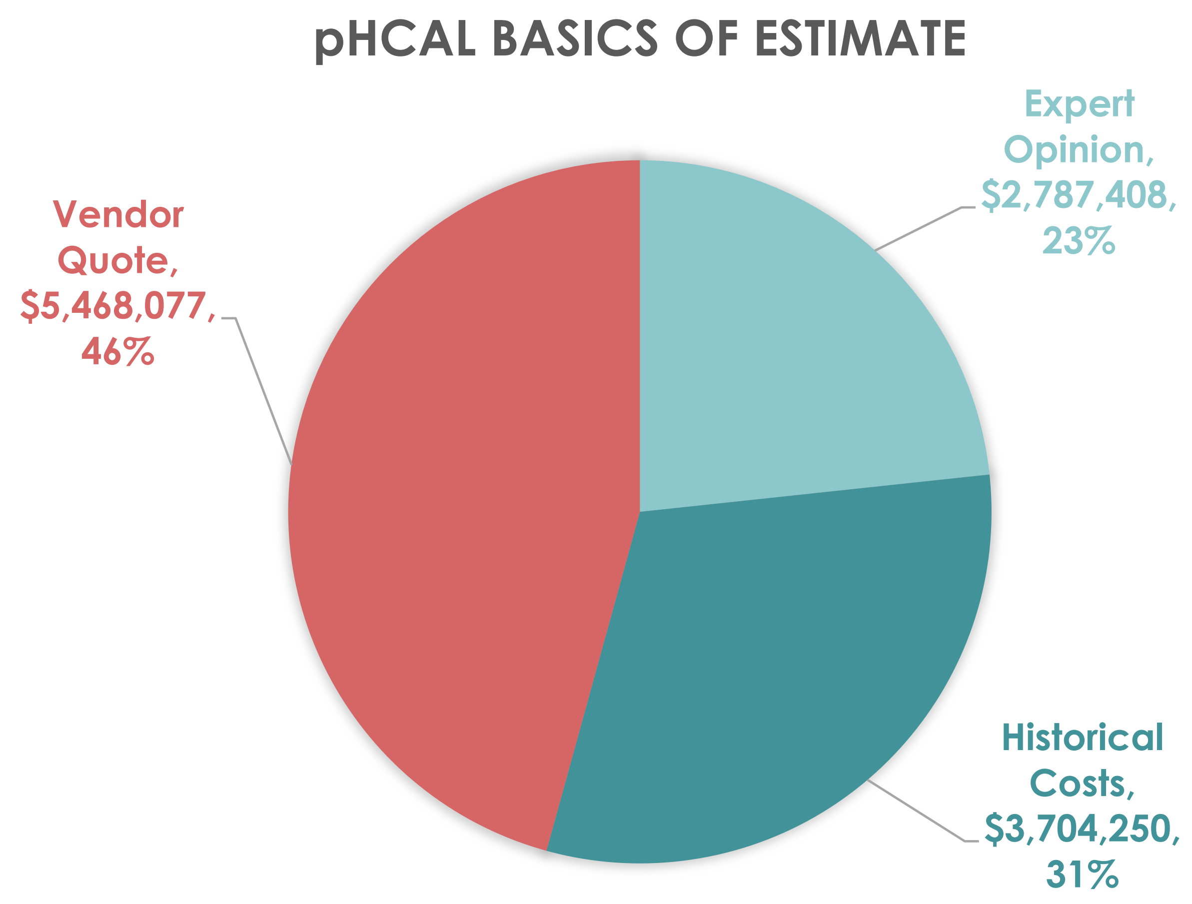

pECAL PROJECT VS. IN-KIND
In-kind, $2,993,097, 25%
Project, $8,880,378, 75%

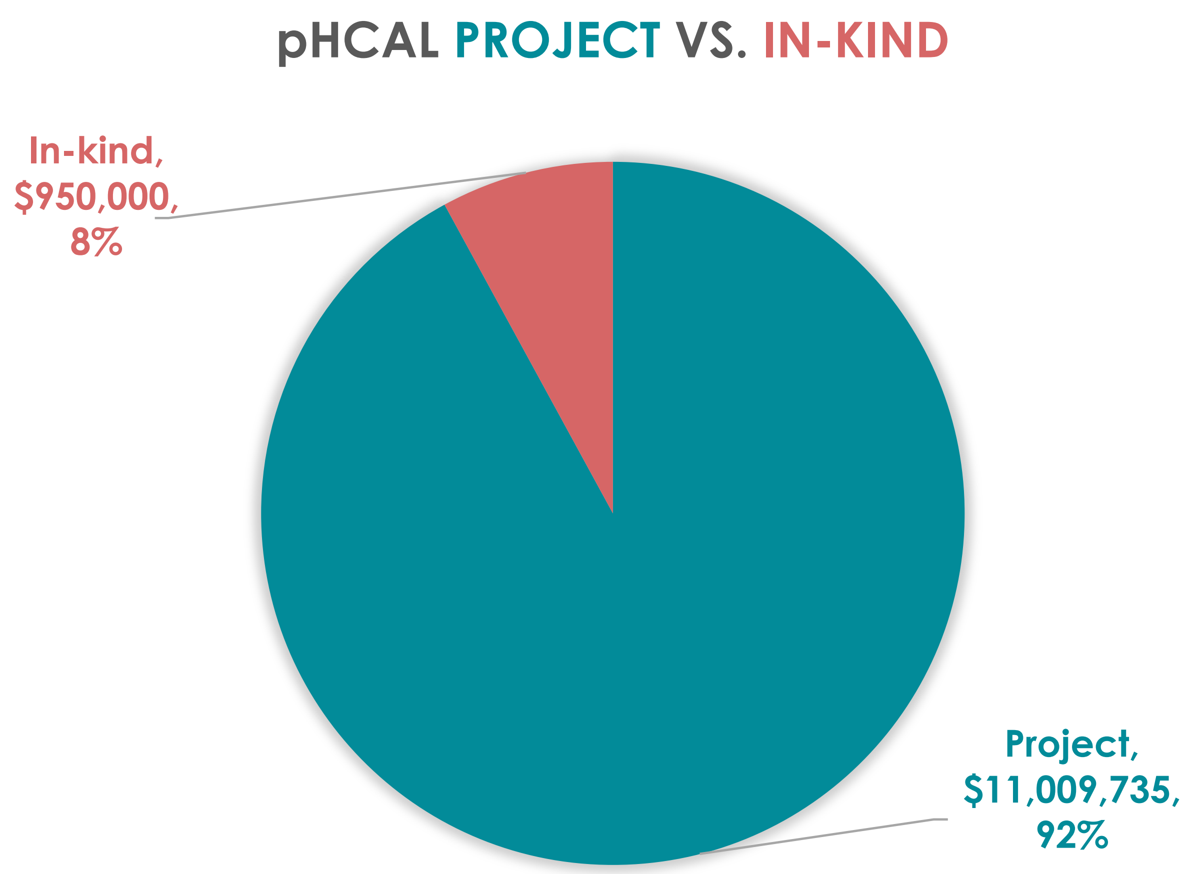

pECAL MATERIAL VS. LABOR
In-Kind Labor, $2,993,097, 25%
In-Kind Material, $0, 0%
Project Labor, $1,111,678, 9%
Project Material, $7,768,700, 66%

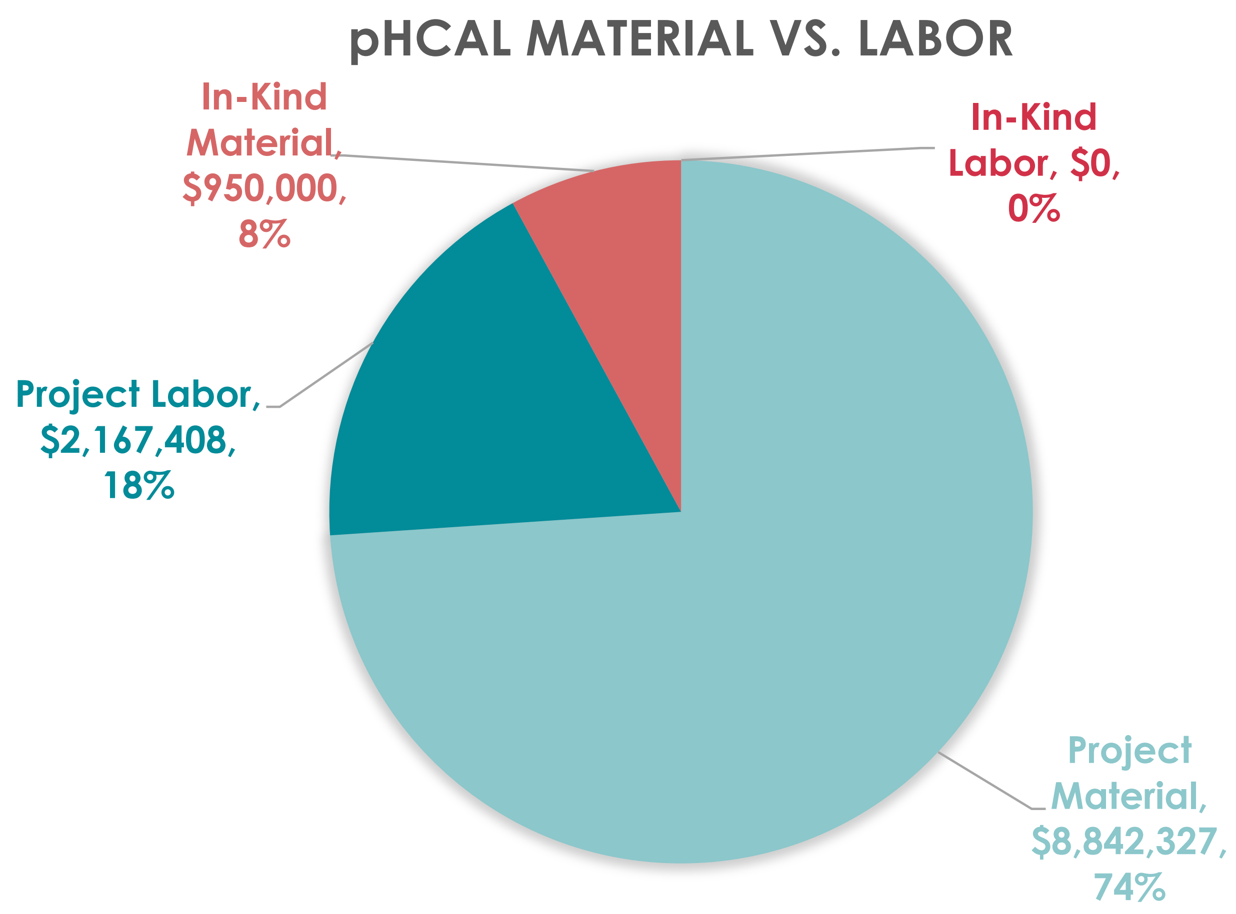

pECAL Labor Total (Project, In-Kind)
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

