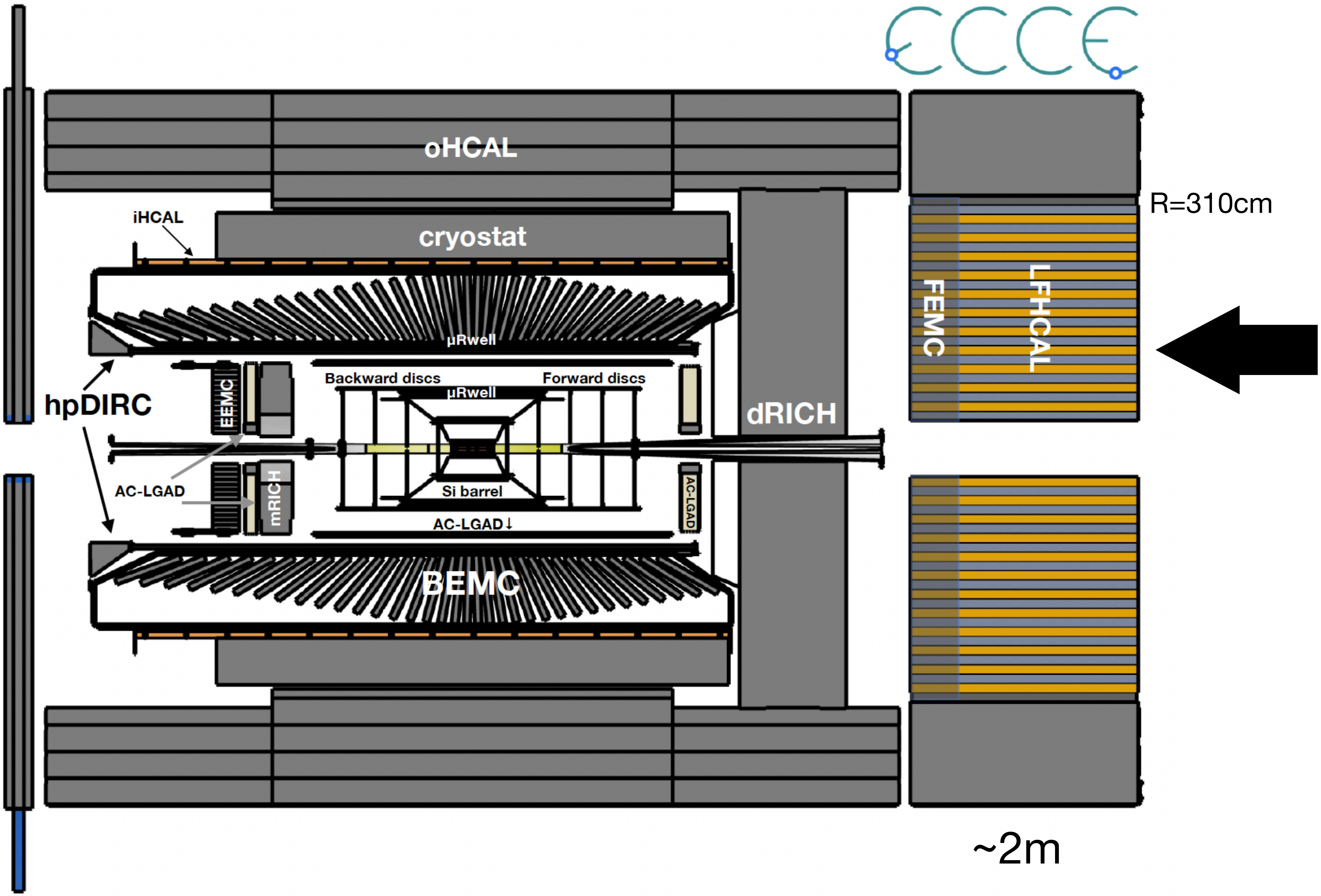
BNL involvement in D1 forward calorimeters

PS with enormous help from from F. Bock, O. Tsai, C. Woody, J. Huang…

Reference EIC detector



Basic properties (from FB's talk)

LFHCAL	inner radius (envelope)	17 cm
	outer radius (envelope)	270 cm
	η acceptance	$1.2 < \eta < 3.5$
tower information		
	x, y	5 cm
	z (active depth)	140 cm
	z readout	20 cm
	# scintillor plates (0.4 cm)	70
	# steel plates (1.6 cm)	60
	# thungsten plates (1.6 cm)	10
	weight	$\sim$ 30.6 kg
	# towers	9040
	# read-out channels/ SiPM	7 x 9040 = 63 280
	interaction lengths λ / λ_0	6.9
	Molière radius R_M for $\pi^{\pm}$	21.1 cm
	Sampling fraction f	0.040
Assembly Modules		
8 LFHCAL towers (8M)	total	1091
no FEMC towers	LFHCAL only	538
200 FEMC towers	LFHCAL+FEMC (inner)	87
72 FEMC towers	LFHCAL+FEMC (outer)	466
4 LFHCAL towers (4M)	total	76
no FEMC towers	LFHCAL only	36
100 FEMC towers	LFHCAL+FEMC (inner)	16
36 FEMC towers	LFHCAL+FEMC (outer)	24
2 LFHCAL/ 50 FEMC towers (2M)	LFHCAL+FEMC (inner)	2
1 LFHCAL/ 25 FEMC towers (1M)	LFHCAL+FEMC (inner)	4

General case for forward calo at BNL

- **The forward calorimetry contributes to a wide range of important physics measurements**
  - Hermetic coverage
  - High energy, high-Q^2 jets (higher x)
    - *Improves containment, esp. jets with neutral hadrons*
  - High resolution allows substructure measurements
  - Important for determining exclusivity, e.g. for diffractive VM
  - Important for determining gaps, e.g. for inclusive diffraction

