WBS 6.10.11
Interaction Region integration and Ancillary Detectors

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L3 CAM ANC Detectors

EIC Detector Comprehensive Design Review

August 29-30, 2023

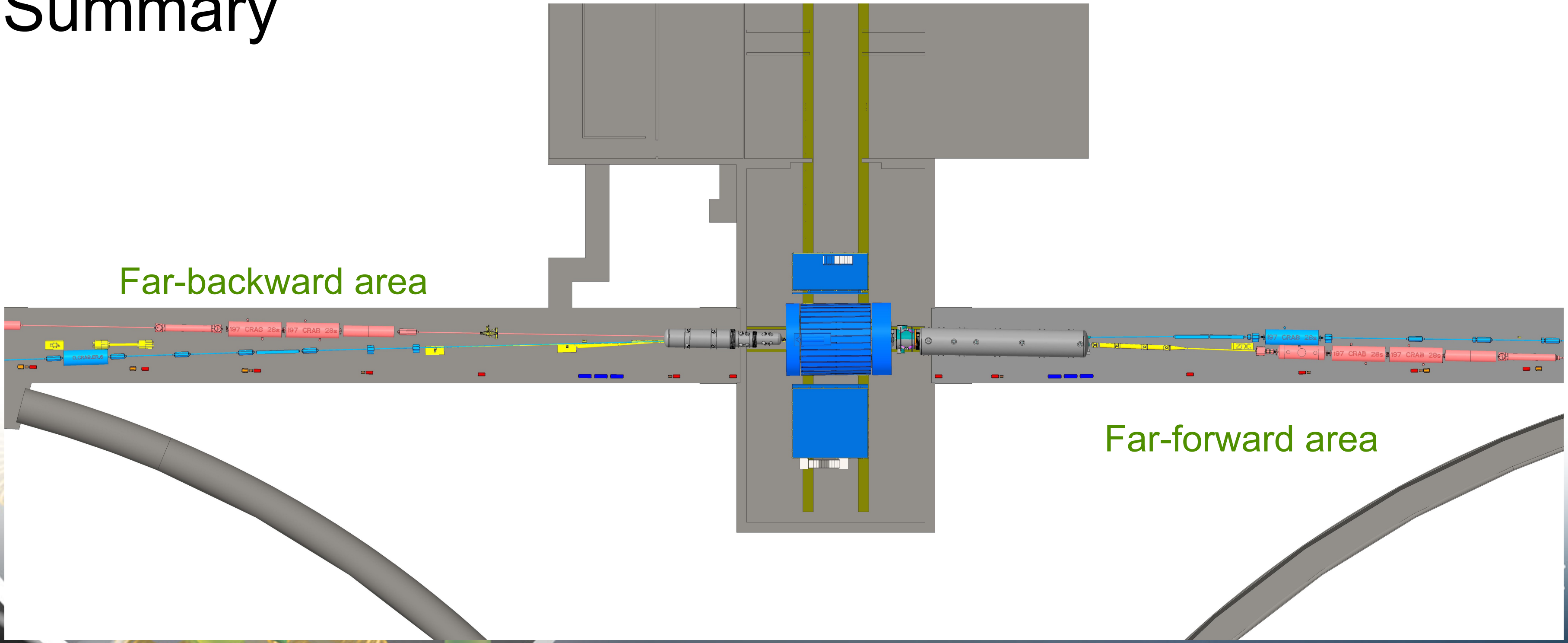
Electron-Ion Collider

Brookhaven National Laboratory · Jefferson Lab · U.S. Department of Energy Office of Science

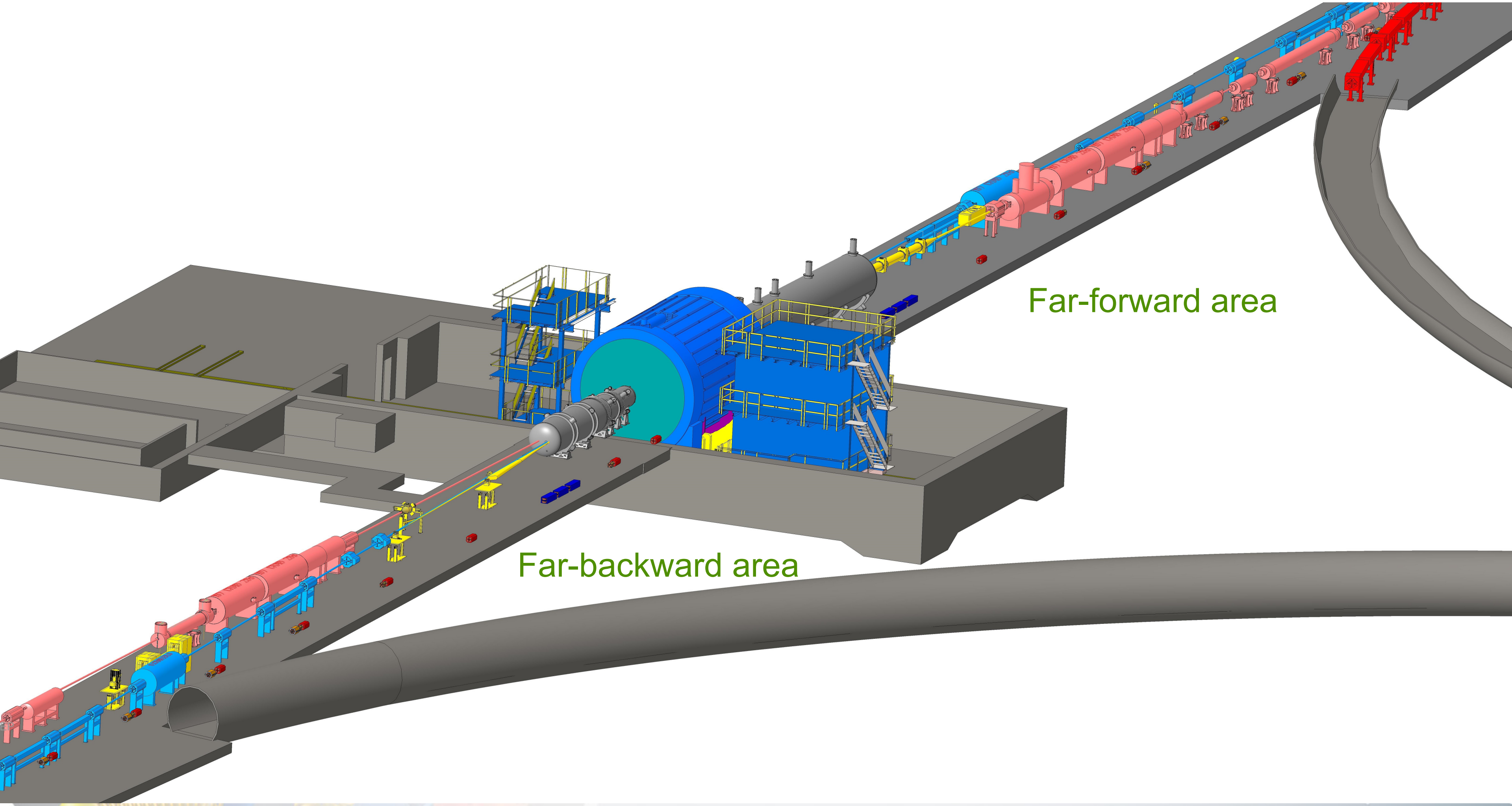
Outline

- IR layout
- Physics requirements
- Far-forward area
- Far-backward area
- Summary

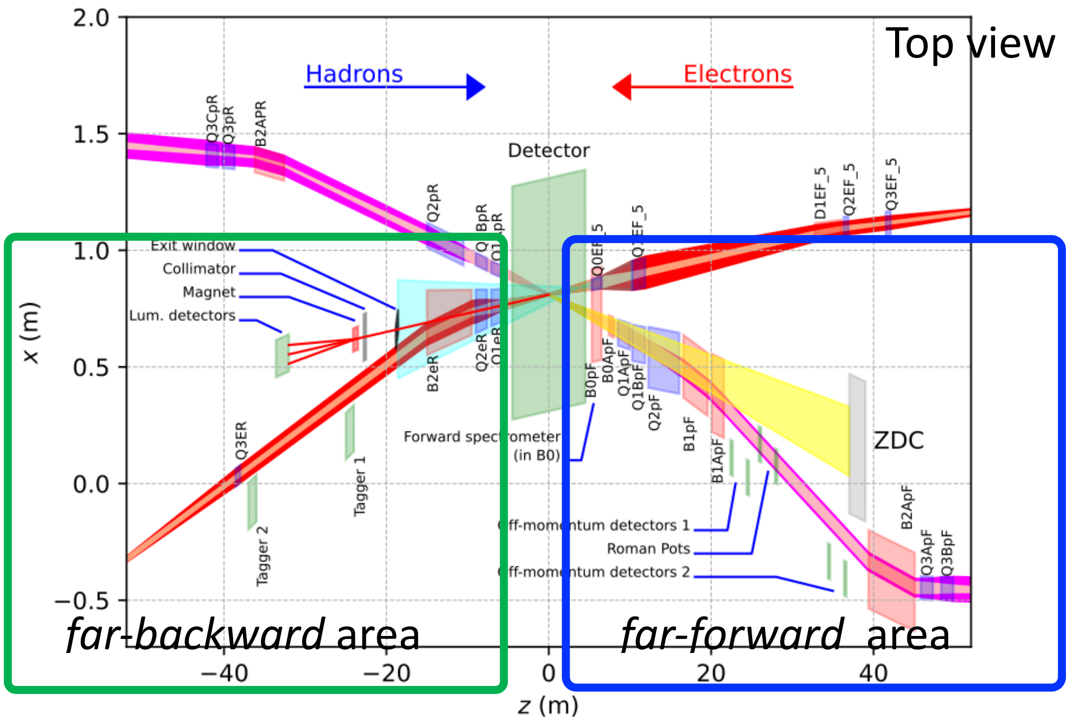
1. Given the detector progress over the last two years and the status of the ePIC detector, are the projected timelines of the Electron-Ion Collider detector feasible? Do there remain significant open detector technology questions?
2. Are the requirements for the detector and their flow down sufficiently comprehensive for this stage of the project to complete the design of the various detector technologies?
3. Are the interfaces between the elements of the design adequately defined for this stage of the project and to proceed with the detector long-lead procurement items?
4. Is the design of these long-lead procurement items sufficiently advanced and mature to start procurement in 2024? Are the technical specifications complete?
5. Is the projected design maturity of the further detector components likely to be accomplished by the end of 2024 for CD-2 and CD-3?
6. Is the overall schedule for completion of the design, production, and installation of detector components realistic?