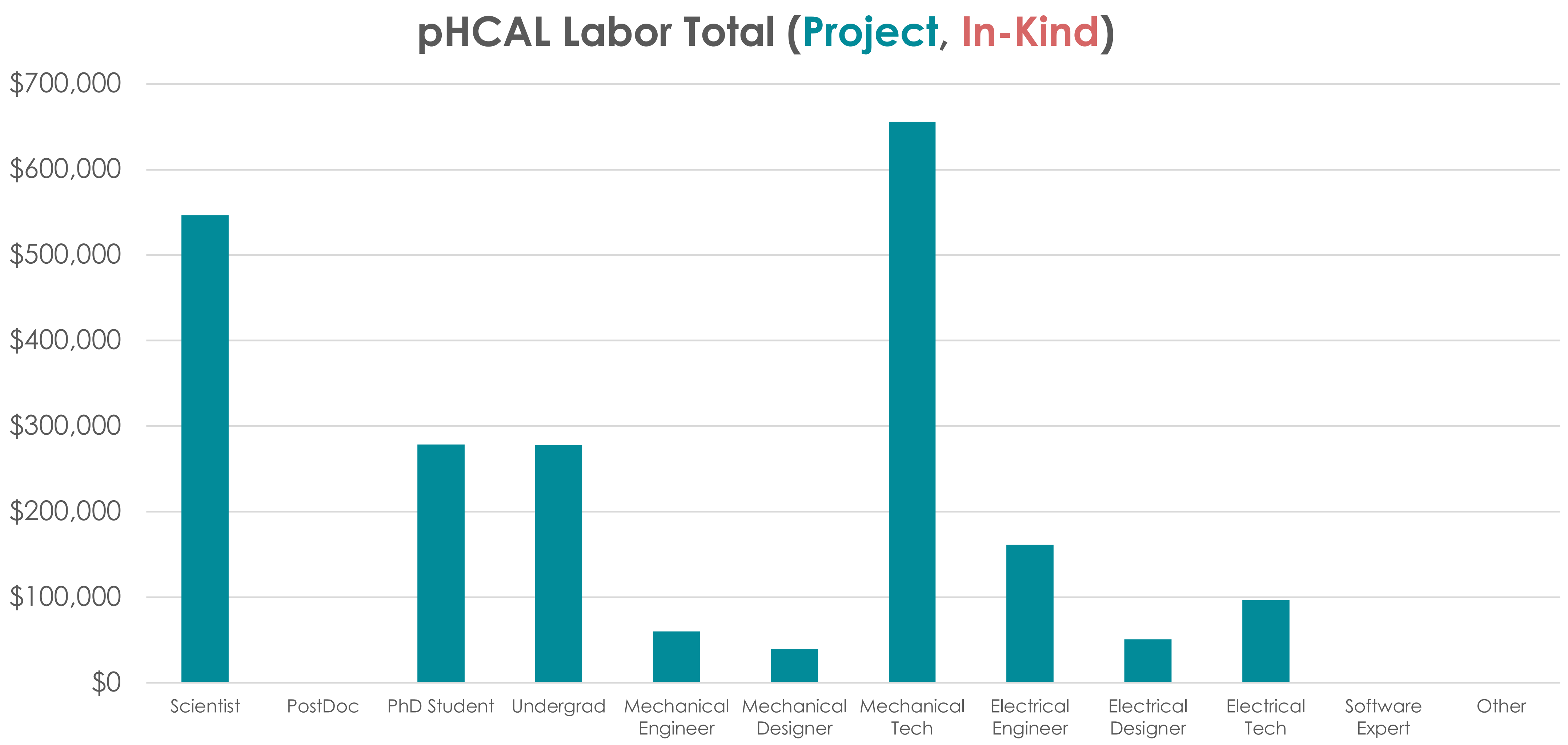

pECAL Labor in FTE
16
14
12
10
8
6
4
2
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

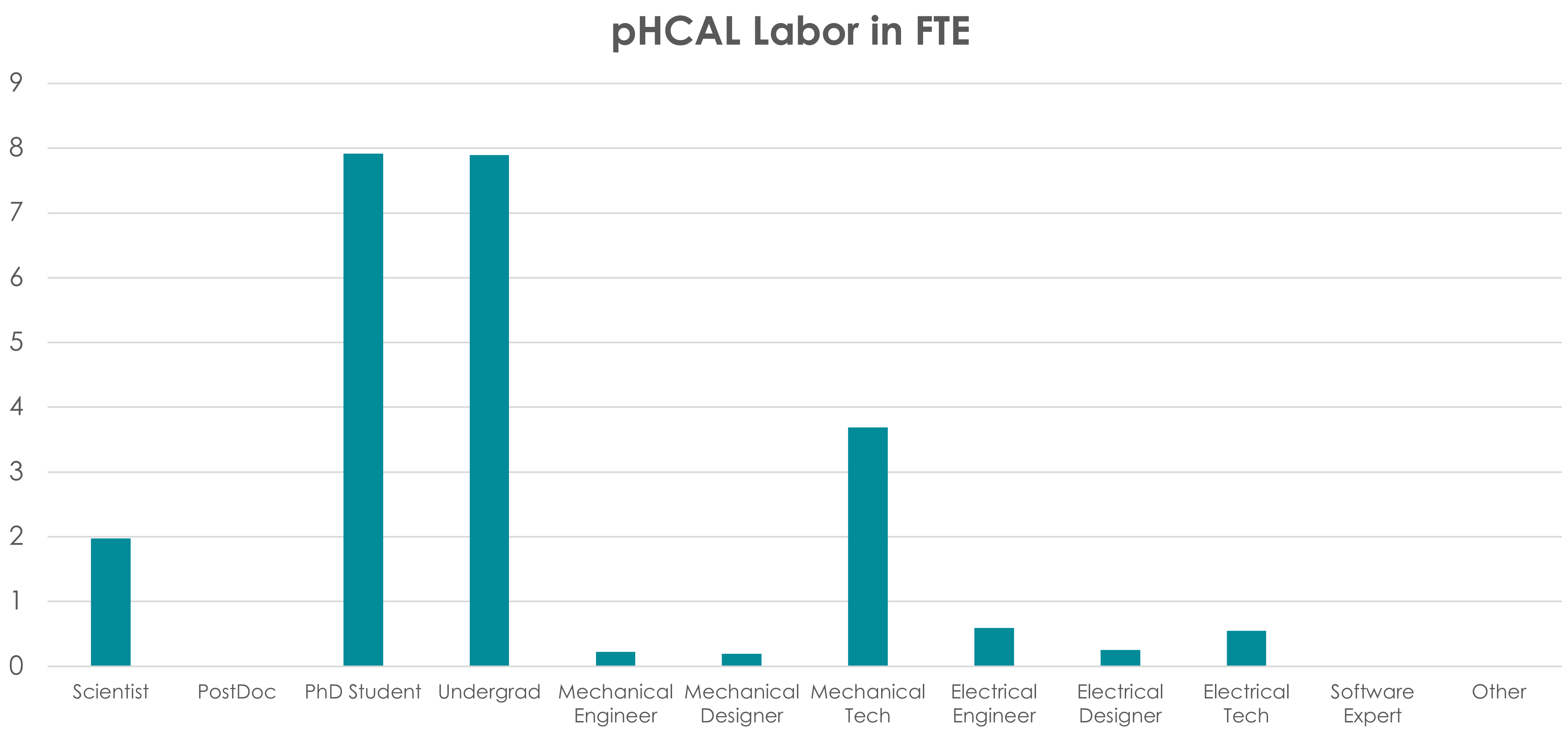
Backup


pHCAL BASICS OF ESTIMATE
Expert Opinion, $2,787,408, 23%
Vendor Quote, $5,468,077, 46%
Historical Costs, $3,704,250, 31%