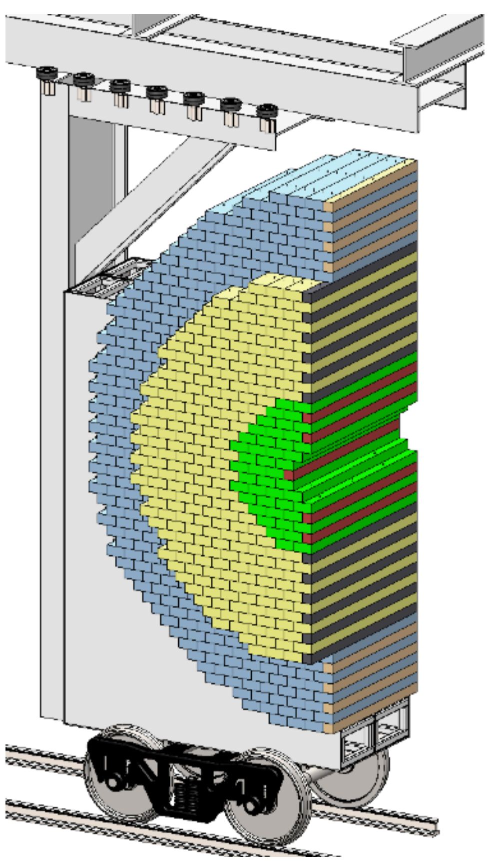
- **Technologies chosen are well matched to skills of our department**
  - sPHENIX group has just built sPHENIX, including a WSciFi EMcal and ECCE OHCal
  - coldQCD group contributed extensively to STAR forward upgrade
  - Extensive experience in how to move from initial concepts to final designs, in close collaboration with other institutions

- **Proposed investment : 15-20 FTE after 2025, perhaps 3-5 in shorter term to contribute to design/R&D process before CD2/3A**
  - R&D proposal deadline for 2022-2023 is July 25

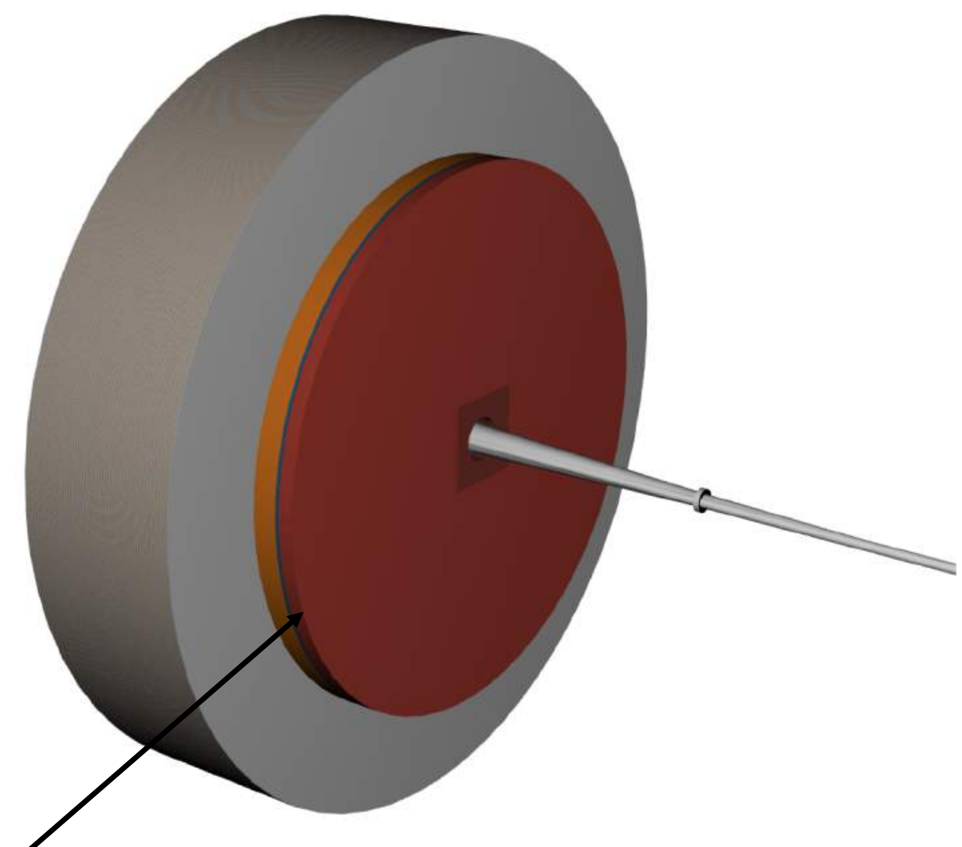
- **I have been discussing this with ORNL and they are eager to see a proposal for a large contribution from BNL**

Current plans

- **ECCE and Athena proposals had separate concepts for both detectors**
  - Detector 1 process has converged on a merger of the two concepts
- **The forward EMCal will be based on WSciFi technology, familiar to the sPHENIX group**
  - Easier construction
  - Smaller extent in Z (fits available envelope)
- **Forward HCal will be based on ECCE LFHCal, itself based on the CBM PSB design**
  - 7 longitudinal segments of steel/scint with W/scint. as tail catcher, readout by WS fibers