3D view



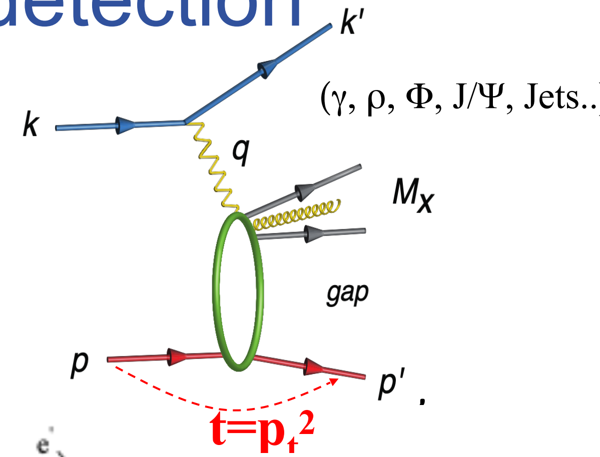
EIC Interaction Region layout (IP6)



- ❑ 9.5 m around the IP is reserved for the *central* detector
- ❑ Crossing angle provides beam separation and space for detector placements
- ❑ Apertures of FFQs and dipoles are designed to allow forward going particles to go through
- ❑ Design should be able to operate at different beam energies and high luminosity

- ❑ F*ar forward* and *far backward* detector components are distributed along the beam line within +/- 50 m
- ❑ We are keeping a full detector integration in sync with the accelerator design from the early stages on
- ❑ In total 7 sub-detectors (12 sub-components) => Maximizing synergies between different sub-detectors as much as possible, but keeping performance

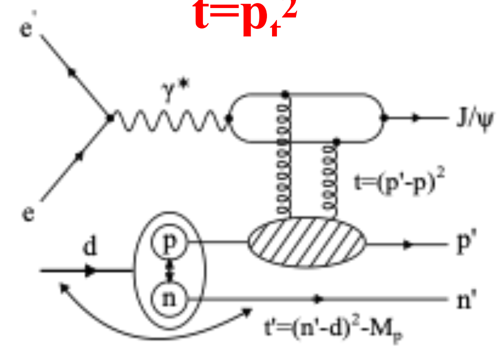
Physics motivation for far-forward detection



Exclusive /diffractive reactions in ep/eA:

- Exclusivity criteria:
  - -> reconstruction of all particles in the final state in a wide coverage in t (~ p_T^2)] (outside of the acceptance of central detector)
  - -> charge and neutral particles
  - -> rapidity gap

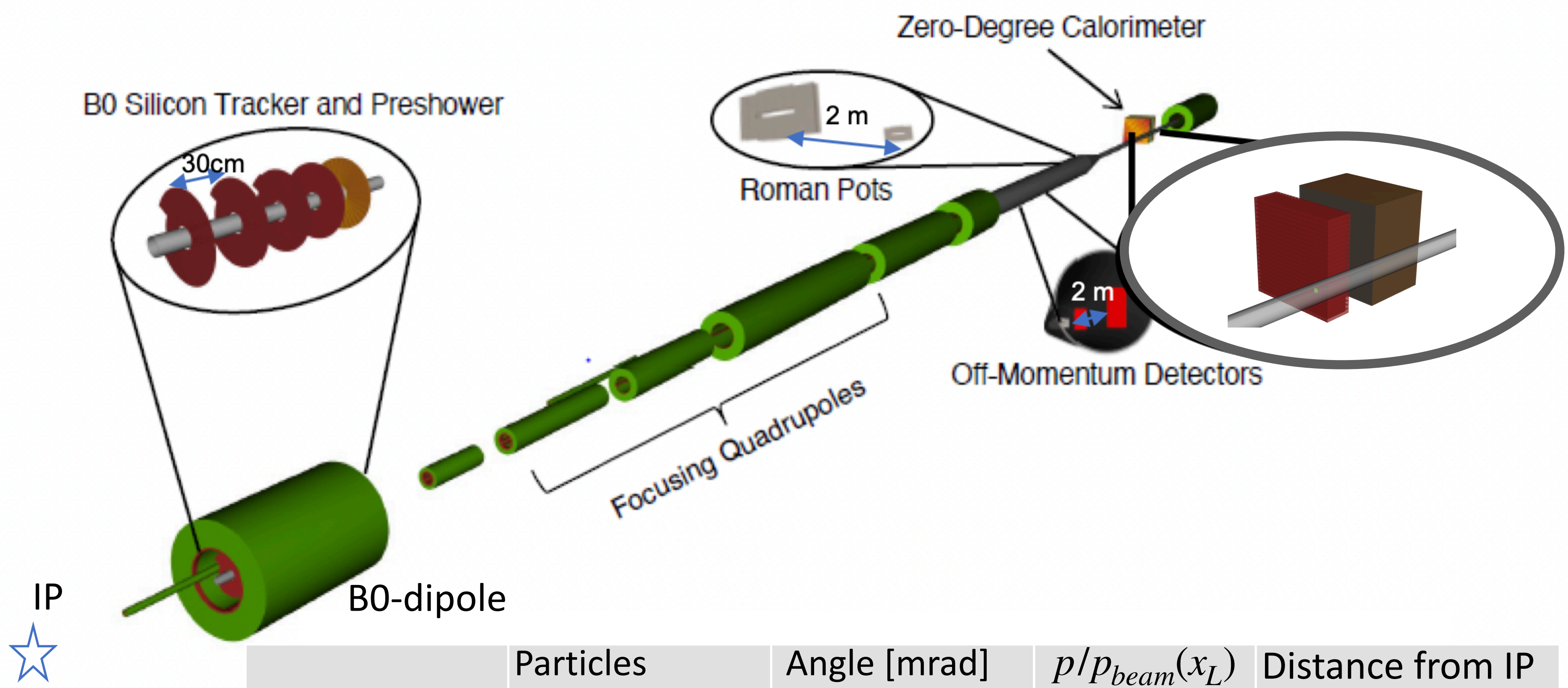
  Note, Central detector coverage $-4 < \eta < 4$ (crossing angle)
- for eA (Ion Species Range p to Uranium)
  - ✓ veto nuclear breakups
  - ✓ neutron and proton tagging
  - ✓ protons with **different rigidity**
  - ✓ **nuclear breakups**.
  - ✓e+Au events with neutron tagging to **veto breakup** and photon acceptance.
  - ➢ Protons that come from nuclear breakup have a different magnetic rigidity than their respective nuclear beam : P/P_{beam} (x_L) <1



- Variable CM energy √s (eN) ~ 20–140 GeV

  p: 40- 275 GeV ,
  e: 5- 18 GeV

Far-Forward detectors (hadron)



	Particles	Angle [mrad]	$p/p_{beam}(x_L)$	Distance from IP
B0-tracker	Charged particles Photons (tagged)	5.5 - 20		ca 6-7 m
Off-momentum	Charged particles	0-5.0	0.4< xL< 0.65	ca 23-25 m
Roman Pots	Protons Light nuclei	$(*) 10\sigma cut$ 0*-5.0	0.6 < xL< 0.95	ca 27-30 m
ZDC	Neutrons Photons	0-4.0 (5.5)		ca 35 m

Detector requirements: RPOT and OMD

Roman-Pots

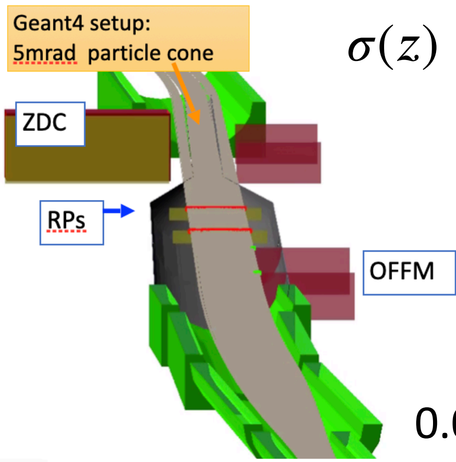
-- small |t| value

$$\sigma(z) = \sqrt{\varepsilon \bullet \beta(z))}$$

$\sigma(z)$ is the Gaussian width of the beam,

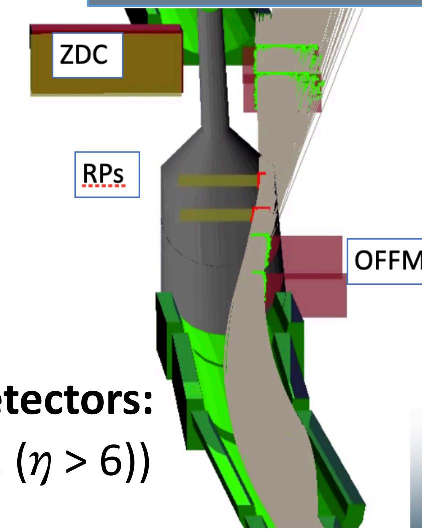
$\beta(z)$ is the RMS transverse beam size.