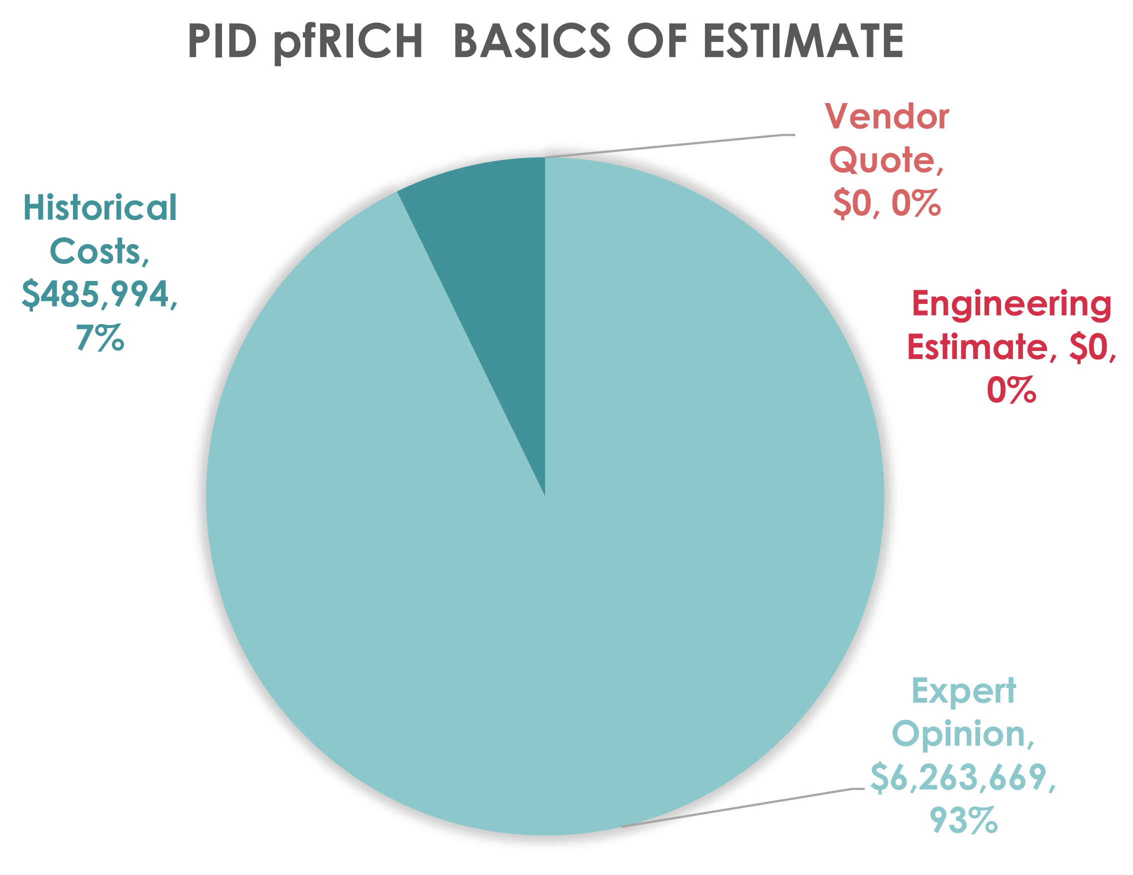

pHCAL PROJECT VS. IN-KIND
In-kind, $950,000, 8%
Project, $11,009,735, 92%

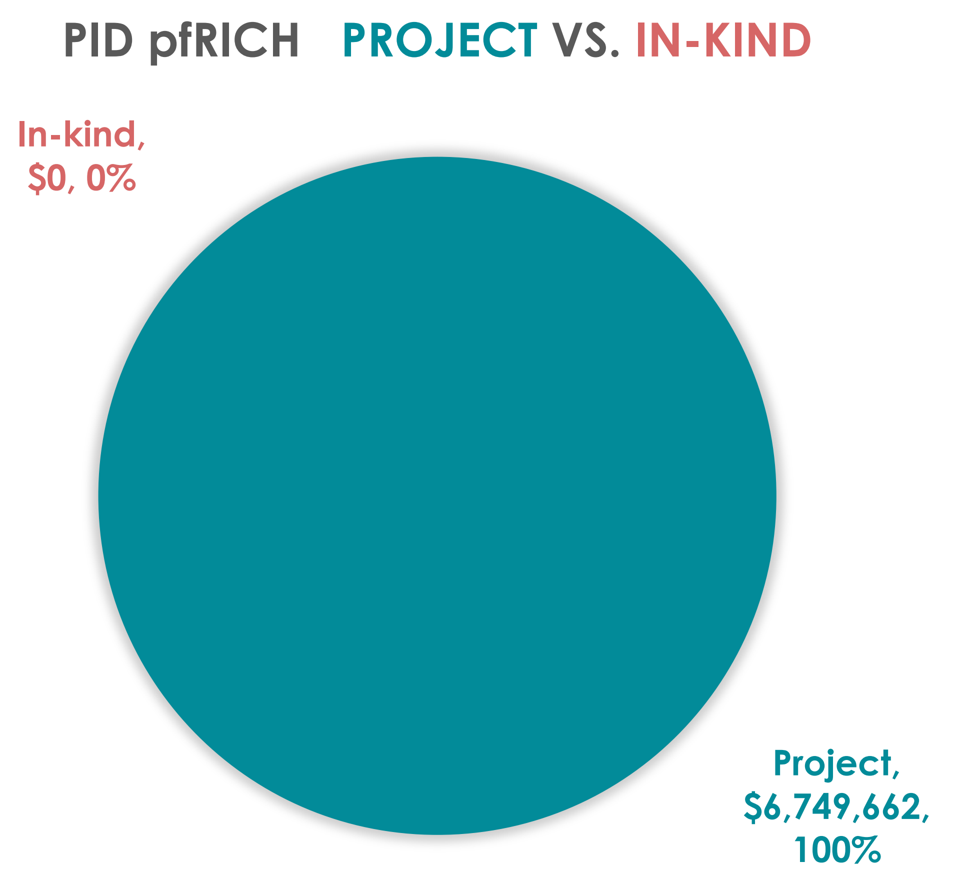

pHCAL MATERIAL VS. LABOR
In-Kind Material, $950,000, 8%
In-Kind Labor, $0, 0%
Project Labor, $2,167,408, 18%
Project Material, $8,842,327, 74%

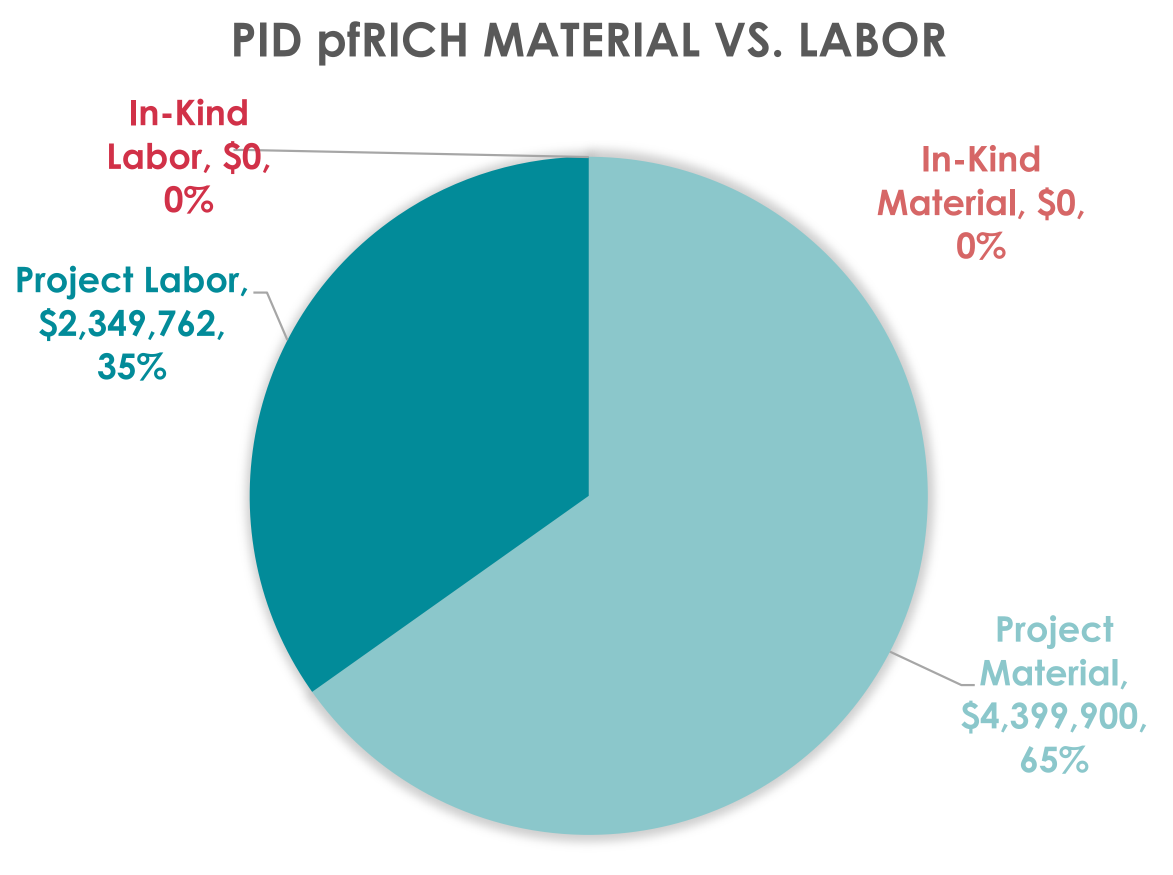

pHCAL Labor Total (Project, In-Kind)
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