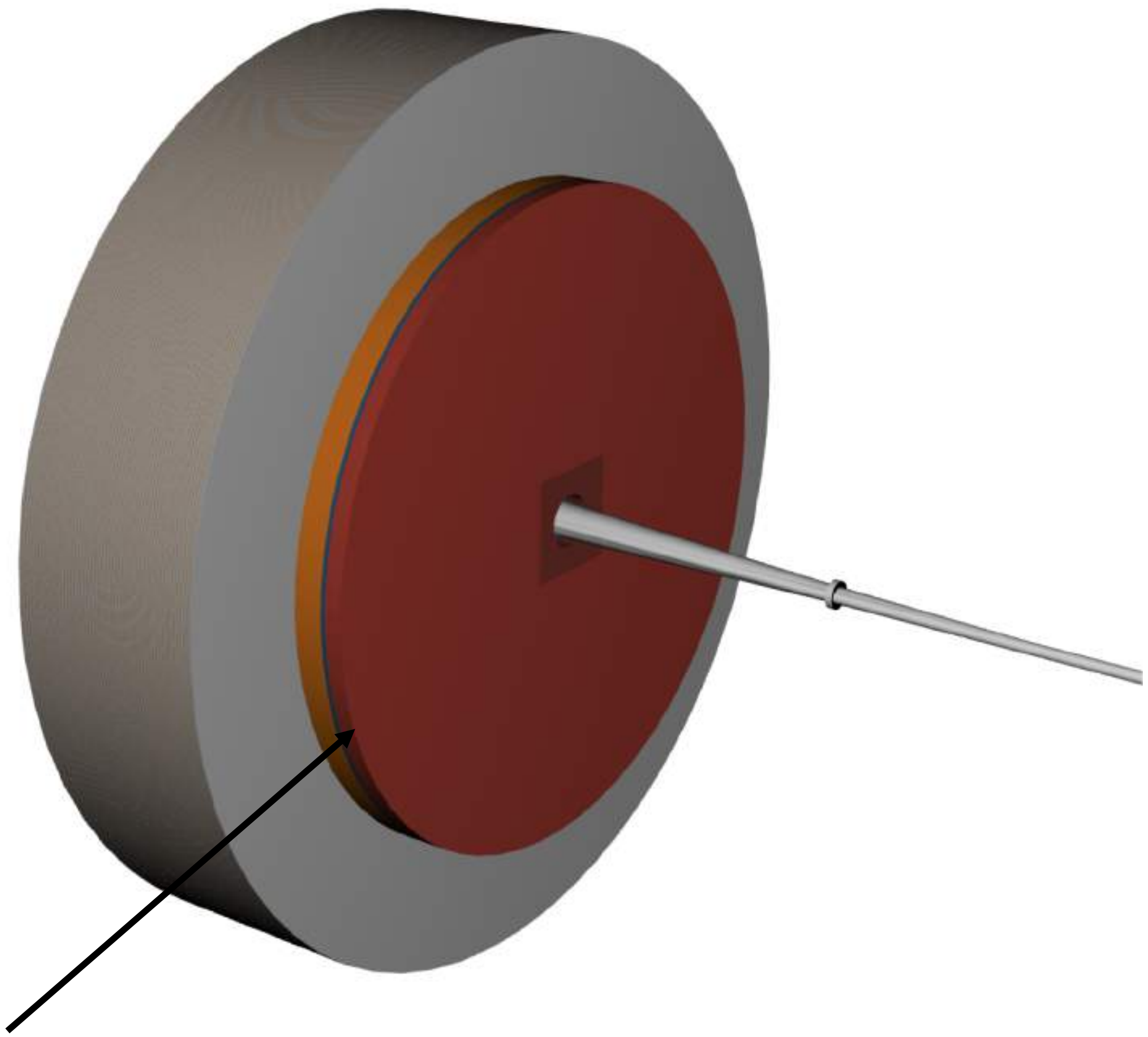


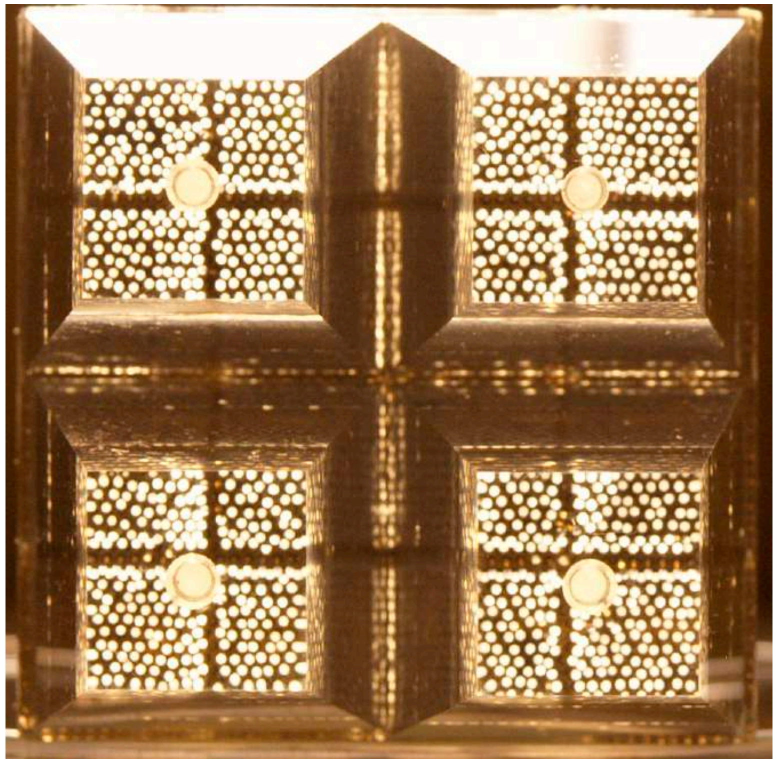
talk by F. Bock

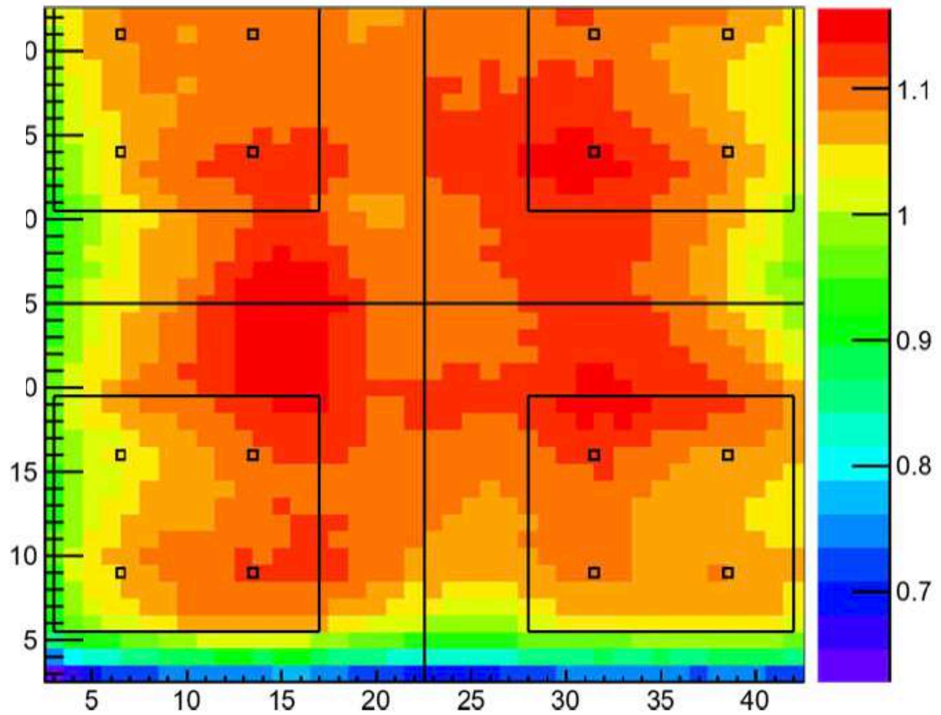


talk by O. Tsai

pECal concept







non-projective stack of WSciFi, technology similar to sPHENIX EMCal.
Lots of work to optimize light yield (LY).
Insert to cover very small angles.

New BEMC, Lumisil 591
Better fiber arrangement and better coupling.

2. The full pro/con list that was used to inform your recommendations. This should include any and all considerations that helped the WG form your recommendations.

Technology Pro:

- WScFi is a unique technology allowing to achieve e/h ~1 (response to hadrons) and at the same time keep em energy resolution at ~10%/√ E + 2%, no other known technology for EMcals can achieve this. (details https://indico.bnl.gov/event/15493/)
- WScFI is a self supporting structure – no dead areas within detector volume.
- WScFi technology allowing to build detectors with different configurations such as an Optical Accordeon, eRD1. Insert next to beam pipe (channeling).
- WScFi technology allows to build very high density calorimeters. Insert next to the beam pipe. $23X_0$ WScFI 30 cm integration length in Z vs $18X_0$ SHASHLYK with ~60 cm in Z.
- WScFi method is very simple requires only few components to build detector.
- Very simple mechanical integration (with Hcal and readout).

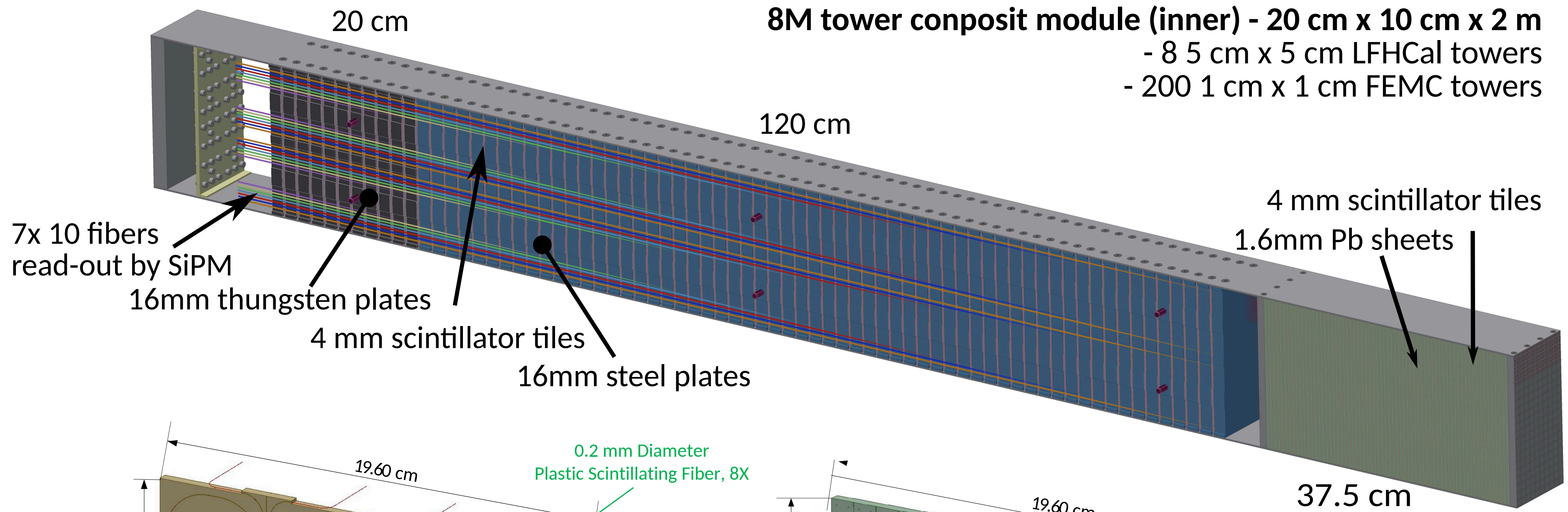
Technology Con:

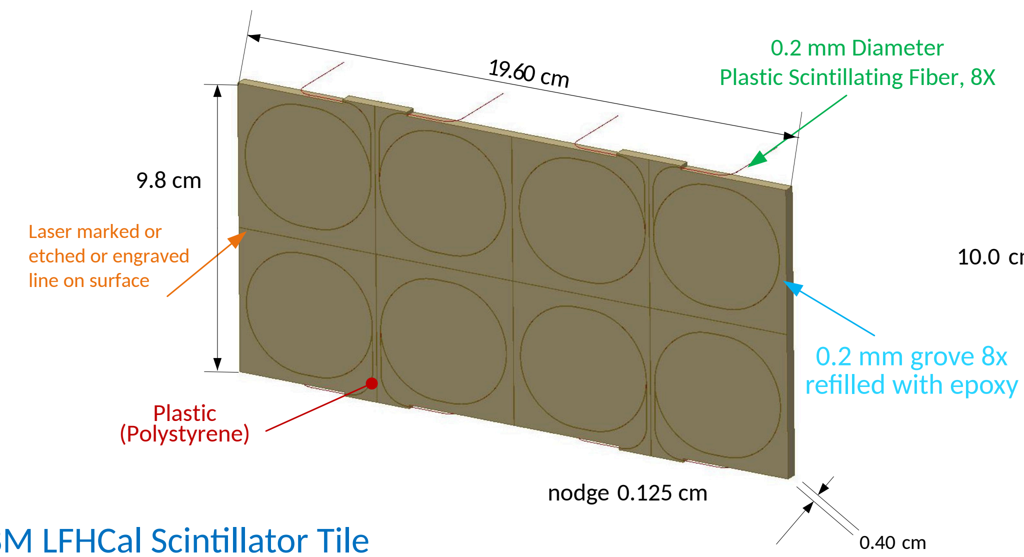
- Absolute light yield is lower than in SHASHLYK (small sampling fraction).
- Uniformity of light collection need to be improved, compared to sPHENIX

Important considerations:

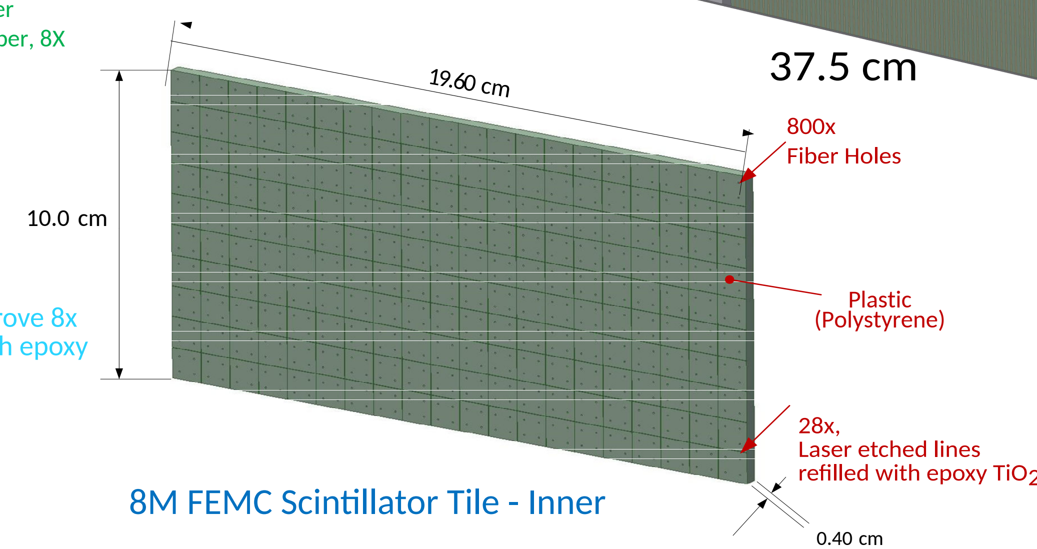
- Strong/good record team interested in pECAL (UC_EIC Consortia, Chinese Consortia, eRD106) see presentation from Chinese consortia https://indico.bnl.gov/event/15812/
- Performance, cost and risk are well understood due to almost 10 years long R&D and sPHENIX construction. Know How well spread in EIC Users community.
- Technology is simple and can be easily transferred (US, China), has minimal requirements on infrastructure at production site.
- R&D plan was submitted (pended now) eRD106 to address LY and uniformity of light collection with compact readout.

LFHCal concept: module





8M LFHCal Scintillator Tile



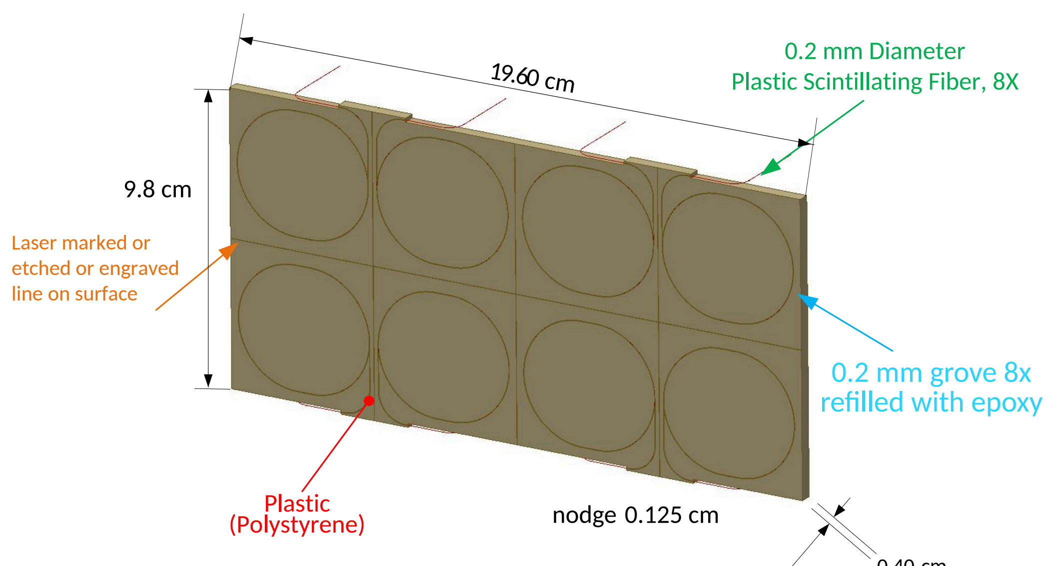
8M FEMC Scintillator Tile - Inner

Based on CBM PSD design:
sandwich of 60 layers of 16mm steel/4mm scint.,
and 10 layers of W/scint as a tail catcher:
groups of 10 fibers read out by SiPM
(so 7 longitudinal sections)