ε is the emittance.



0.0* ($10\sigma cut$) < θ < 5.0 mrad

- ✓ The Roman-Pots should provide measurements of **charged particles close to the beam core.**
- ✓ **Movable** : as close as 10σ away from the beam; move out during an injection.
- ✓ RPs needs to be **integrated into the vacuum system =>** very close contact with accelerator to avoid negative impacts on the machine operation
- ✓ Insertion from top and bottom - need to minimize amount of material in front of ZDC.
- ✓ Good t-measurements of far-forward charged particles => momentum resolution < 5%, and pT resolution of 5% for pT > 500 MeV/c
- ✓ Must be resistant to extreme background conditions at the levels specified by the simulation studies.



Off-Momentum Detectors:

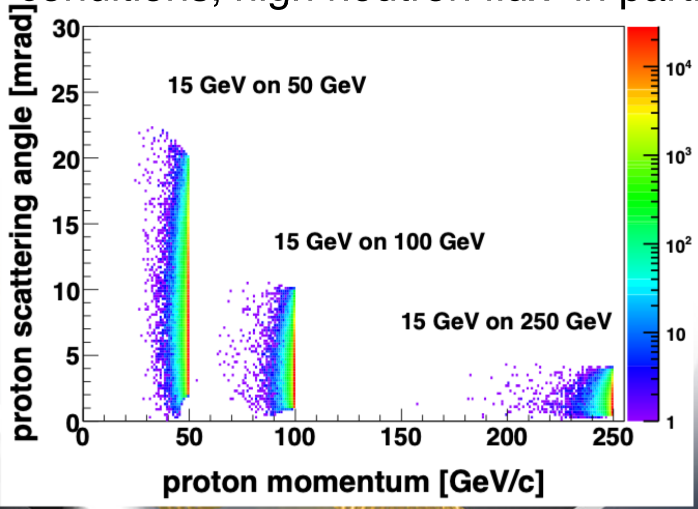
(0.0 < θ < 5.0 mrad, (η > 6))

- ✓ Protons that come from nuclear breakup have a different magnetic rigidity than their respective nuclear beam (x_L<1)
- ✓ This means the protons experience more bending in the dipoles.
- ✓ As a result, small angle (Θ < 5mrad) protons from these events will not make it to the Roman Pots, and will instead exit the beam pipe after the last dipole.
- ✓ Movable, beam pipe integration
- ✓ Detector with sufficient timing and spatial resolution will provide tracking measurements of the charged particles in the hadron-outgoing direction.

Detector requirements: B0 and ZDC

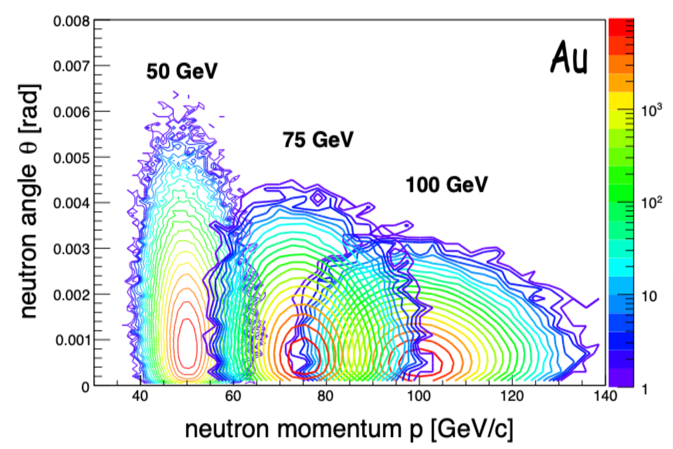
B0-detectors

- ✓ Full p_T coverage for forward-going protons is critical for EIC physics. High p_T-acceptance in RPOTs is limited by magnet's apertures . => B0 detectors . Especially important for low-energy operation
- ✓ B0-system shall provide theta coverage in the range **5.5 < θ < 20.0 mrad** (4.6 < η < 5.9) with respect to the hadron beam line.
- ✓ Need to provide measurements of forward photons and pi0: $\gamma + \gamma$ from π^0 separation to clearly isolate u-channel DVCS
- ✓ Must be resistant to extreme background conditions, high neutron flux in particular



ZDC

- ✓ The Zero Degree Calorimeter should provide measurements of neutral particles (**neutrons and photons**).
- ✓ need **+/- 4 mrad** coverage => beam element free cone before the zero degree calorimeter to detect the breakup neutrons from heavy Ions
- ✓ For neutrons: provide good angular resolution and energy measurements (<50%/$\sqrt{E}$+5%)
- ✓ For photons: provide photon measurements down to 100 MeV.



Far-forward: participating institutions

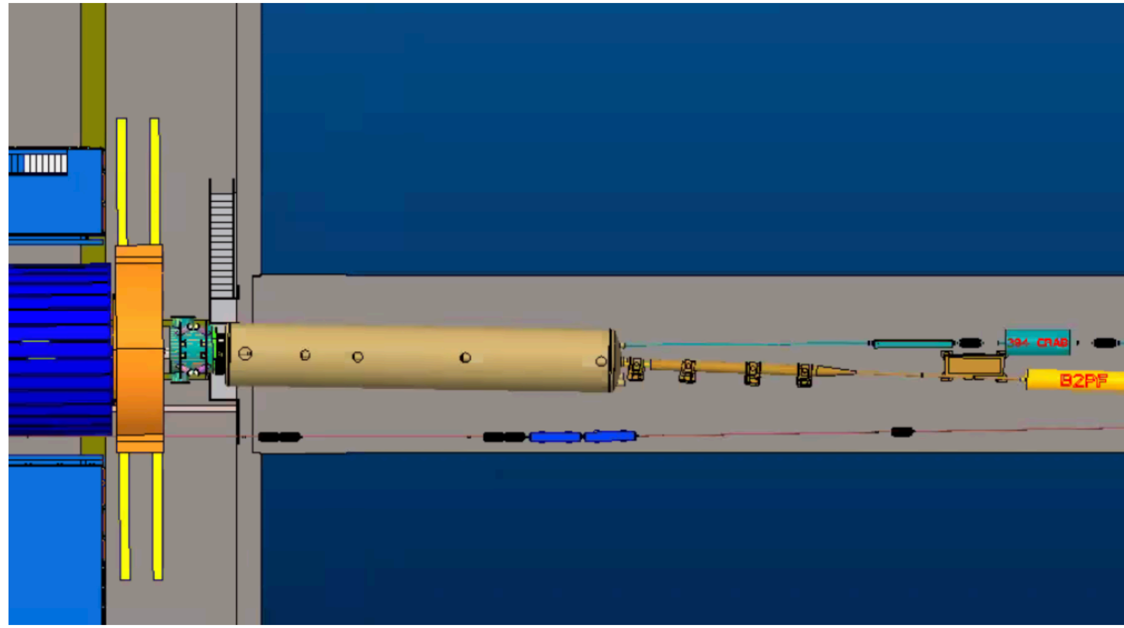
B0 tracker

Tel Aviv University, Israel

Hebrew University of Jerusalem, Israel

B0 calorimeter

Ben Gurion University of the Negev, Israel



ZDC

Riken, Japan

Kobe, Japan

Kansas university, USA

PNNL, USA

also recently joined Uni's from Taiwan and South Korea

RomanPots and OMD

AC-LGAD consortium :
BNL, USA
IJCLab - Orsay, France
OMEGA , France
IRFU/CEA-Saclay, France

Roman Pots/OMDs

- **Technology**: AC-LGADs

Total size 25.6cm x 12.8 cm

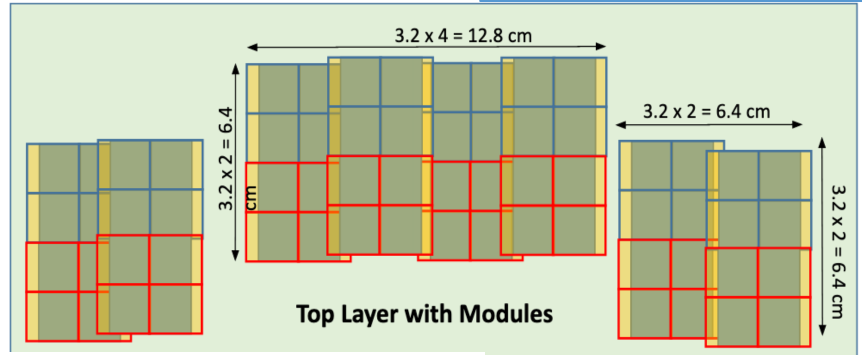
Si sensor 3.2 cm x3.2 cm, 500 μm (pixel pitch)
and with charge-sharing can achieve spatial resolution < 20um per hit .
Timing resolution < 35ps