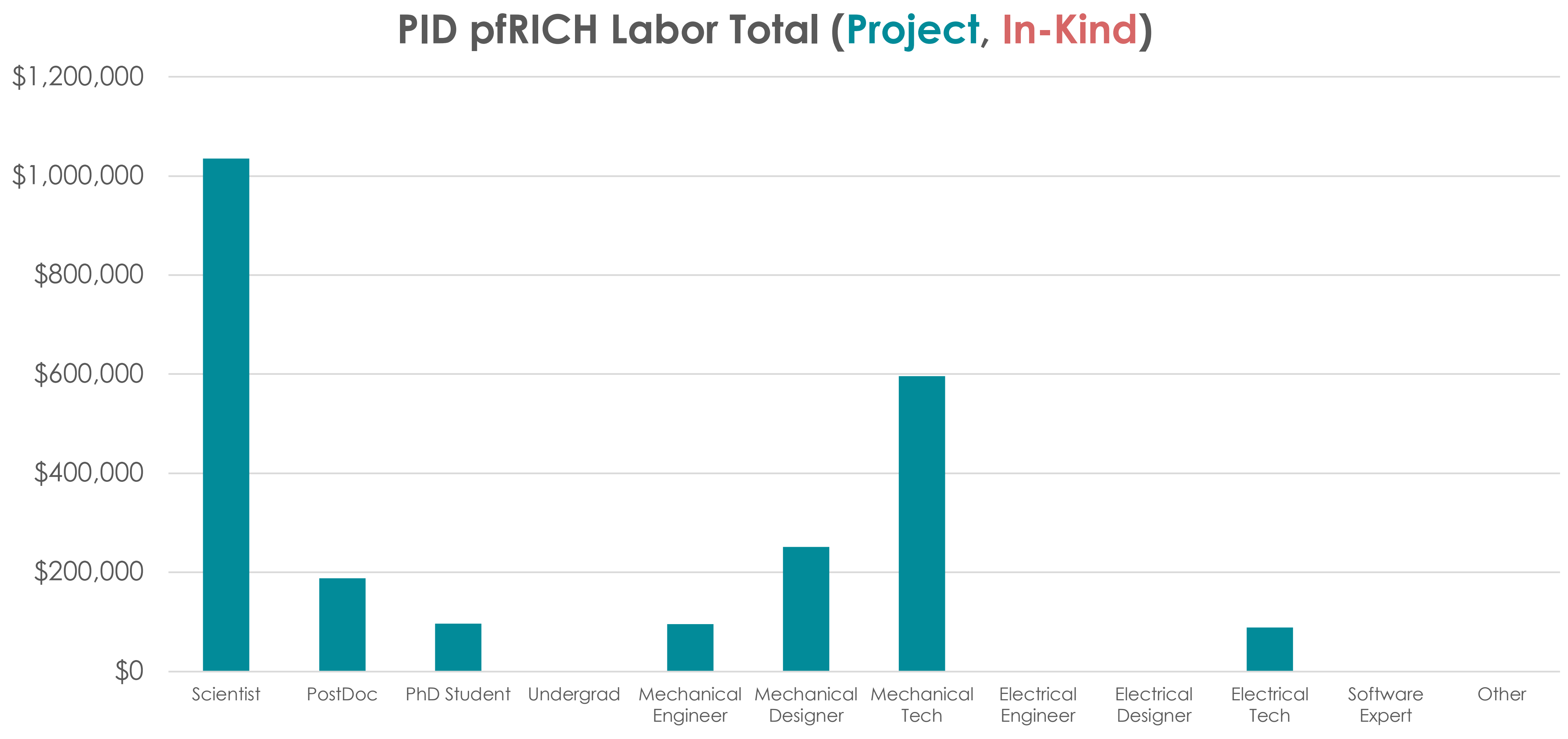

pHCAL Labor in FTE
9
8
7
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

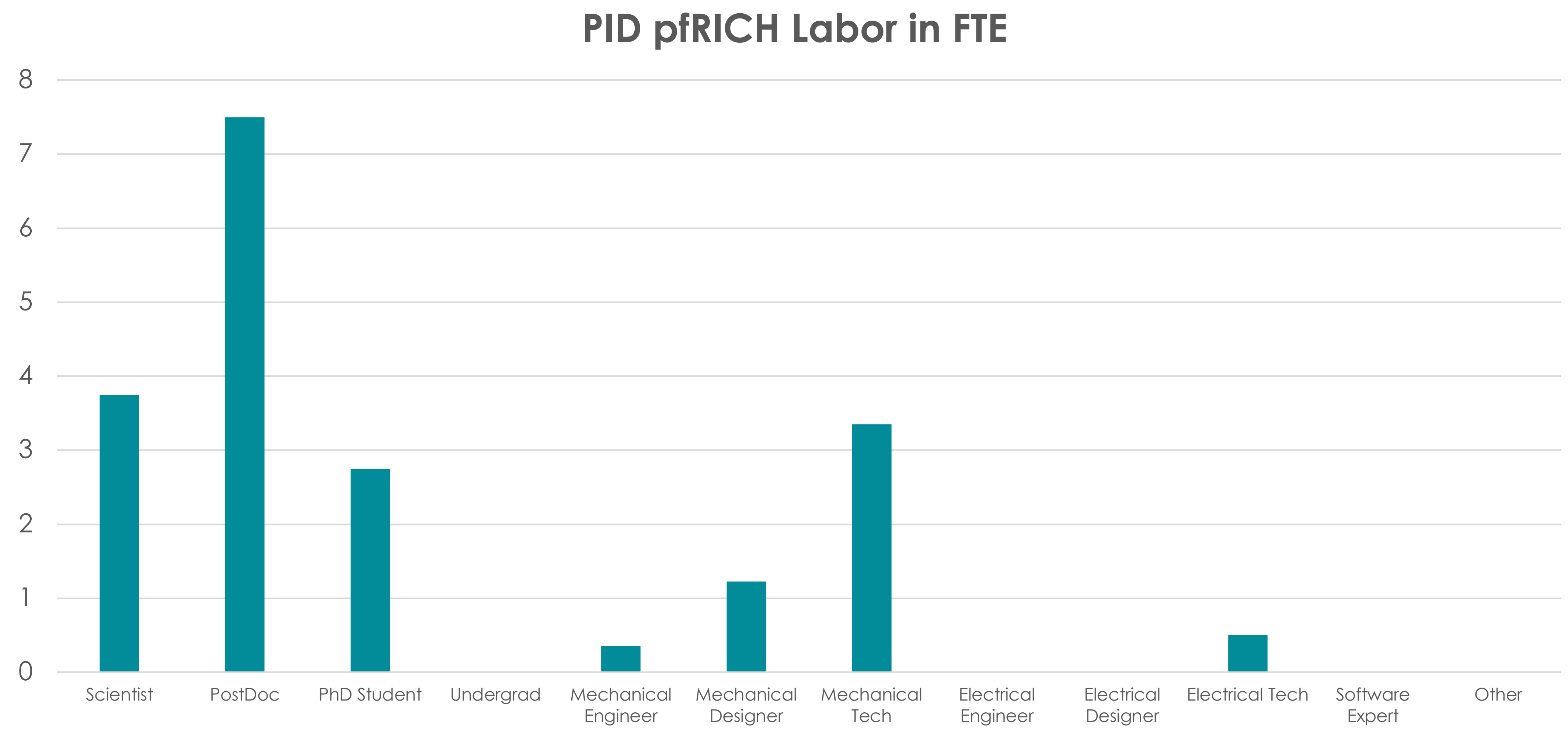
Backup


PID pfRICH BASICS OF ESTIMATE
Vendor Quote, $0, 0%
Historical Costs, $485,994, 7%
Engineering Estimate, $0, 0%
Expert Opinion, $6,263,669, 93%

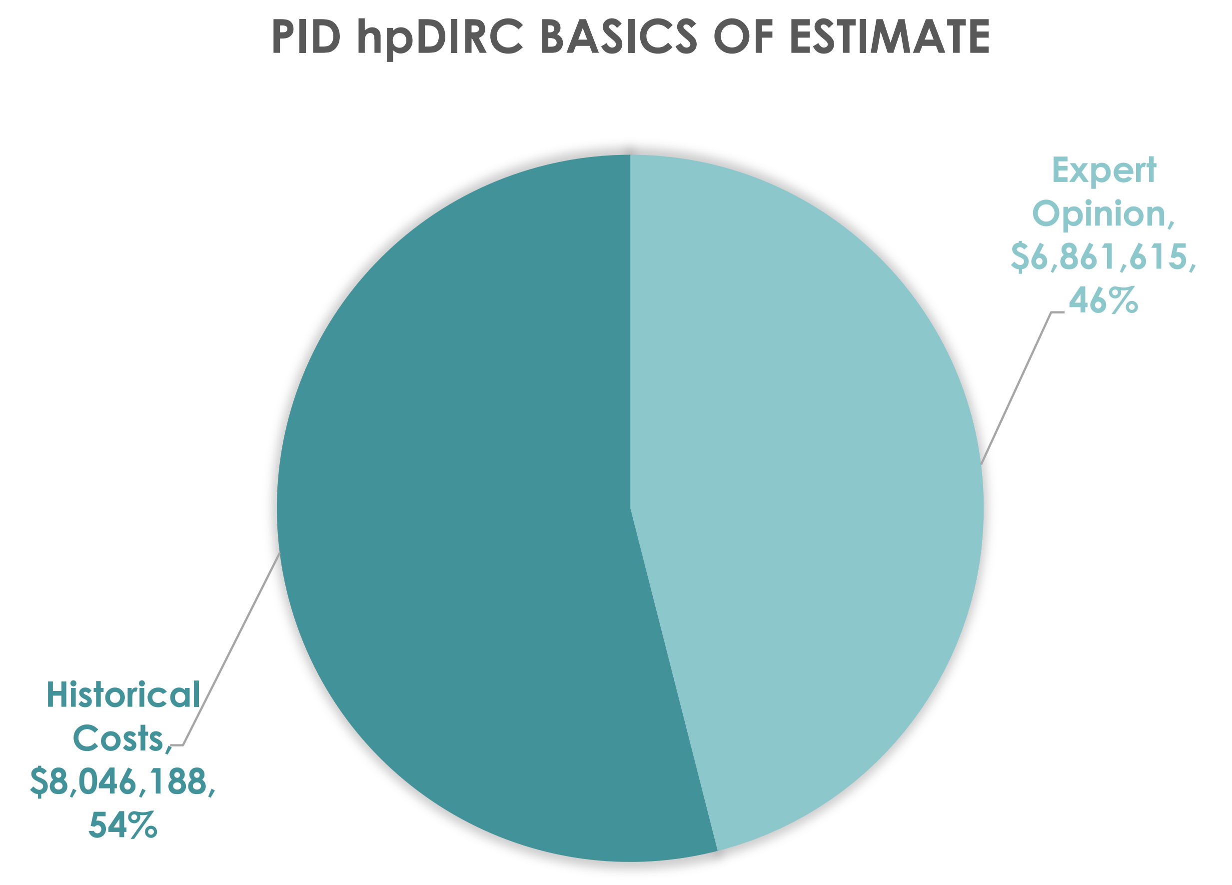

PID pfRICH PROJECT VS. IN-KIND
In-kind, $0, 0%
Project, $6,749,662, 100%

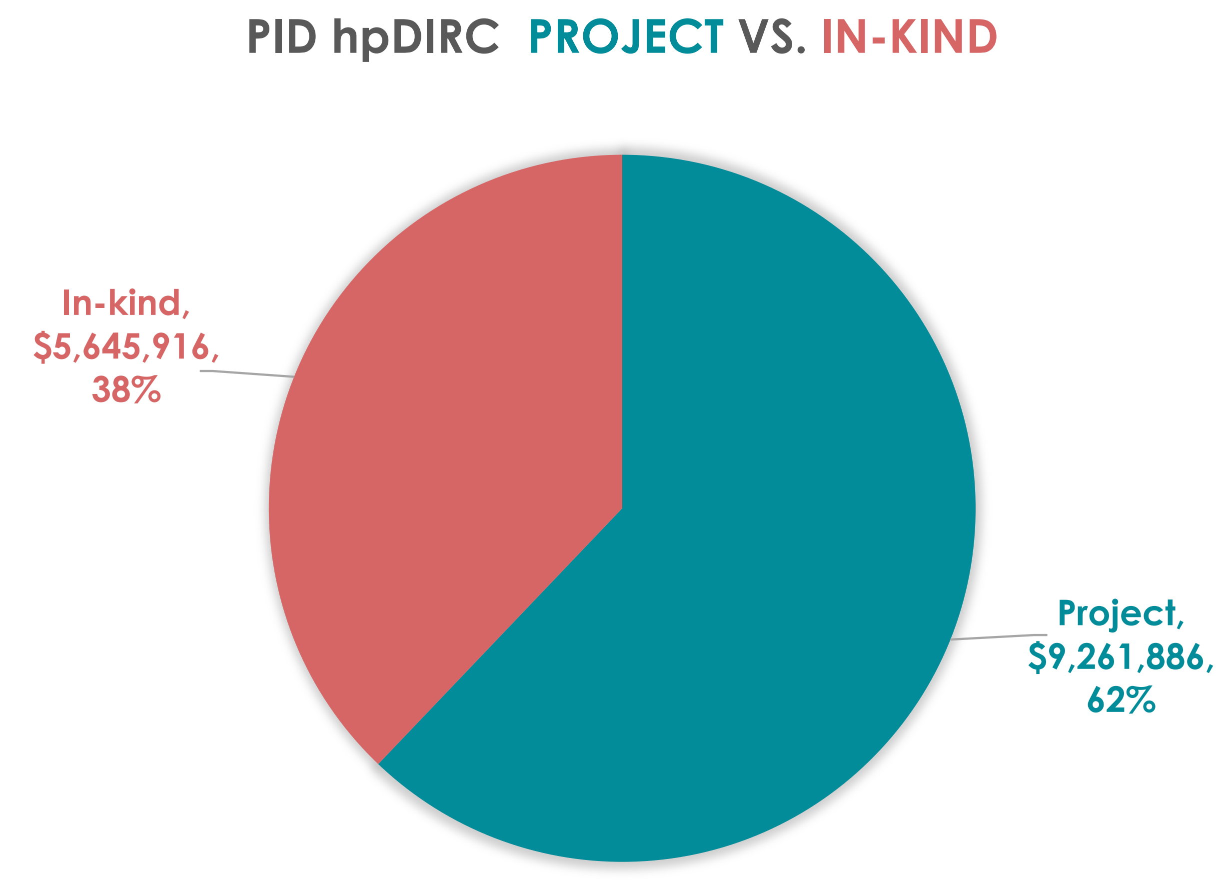

PID pfRICH MATERIAL VS. LABOR
In-Kind Labor, $0, 0%
In-Kind Material, $0, 0%
Project Labor, $2,349,762, 35%
Project Material, $4,399,900, 65%