Notable challenge
is production of
grooved scintillator

Current 8M Scintillator Plate Design

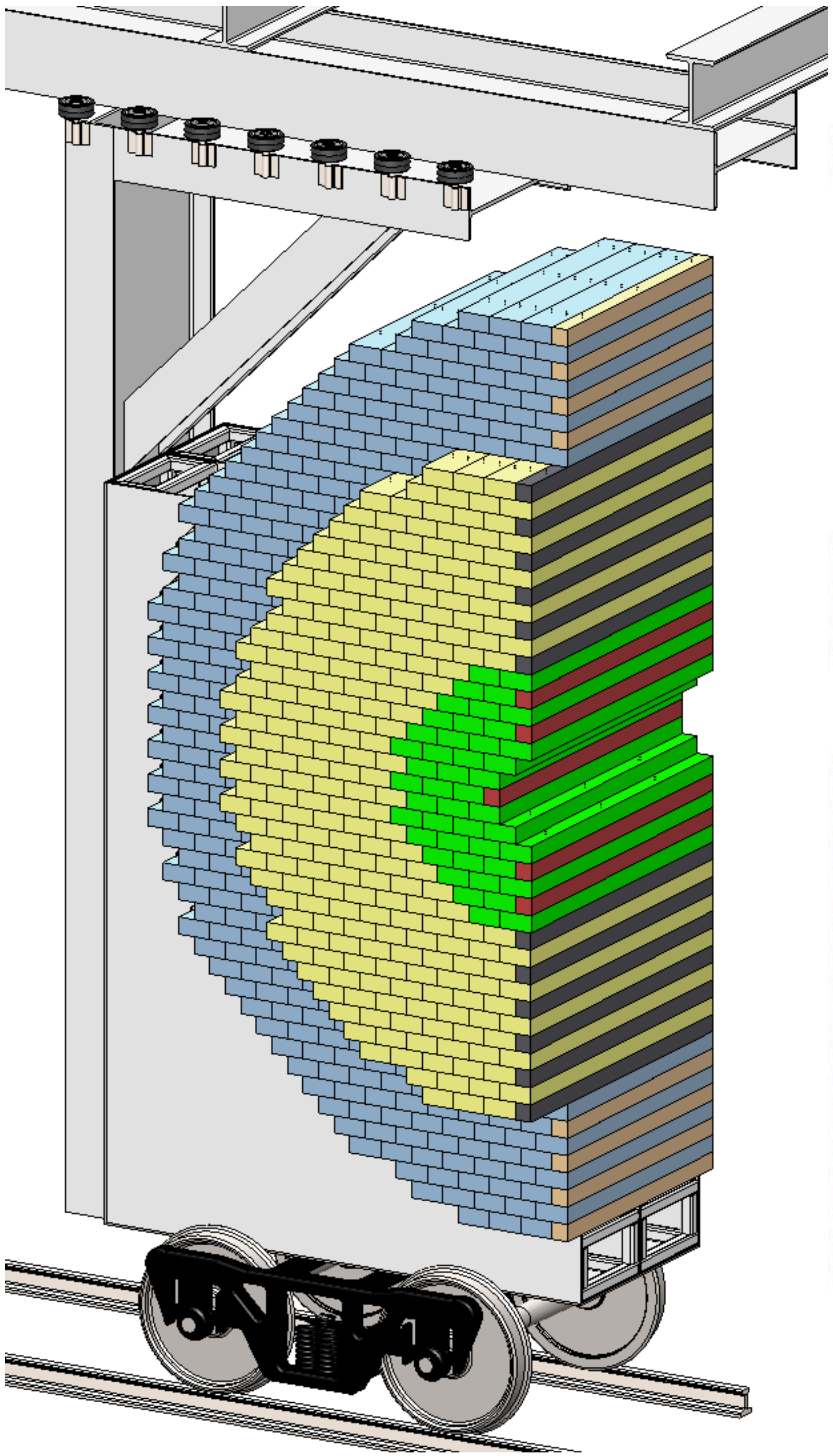
- Most Scintillator plates produced as 1 unit of 100x200mm plates (8 single tower tiles)
- Separation of tiles edged into the plate (95%) through, refilled with Epoxy-TiO_2 mix
- Wrapped in Tyvek paper and Kapton tape