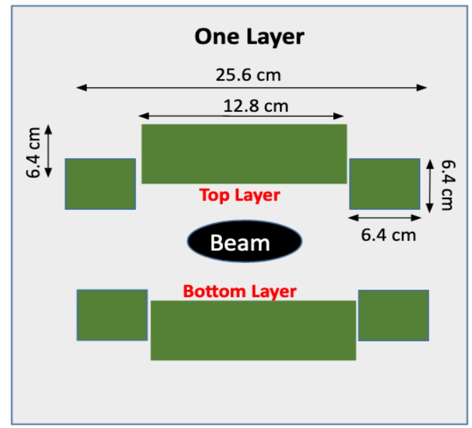
Placement: as close as 10-sigma (1 sigma ~1mm)

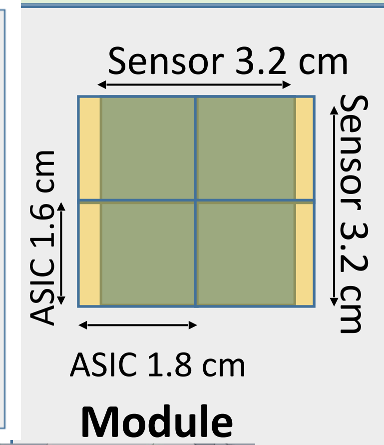
- **Readout:** ASIC readout chip EICROC (ALTIROC) for use with AC-LGADs -> R&D

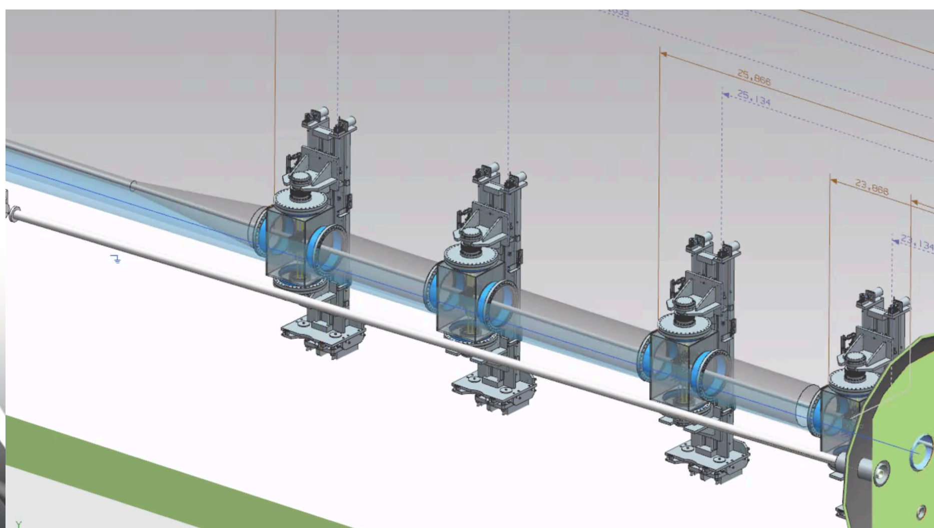
for each Si-pad 4 ASICS 1.6cm x1.8 cm

- **Support structure** and integration : close contact with vacuum and accelerator teams



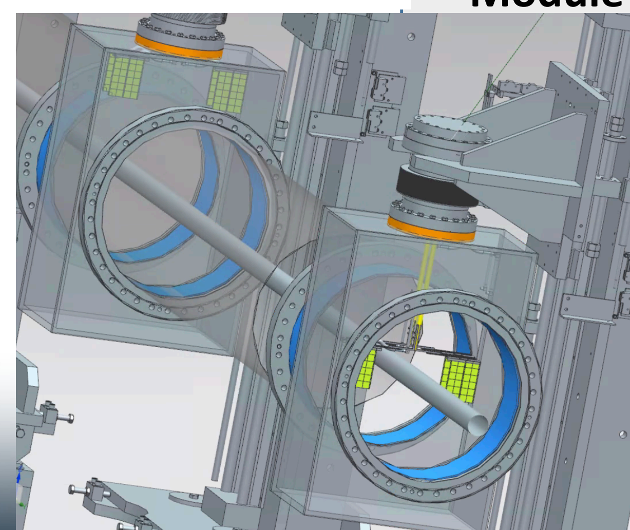






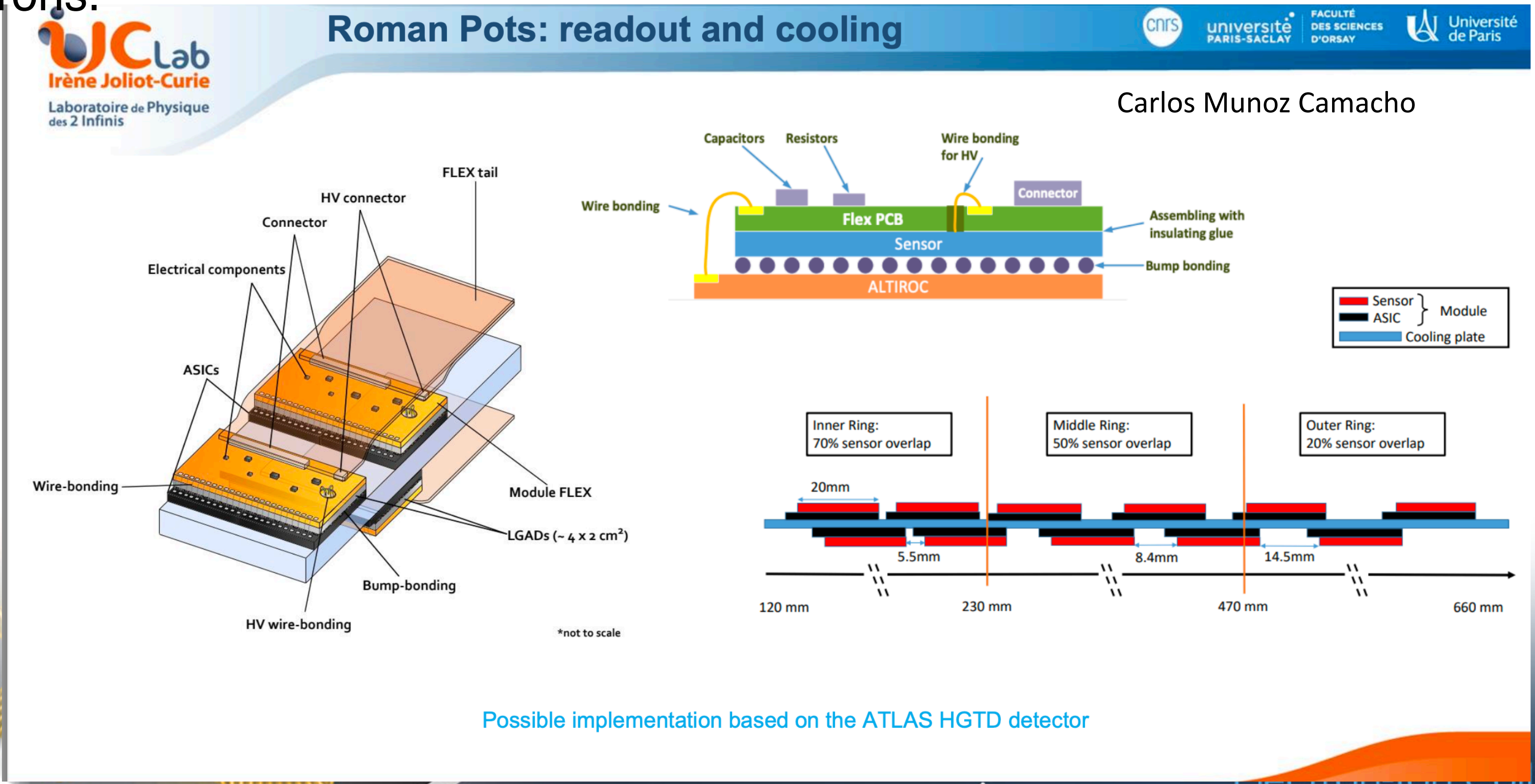
RP/OMD Location: z= 23-30m

IP

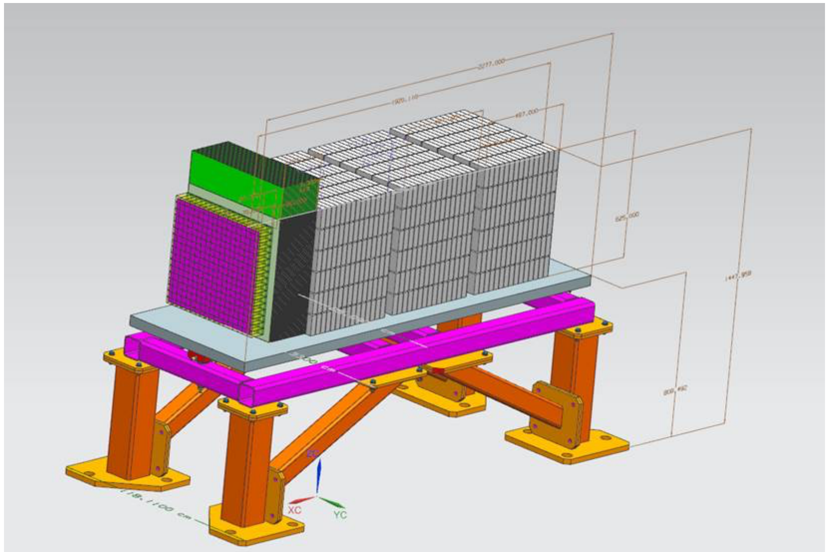


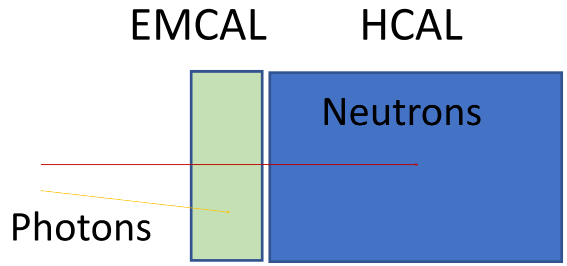
Roman Pots: readout, cooling, integration