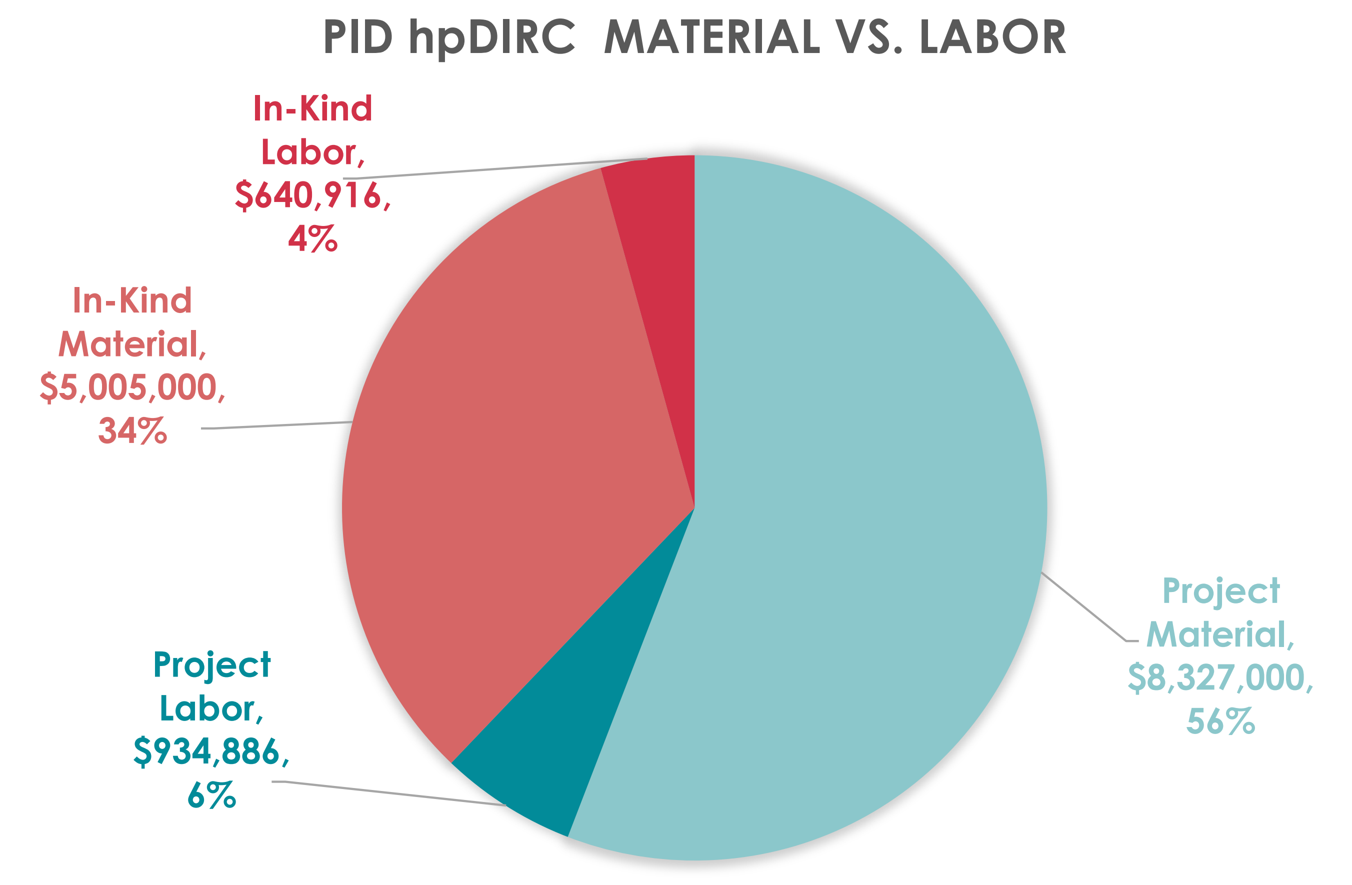

PID pfRICH Labor Total (Project, In-Kind)
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

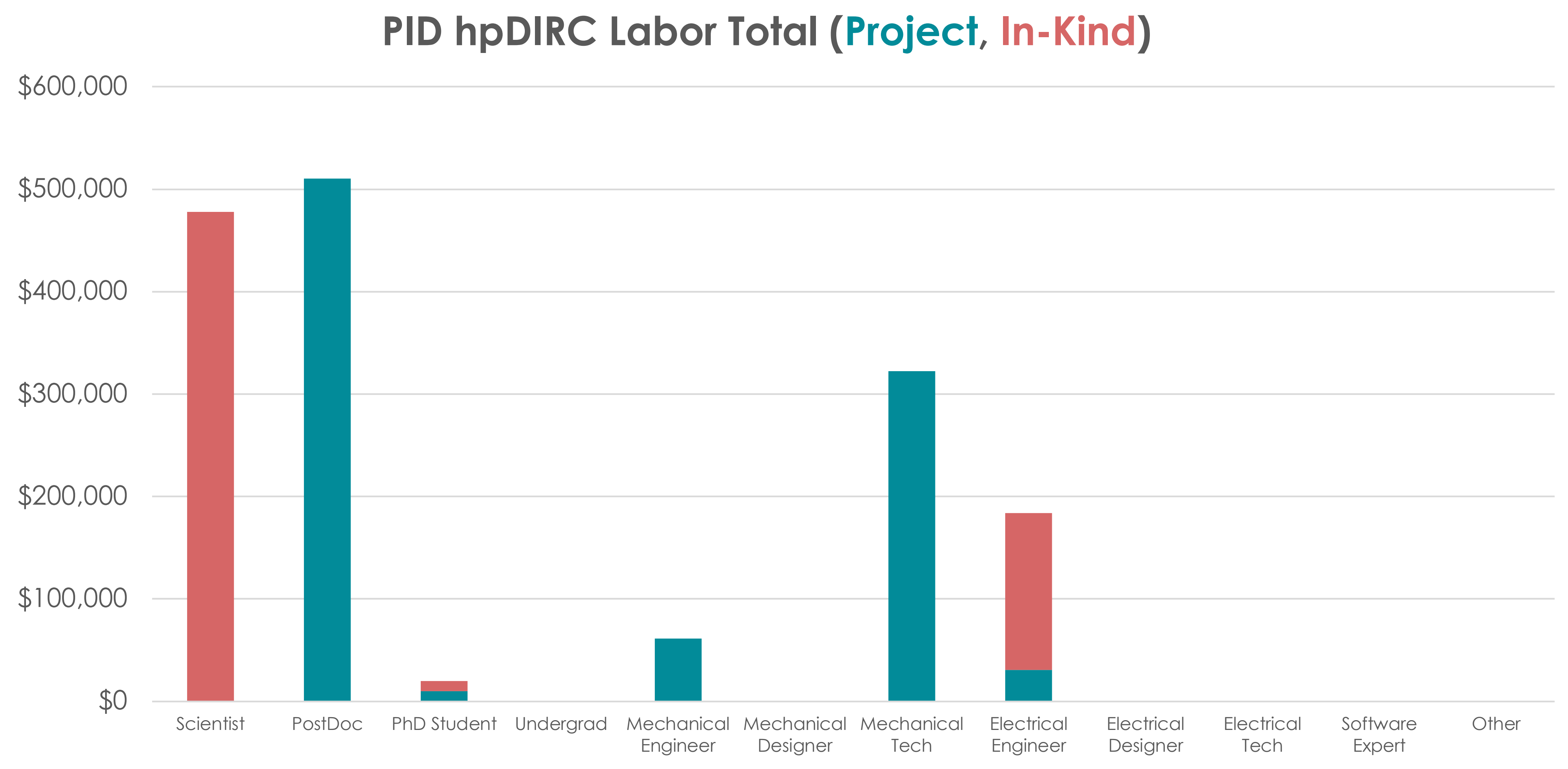

PID pfRICH Labor in FTE
8
7
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

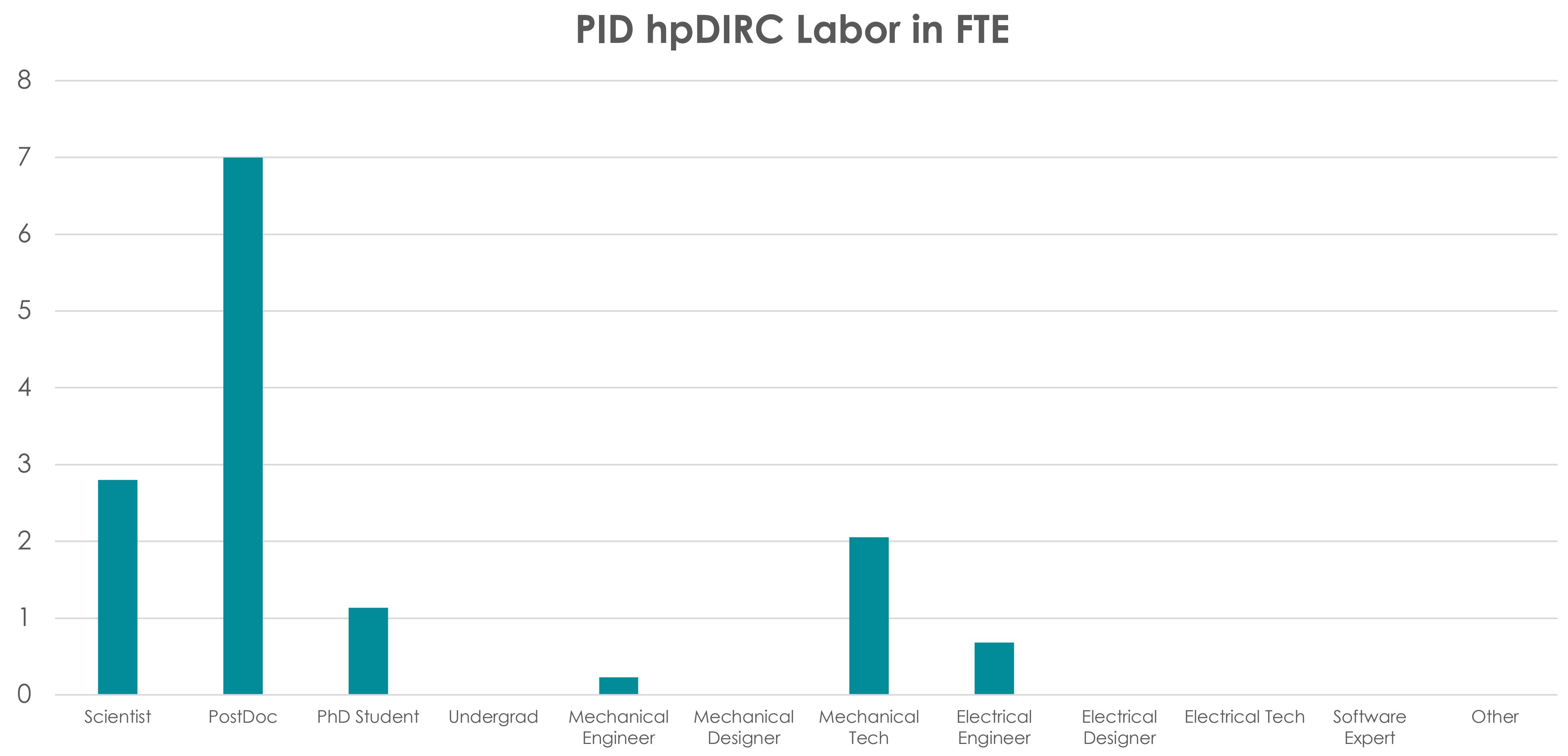
Backup


PID hpDIRC BASICS OF ESTIMATE
Expert Opinion, $6,861,615, 46%
Historical Costs, $8,046,188, 54%