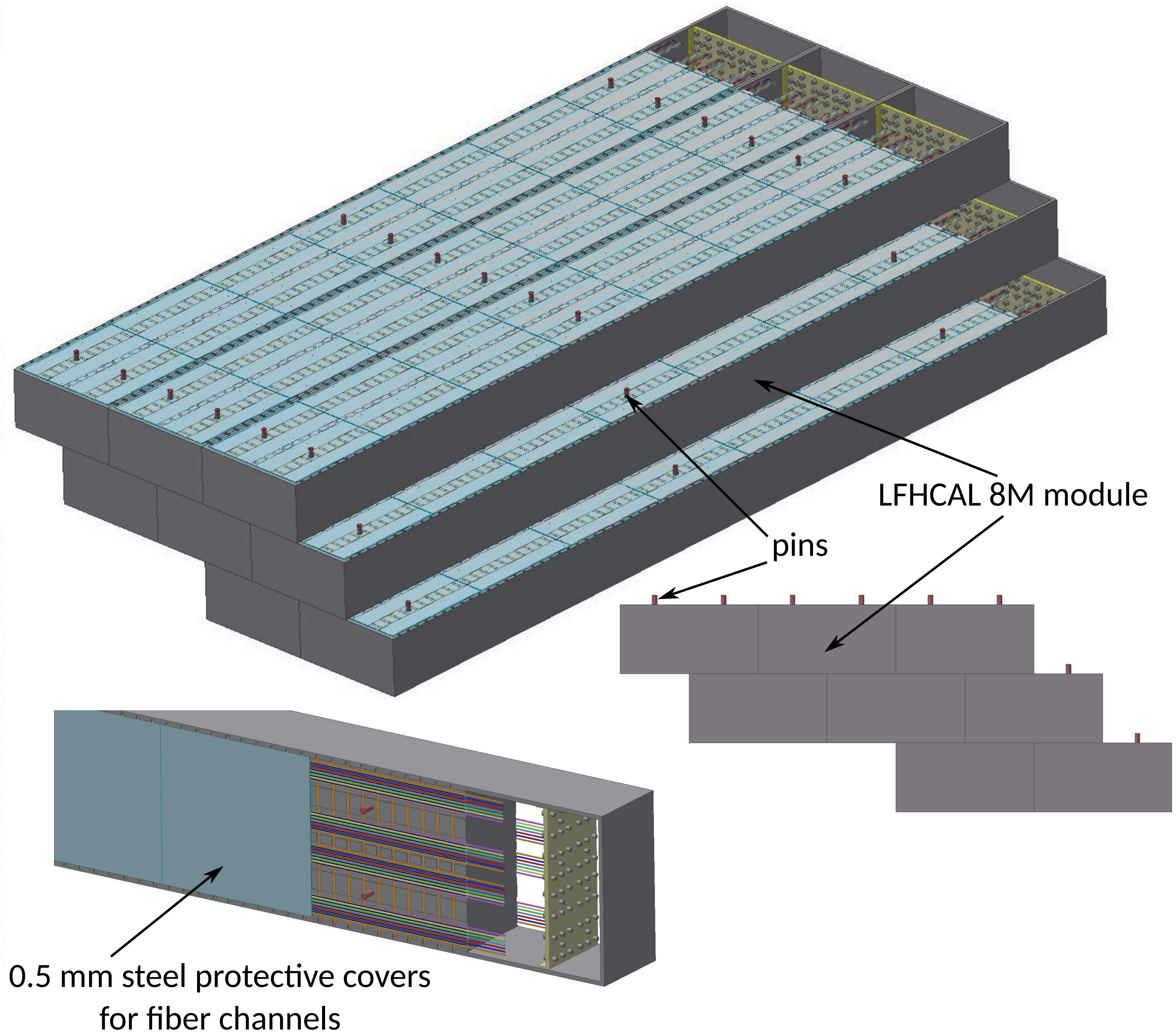


8M LFHCal Scintillator Tile

- Fiber thickness chosen for minimal light loss while bending, might be increased to 0.5mm
  $\rightarrow$ other geometries under consideration (i.e. 1/4 circle)
- Originally costed from Uniplast as 1 unit of assembly + material
- Updated estimate:
  - tile material produced, finished & groved externally
  - fiber installation: 0.25h enginering time/per tile
  - wrapping: 0.1h students time/per tile
  - neccessary tooling 100K
- Exploring possible robot supported options for tile assembly

LFHCal concept: construction





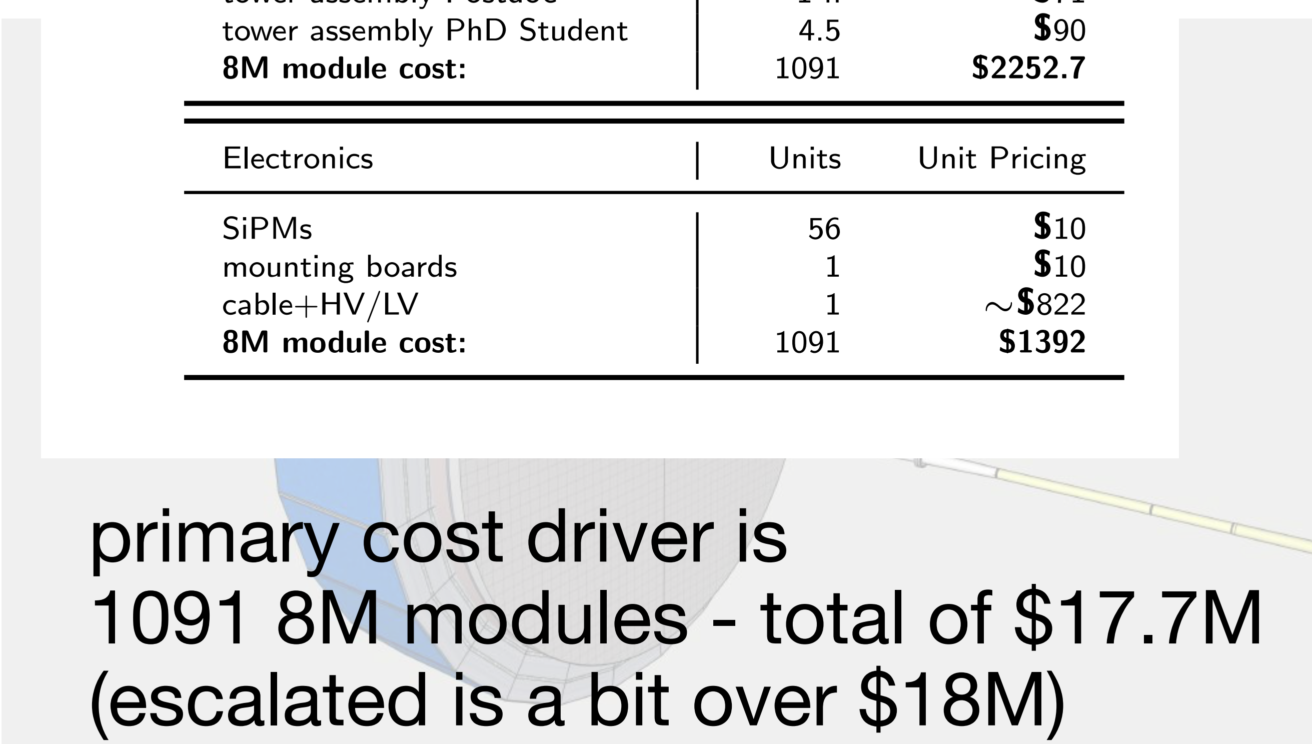
Costs & labor: LHFCal and pECal

Example 8M module costs:

Material procurement	Units	Unit Pricing
Absorber plates + support	1	$1750
Scintilator plates	70	$65
tyvek + capton	4.04	$0.4
WLS fibers	1360	$3
8M module cost:	1091	**$9822**

Assembly labor	hours	cost
installing fiber mech. engineer	17.5 h	$2680.5
tile wrapping PhD students	7 h	$140
tower assembly mech. engineer	0.083 h	$12.8
tower assembly PhD Student	1.92 h	$38.4
tower assembly Undergrad	11 h	$220
tower assembly Postdoc	1 h	$71
tower assembly PhD Student	4.5	$90
8M module cost:	1091	**$2252.7**

Electronics	Units	Unit Pricing
SiPMs	56	$10
mounting boards	1	$10
cable+HV/LV	1	~$822
8M module cost:	1091	**$1392**



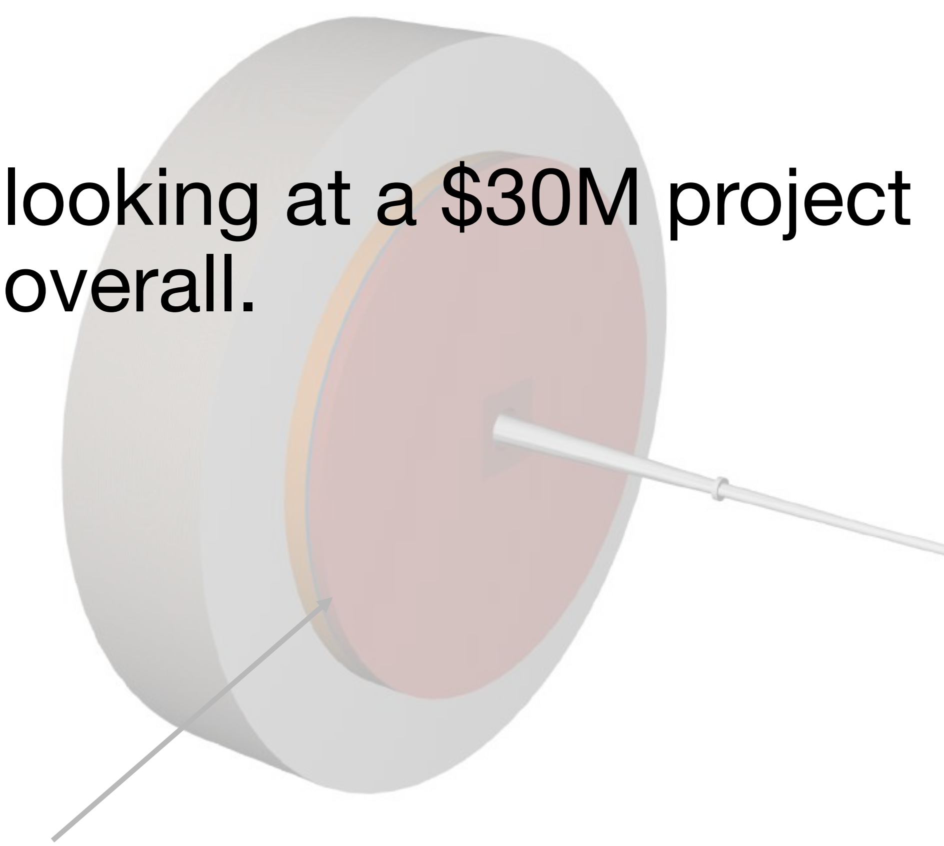
primary cost driver is
1091 8M modules - total of $17.7M
(escalated is a bit over $18M)

pECal

Cost drivers (ATHENA dimensions)

- Scintillating fibers – $1.87M (Quoted, KURARAY)
- W powder - $1.38M (sPHENIX, price in China)
- SiPMs - $2.44M (Quoted)
- Electronics - $1.33M (Direct scaling from STAR FCS)
- Labor - $4.1M ($1.98M to project) (mostly historical)

Total: ~$12.7M (using project templates)



looking at a $30M project overall.

Where can BNL help?

lots of input from Friederike Bock here

- **Physics (motivation and analysis)**
  - jet physics requires high granularity hermetic forward calo - can we do the measurements we need? (TMDs, substructure, etc.)
  - exclusive physics would have less stringent requirements, but still necessary or neutral particles (and forward eID)
  - Can contribute to detector calibration(s), jet calibration, etc.
- **Detector design: lots of design details and R&D needed (right now!)**
  - R&D needed for e.g. LFHCal scintillator production (e.g. use of robots?)
  - Lots of experience from STAR forward upgrade and sPHENIX EMCal
  - Perhaps even optimize final design based on further physics input, e.g. jet substructure
  - Contribute to RD106 and RD107 (testbeam planning and execution)
- **Mechanical engineering**
  - Coordinate construction, assembly and integration into D1
  - Close collaboration with project, but can utilize extensive experience within PO
- **DAQ/electronics**
  - Readout planned to be on-detector but readout concepts still in early stages (e.g. suggestion to use CMS HGCROC) - D1 pECal is following LFHCAL developments
- **Slow controls**