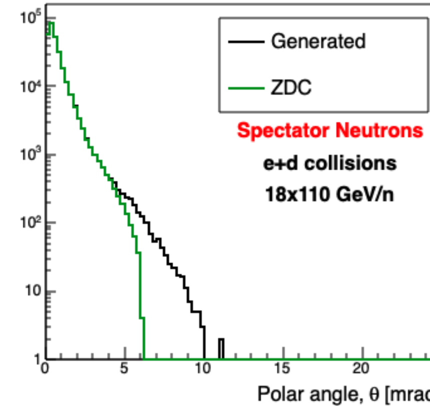
- The Roman pots need cooling of ~100 Watts per active layer, while the OMD needs about 40% less.
- Preliminary concept of the readout and cooling, based on the ATLAS HGTD (R&D)
- Conductive cooling using thin copper strips couple to LN2 exchanger.
- RF -shielding, impact on the accelerator - it is an iterative process , in collaboration with accelerator and vacuum team .
- Exit window for the neutron cone -> minimize an amount of material on the way of neutrons.



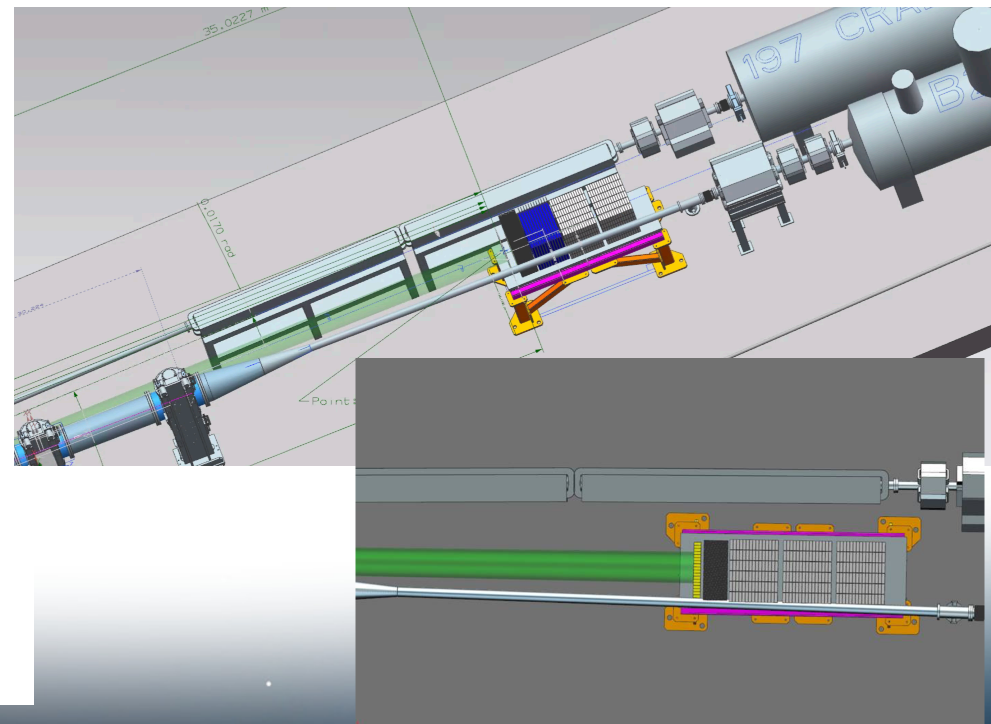
ZDC layout







ZDC integration with accelerator lattice
z-location 34m,
stay-clear zone (ca 2-3cm) around the hadron beam-pipe



Technology (*)
VETO: Si -layer in front for charged particle veto
EMCAL :

- PbWO4 crystals blocks
- W/Si sampling calorimeter (imaging calorimeter)

HCAL:

- Pb/Sci. sampling calorimeter.

(*) Note: Value engineering ongoing to reduce cost and risk but maintain performance, Synergies with other sub-detectors.

ZDC technology

(*)Value engineering ongoing to reduce cost and risk but maintain performance

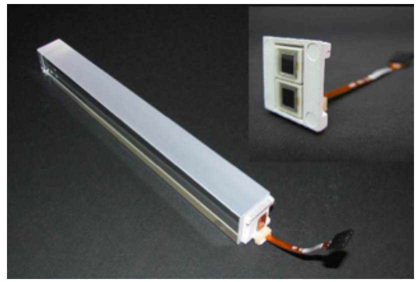
ZDC-EMCAL (~8X0)

- PbWO4 with 2 APD for the readout (default configuration)

Single tower: 3cmx3cmx7cm

total size 56cm x54cm

- Evaluation of radiation hardness.



W/Si sampling calorimeter (~22X0)

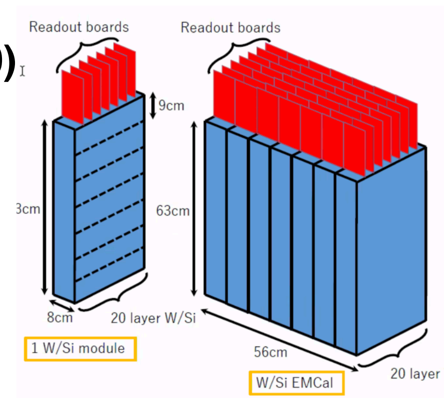
✓Similar to ALICE FoCAL

✓ Tungsten plates: W alloy 3.5mm

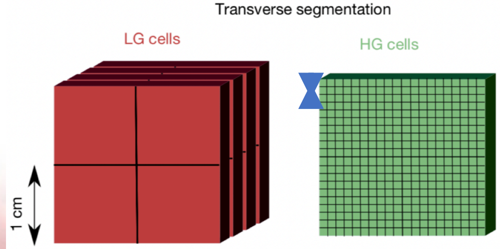
✓Low Granularity (LG) Si pads (1cm x1cm and 320 um thick) , High granularity (HG) Si pads (3mm x 3mm and 300 um thick)

✓Each tower - 20 layers, One module - 7 towers , 7 modules in total (56 cm x 63 cm)

✓HGCROC readout



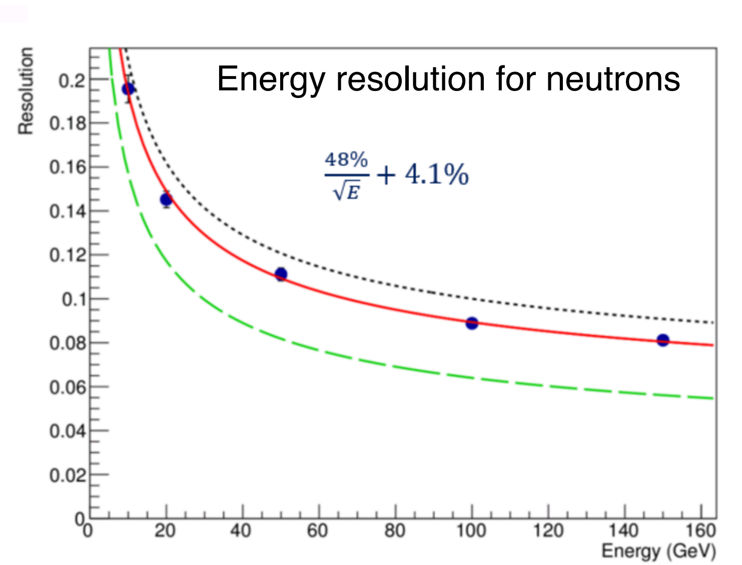
Transverse segmentation



HCAL: Pb/Sci sampling calorimeter (~7.5λ)

✓Lead (Pb) - 3cm , Scintillator - 2 mm
Segmented : towers 10cm x10 cm
For one station (3 in total)
Total towers: 6x6 = 36 towers each with 15 layers

✓Readout under evaluation
APD (15 layers are readout together)



B0-detectors

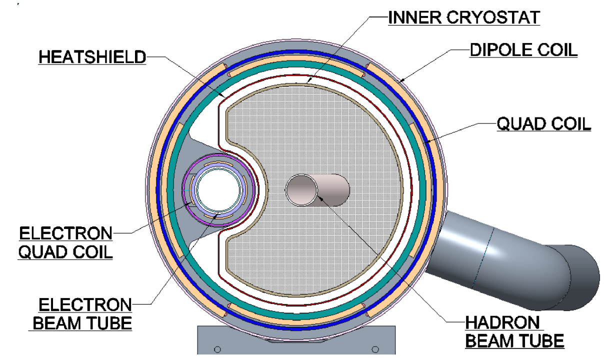
- ✓ **B0-dipole:** length is ca 1.5m, field 1.3T for momentum reconstruction, ~20cm inner bore (design is on the way)