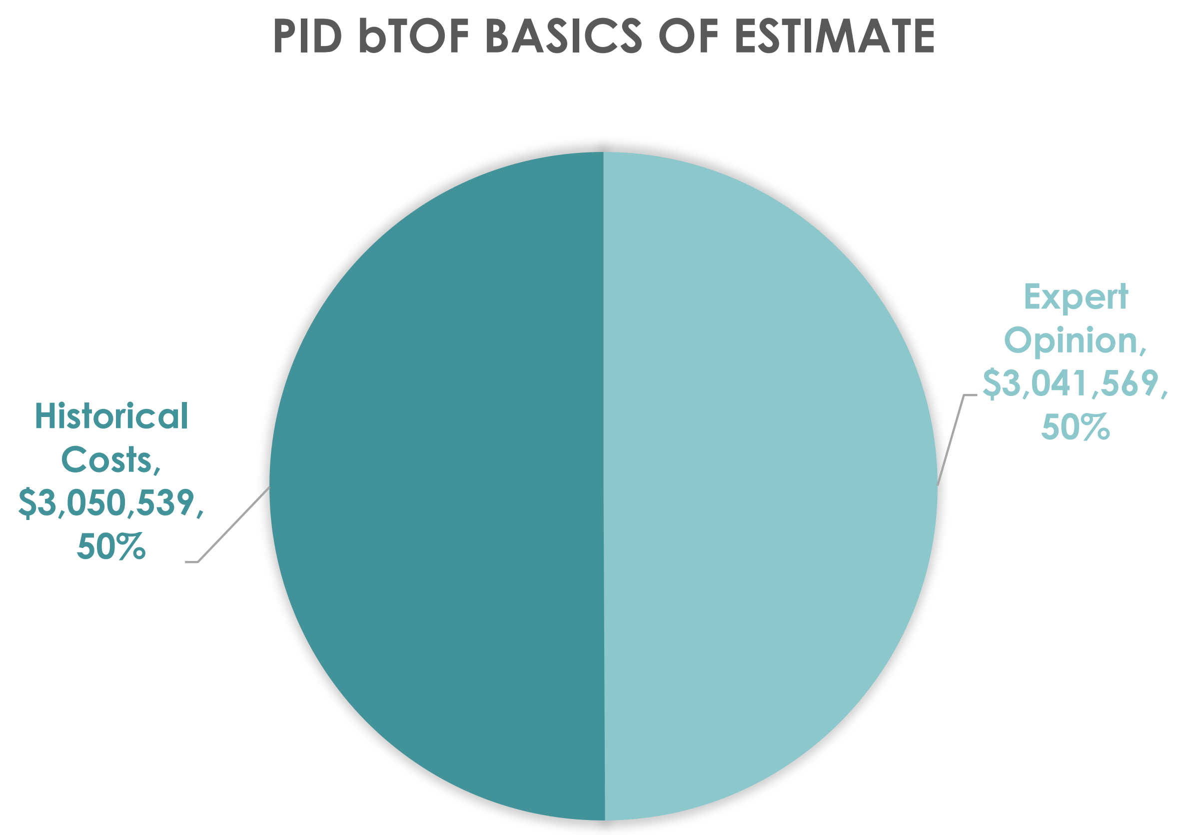

PID hpDIRC PROJECT VS. IN-KIND
In-kind, $5,645,916, 38%
Project, $9,261,886, 62%


PID hpDIRC MATERIAL VS. LABOR
In-Kind Labor, $640,916, 4%
In-Kind Material, $5,005,000, 34%
Project Labor, $934,886, 6%
Project Material, $8,327,000, 56%

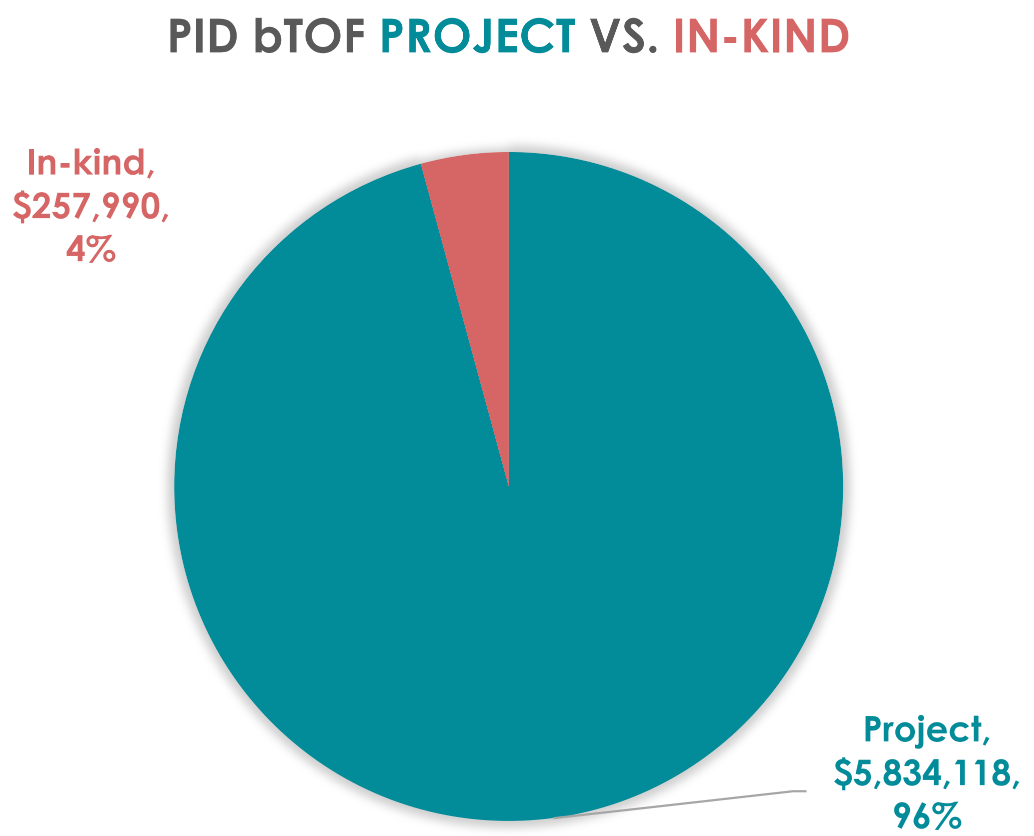

PID hpDIRC Labor Total (Project, In-Kind)
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other


PID hpDIRC Labor in FTE
8
7
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

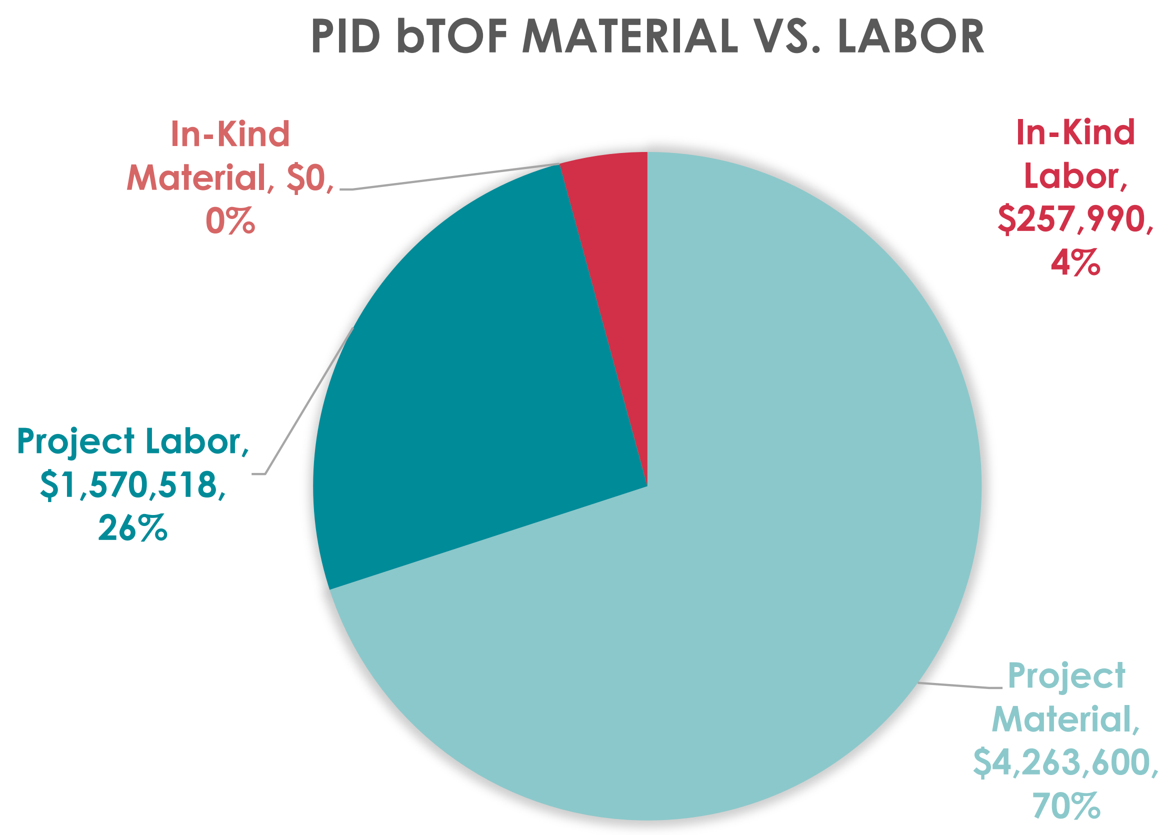
Backup



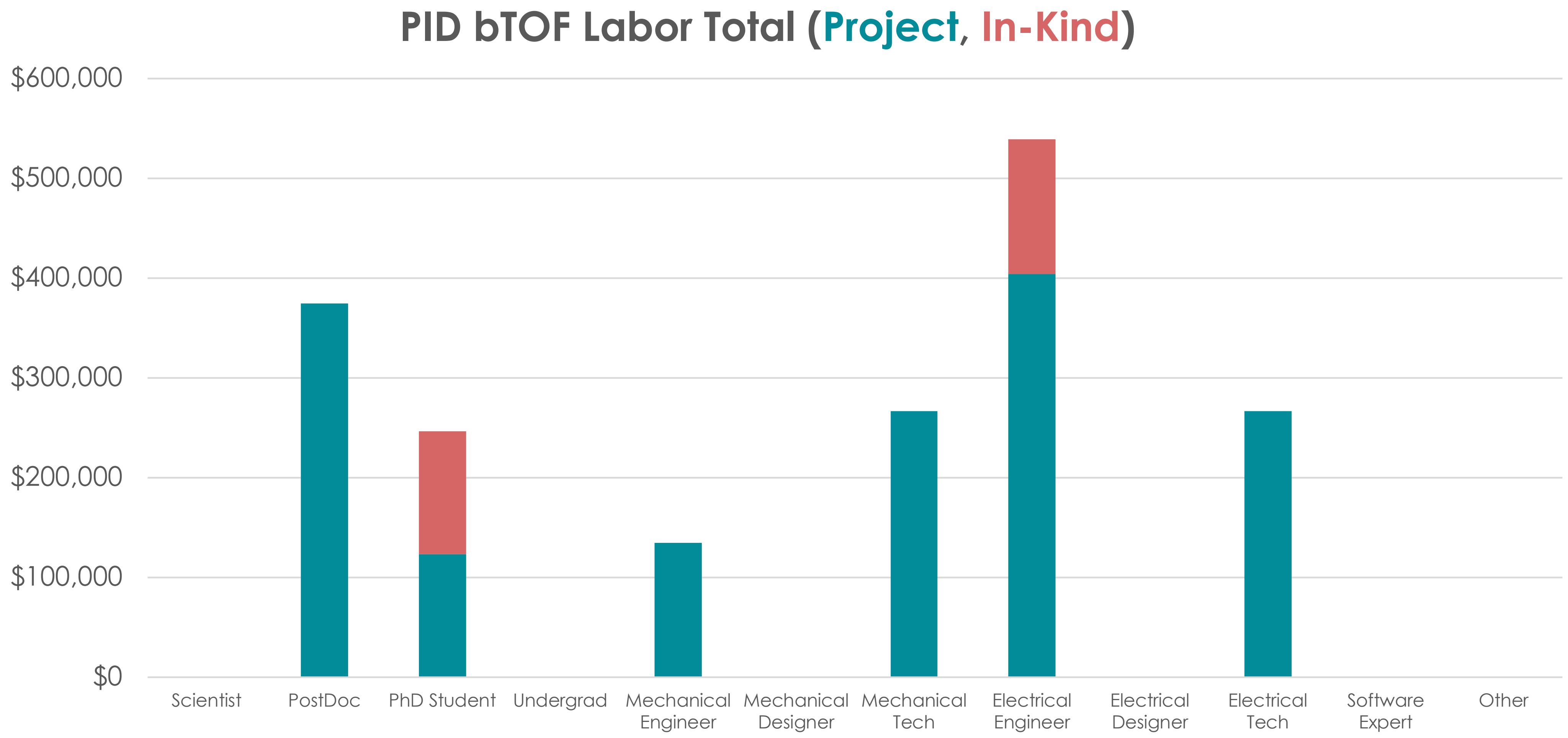
PID bTOF BASICS OF ESTIMATE
Expert Opinion, $3,041,569, 50%
Historical Costs, $3,050,539, 50%