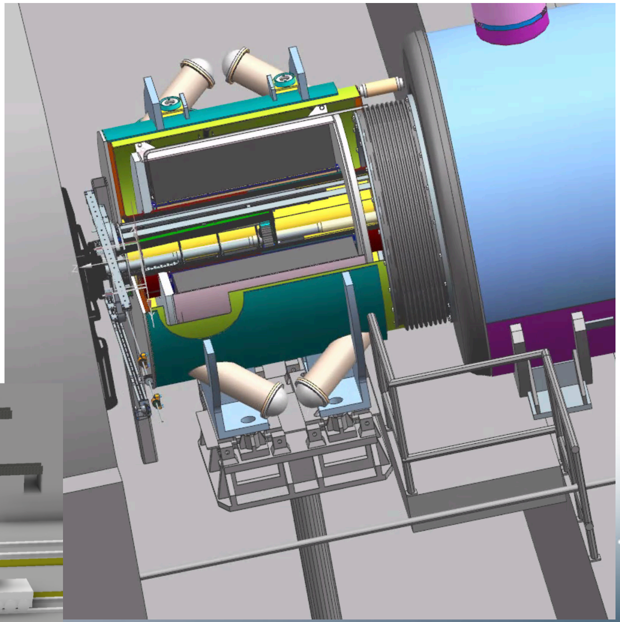
- ✓ **B0 placement** - after HCAL
  - ➡ Limited space:access to B0-detectors only from one side (after opening HCAL) ~ 15cm
  - ➡ Beams are separation into two independent beam-pipes in front of B0, Vacuum pumps
  - ➡ Beam-pipes: crossing angle

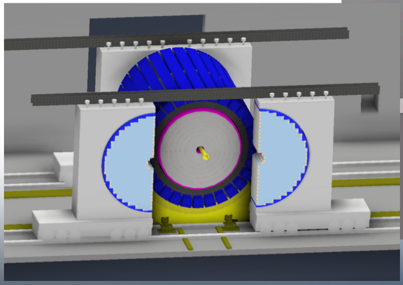
- ✓ **Tracker for charged particles** : Currently considering all layers of AC-LGADs (pixels)
  - ➡ synergies with other detectors(RPs, etc)
  - ➡ evaluation the use of other technologies (Timepix, AstroPix, etc)

- ✓ **Calorimeter:** $PbWO_4$ 2x2x7 cm^3 - synergies with bEMCAL

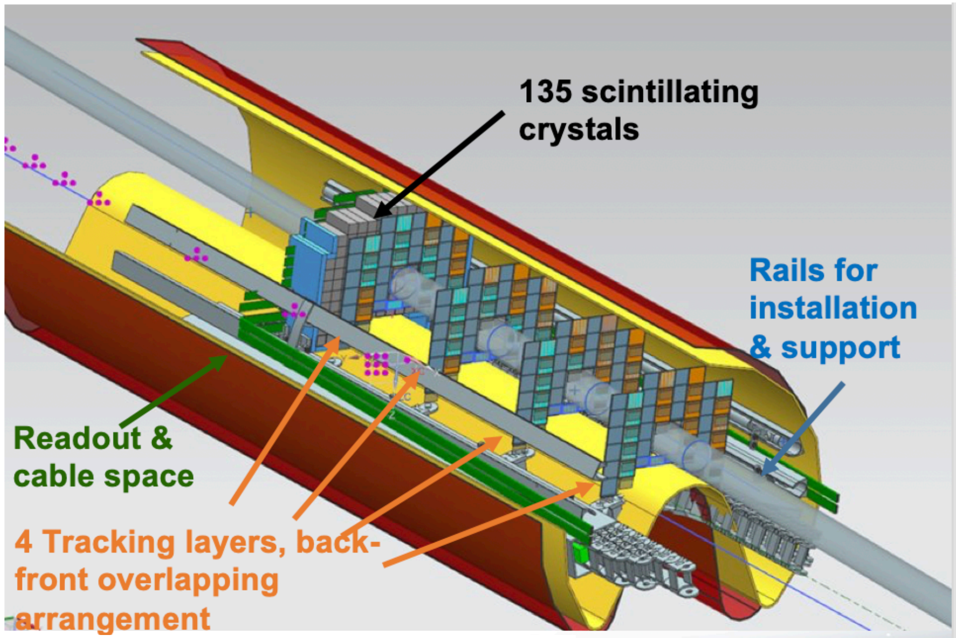
- Create zero field line at electron beam axis.
- Warm space for detector package insert located inside a vacuum vessel to isolate from insulating vacuum.



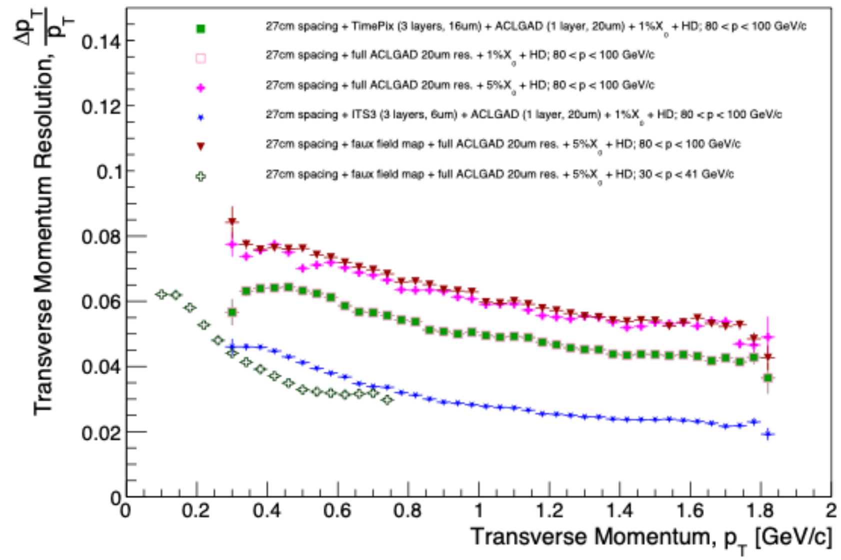


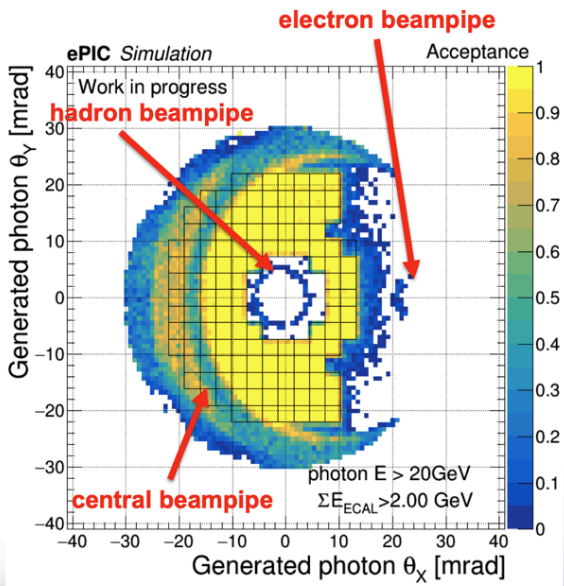


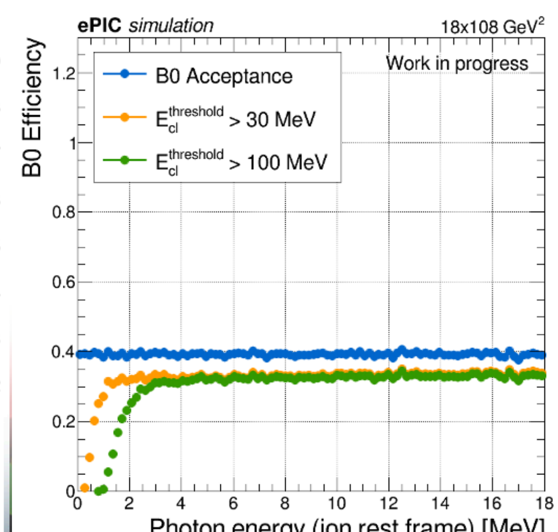
B0-detectors



Tracker: momentum resolution (dp/p) is ~2-4%, depending on configuration.





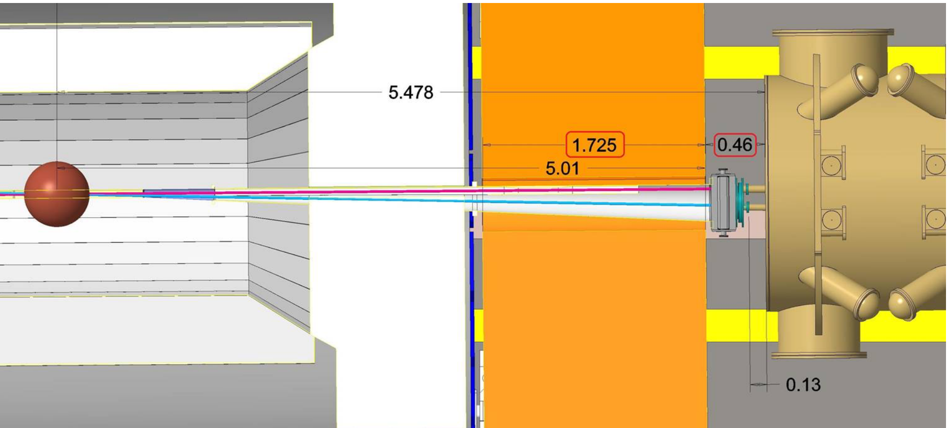


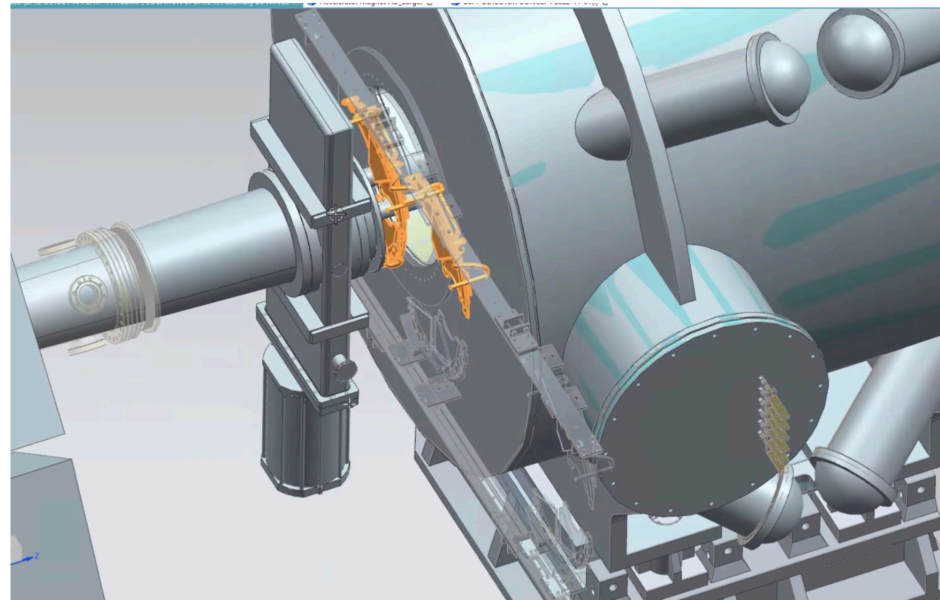
For photons:

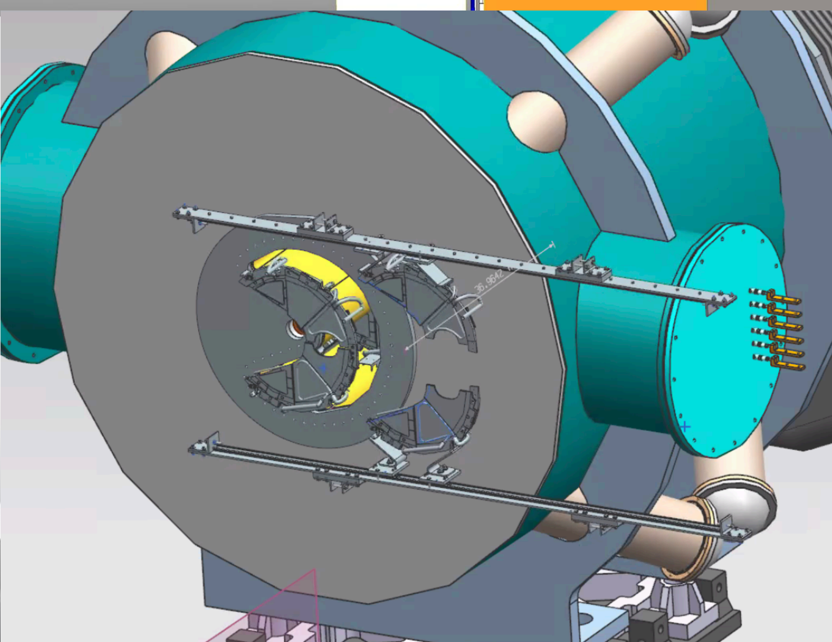
- ➢High acceptance in a broad energy range (> 100s MeV), including ~MeV de-excitation photons
- ➢Energy resolution of 6-7%
- ➢Position resolution of ~3 mm

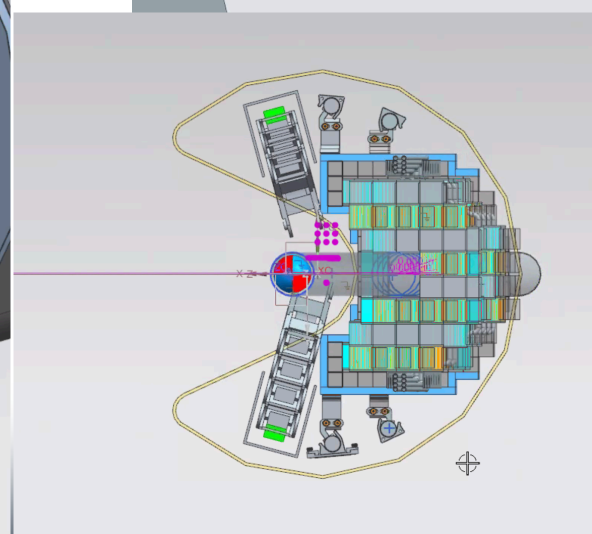
B0-detectors: integration

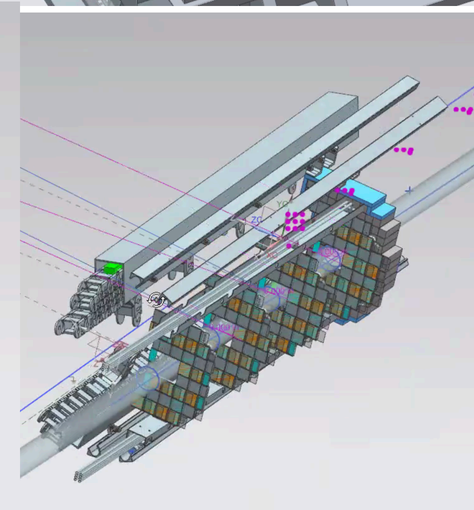
- Mechanical integration/installation
- Cooling/cabling