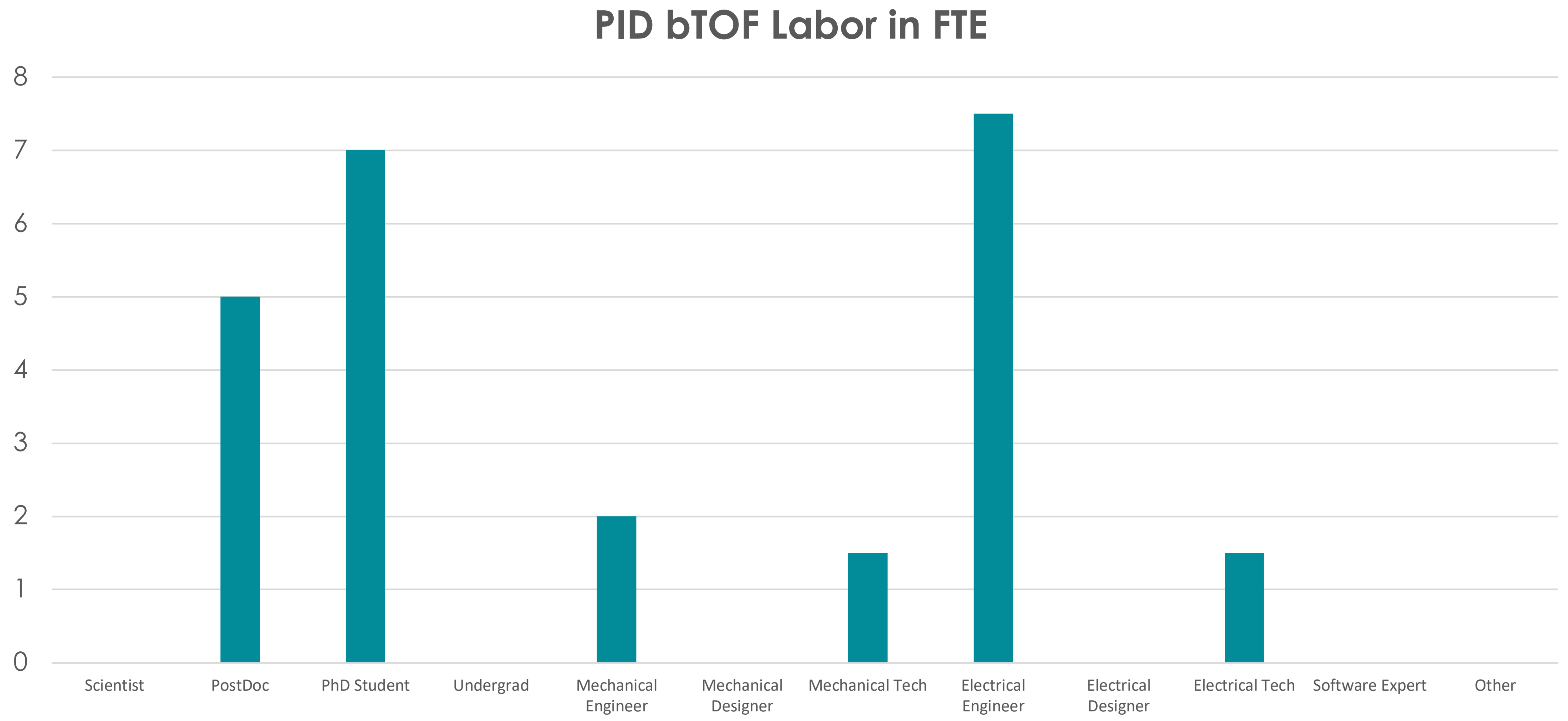
PID bTOF PROJECT VS. IN-KIND
In-kind, $257,990, 4%
Project, $5,834,118, 96%



PID bTOF MATERIAL VS. LABOR
In-Kind Material, $0, 0%
In-Kind Labor, $257,990, 4%
Project Labor, $1,570,518, 26%
Project Material, $4,263,600, 70%

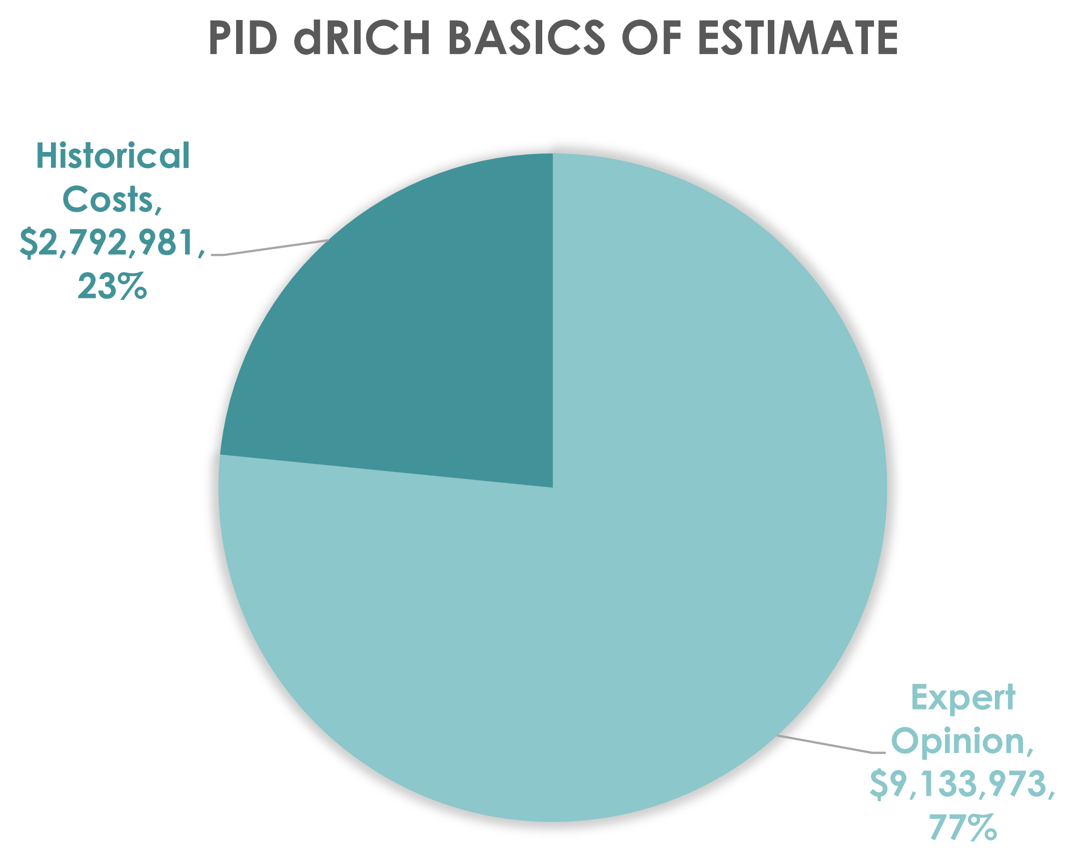


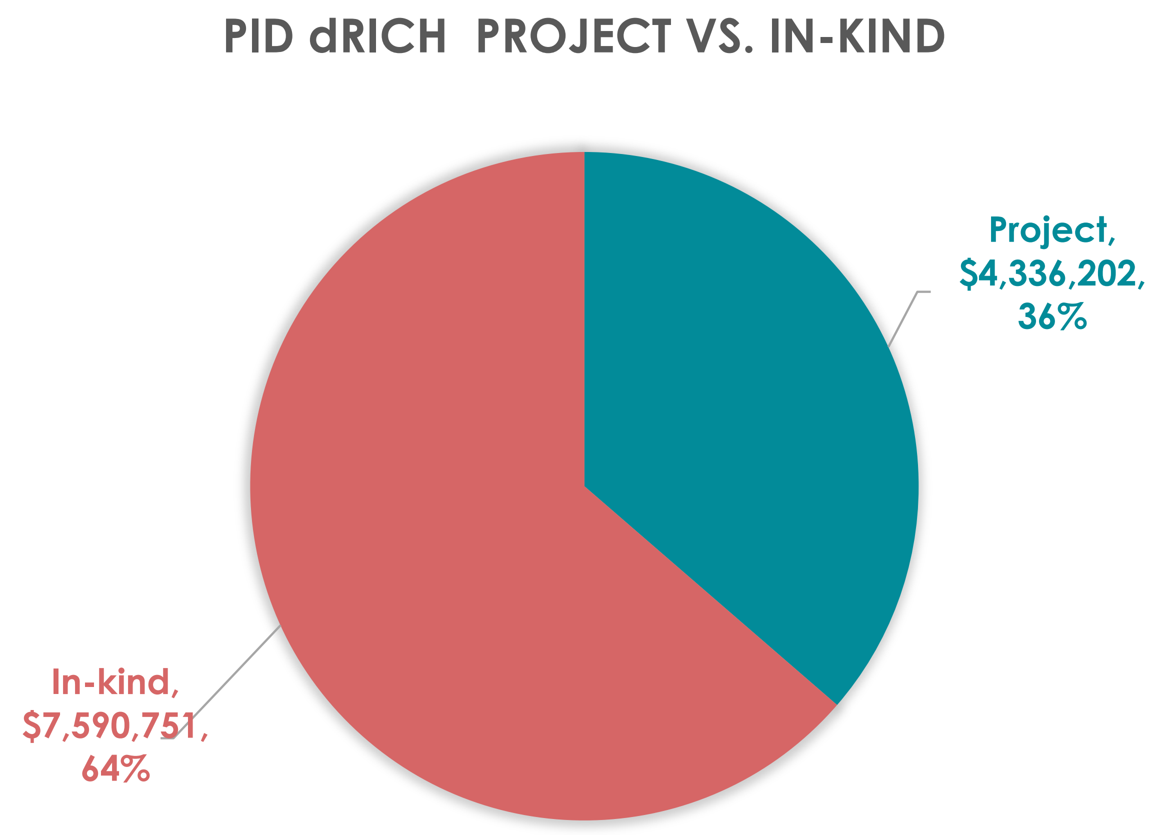
PID bTOF Labor Total (Project, In-Kind)
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

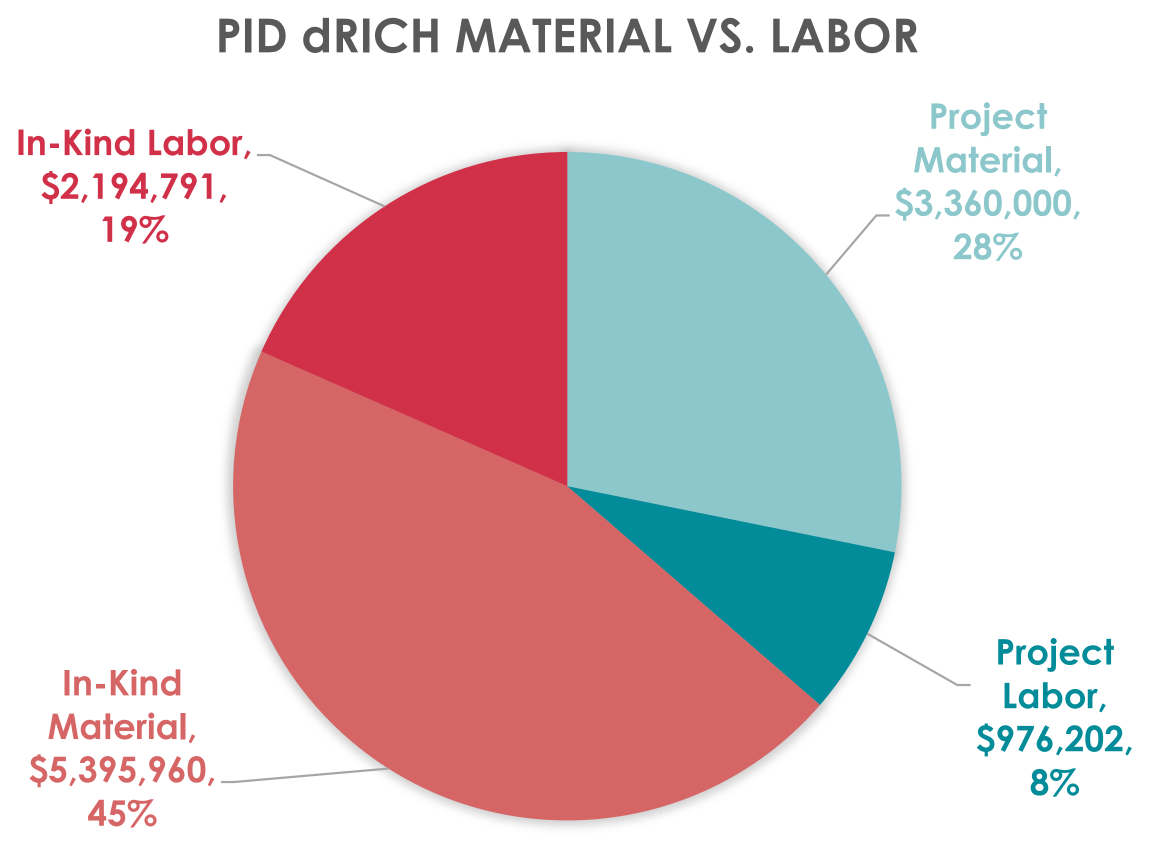


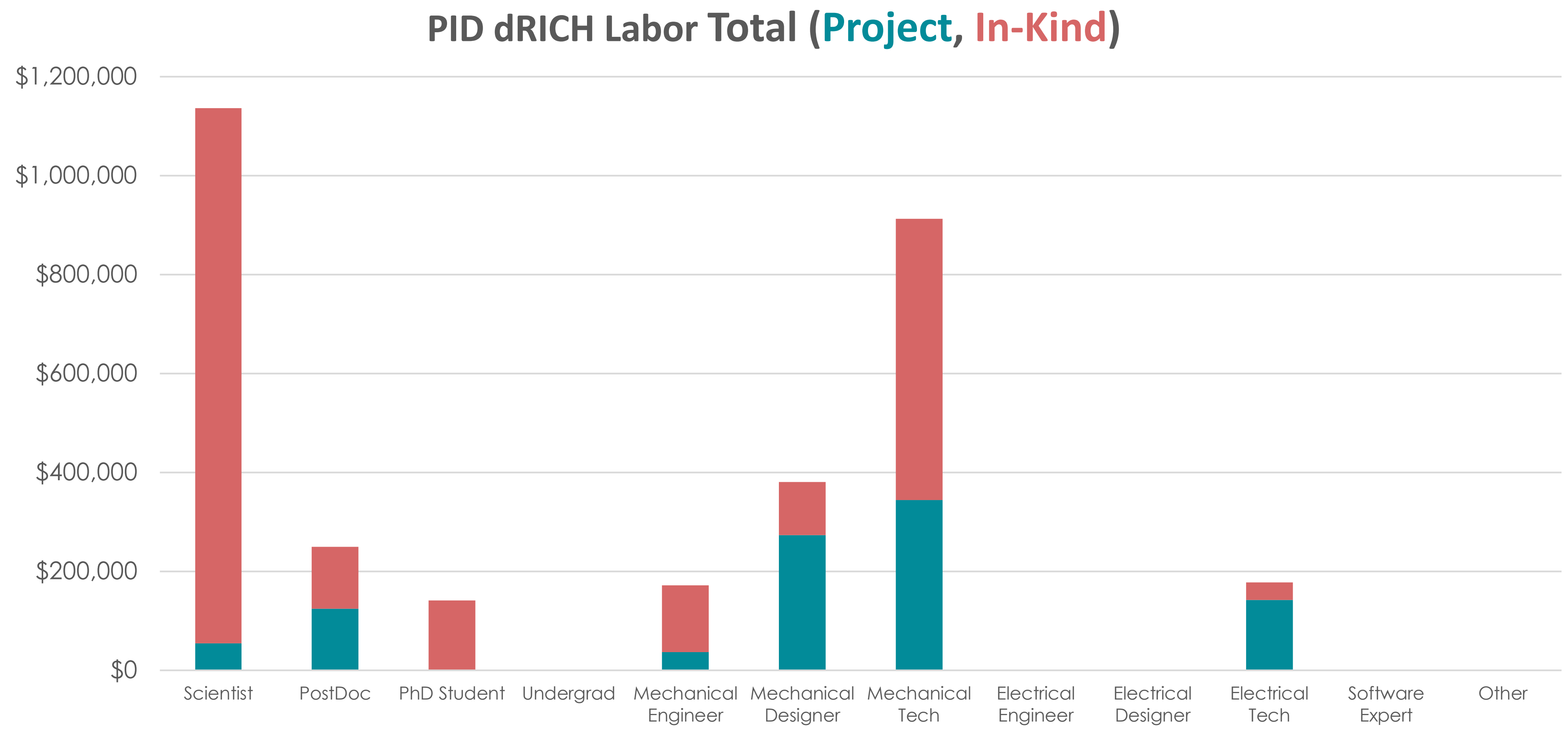
PID bTOF Labor in FTE
8
7
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other

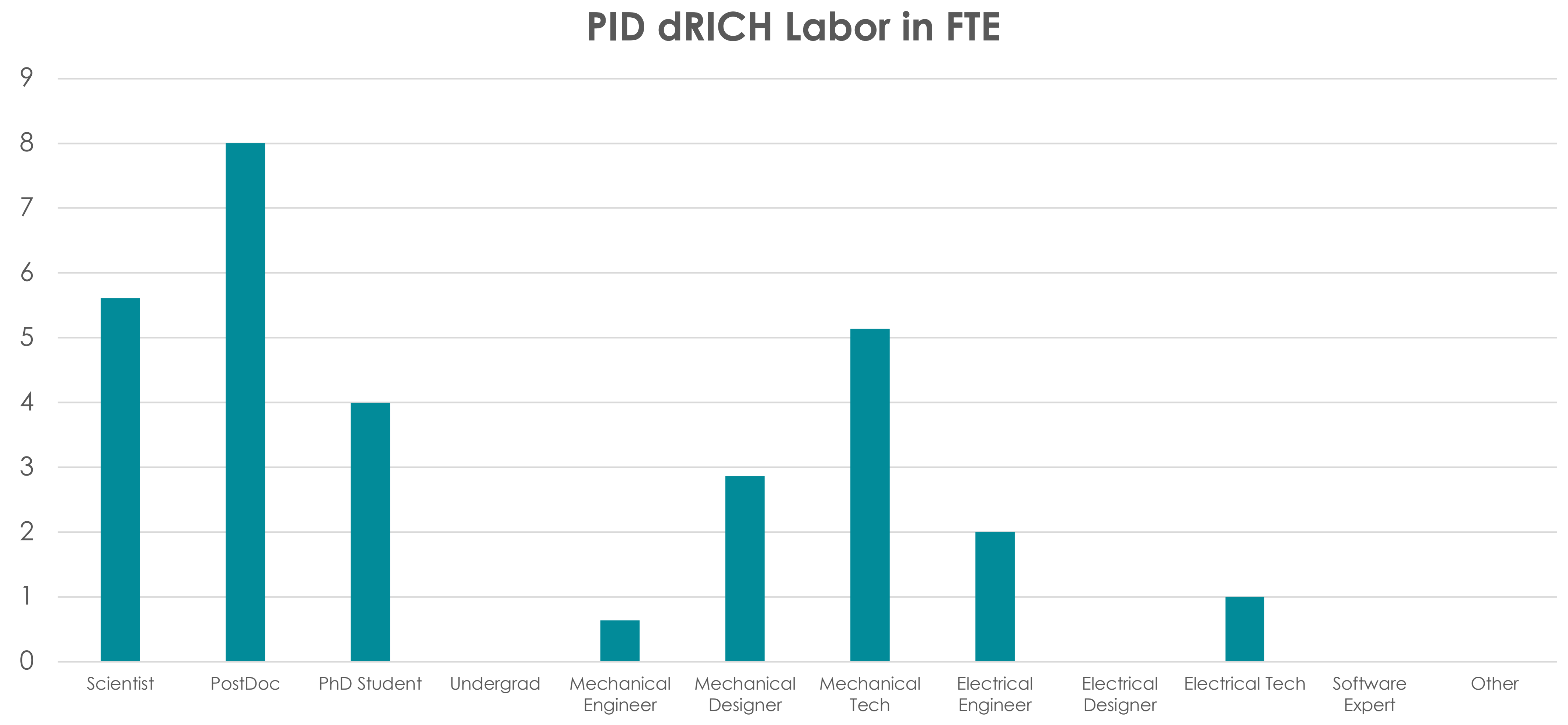
Backup


PID dRICH BASICS OF ESTIMATE
Historical Costs, $2,792,981, 23%
Expert Opinion, $9,133,973, 77%


PID dRICH PROJECT VS. IN-KIND
Project, $4,336,202, 36%
In-kind, $7,590,751, 64%


PID dRICH MATERIAL VS. LABOR
In-Kind Labor, $2,194,791, 19%
Project Material, $3,360,000, 28%
Project Labor, $976,202, 8%
In-Kind Material, $5,395,960, 45%


PID dRICH Labor Total (Project, In-Kind)
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other


PID dRICH Labor in FTE
9
8
7
6
5
4
3
2
1
0
Scientist
PostDoc
PhD Student
Undergrad
Mechanical Engineer
Mechanical Designer
Mechanical Tech
Electrical Engineer
Electrical Designer
Electrical Tech
Software Expert
Other