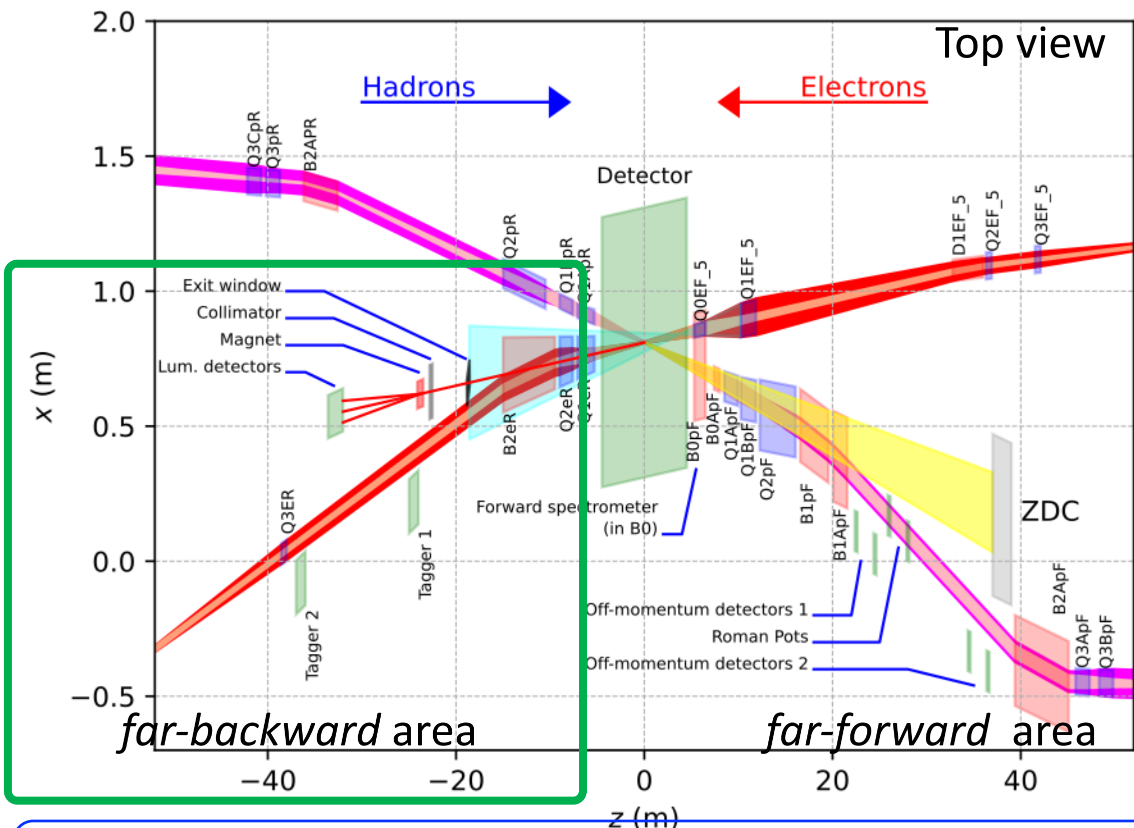


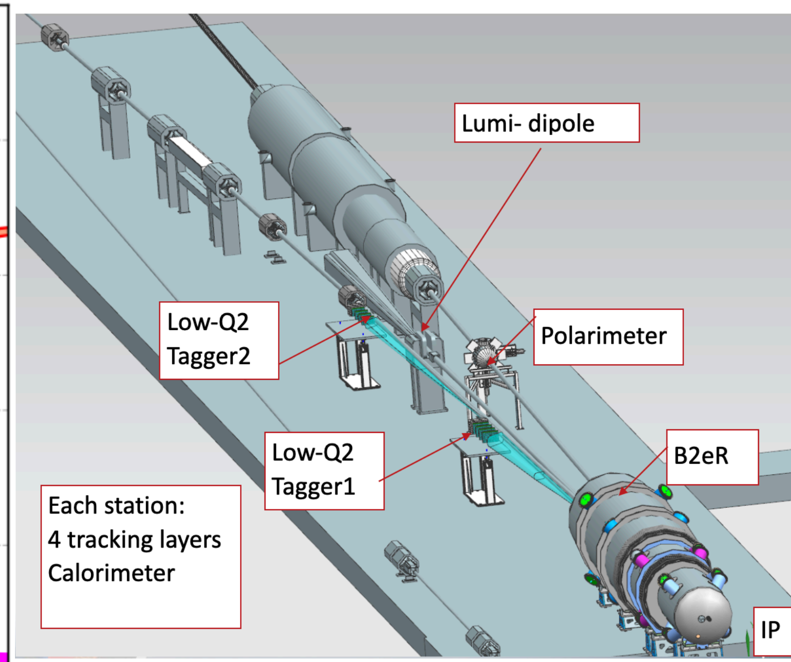






Far-backward (electron-going) region



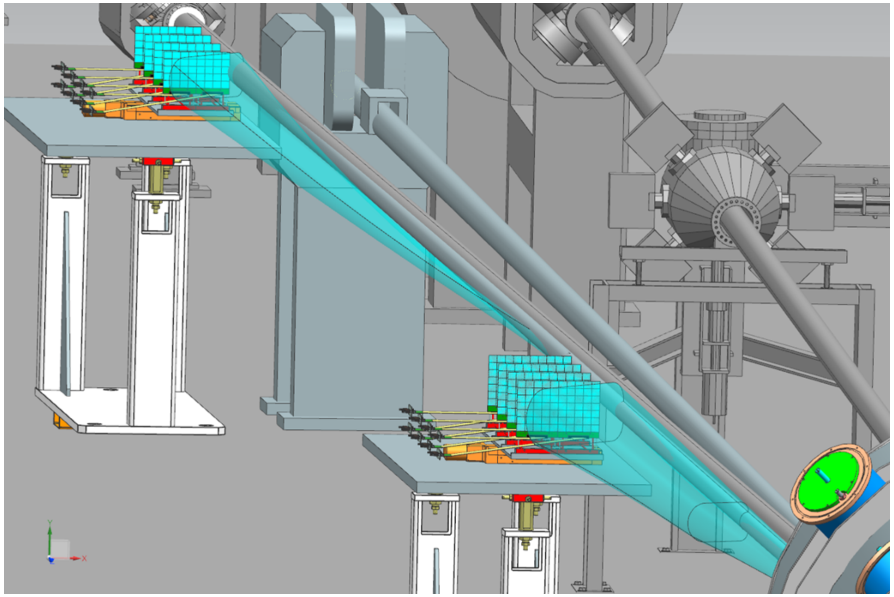


- This area is designed to provide coverage for the low-Q² events (photoproduction, $Q^2 < \sim 1GeV^2$) . Need to measure a scattered electron position/angle and energy

- And luminosity detector (ep -> e'pγ bremsstrahlung photons)

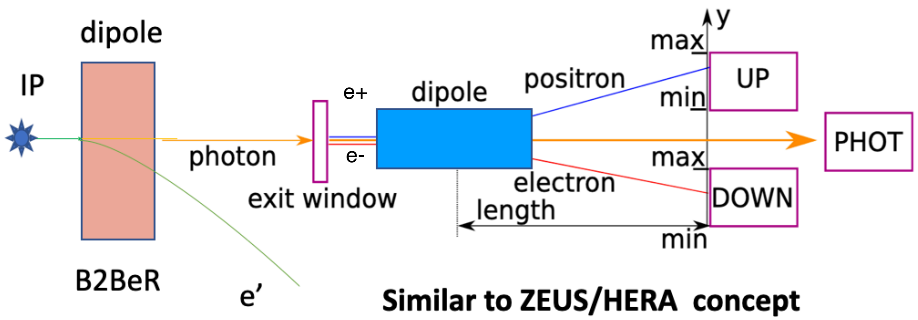
Low-Q2 tagger: requirements

- ✓The Low- Q^2 detectors need to measure the energy and position of the scattering electrons with Q^2 below 1 GeV^2 in the far-backward directions.
- ✓The acceptance for the low- Q^2 tagger should complement the central detector to reach the coverage close to the limit given by the divergence of the beam.
- ✓LowQ2 system must operate at a full projected EIC luminosity and must be resistant to extreme background conditions (synchrotron radiation, bremsstrahlung)
- ✓Should have a capability to handle high rate

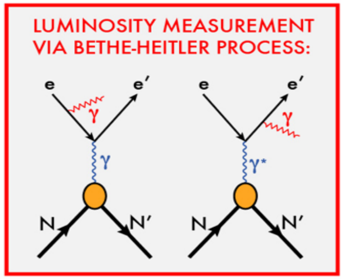


Luminosity system: requirements

Charge Question #2



- Luminosity measurements via Bethe-Heitler process
- Photons from IP collinear to e-beam
- First dipole bends electrons
- Photon conversion to e-/e+ pair
- Pair-spectrometer / direct photon calorimeter



✓ To measure integrated luminosity with precision δL/L< 1%

pair spectrometer:

- Low rate (due to conversion)
- High precision measurement for physics analysis
- The calorimeters are outside of the primary synchrotron radiation fan

zero degree photon calorimeter

- high rate
- Fast feedback for machine tuning
- measured energy proportional to # photons
- subject to synchrotron radiation

Far-backward: participating institutions

Low-Q2 tagger - tracker :

Glasgow, UK — Prague, CZ
W&M, USA

Low-Q2 tagger - calorimeter :

York, UK — Prague, CZ
Temple, USA

Lumi - photon calorimeter:

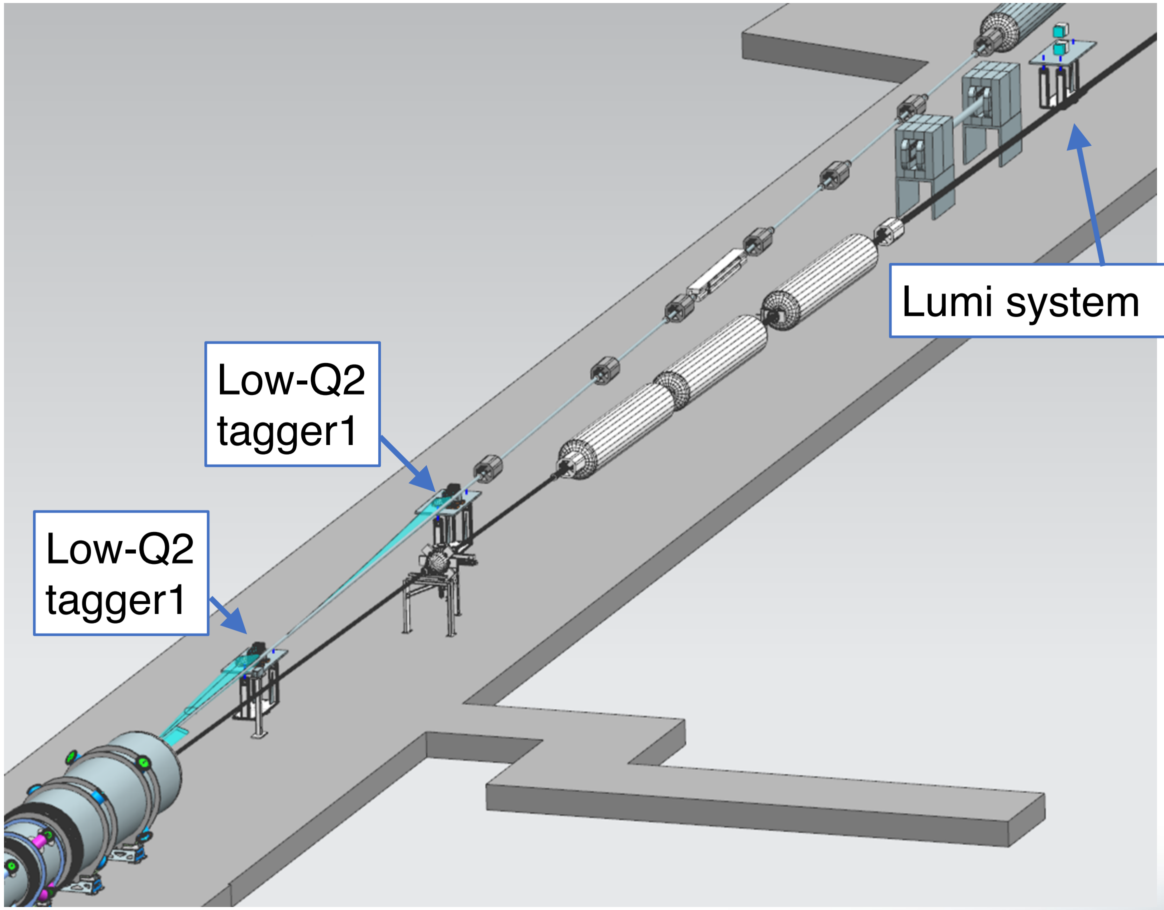
Kraków, Poland — Prague, CZ
York, UK

Lumi - pair-spectrometer:

York, UK — Prague, CZ
Houston, USA

Lumi - pair-spectrometer tracker:

under study, if needed JLAB/BNL



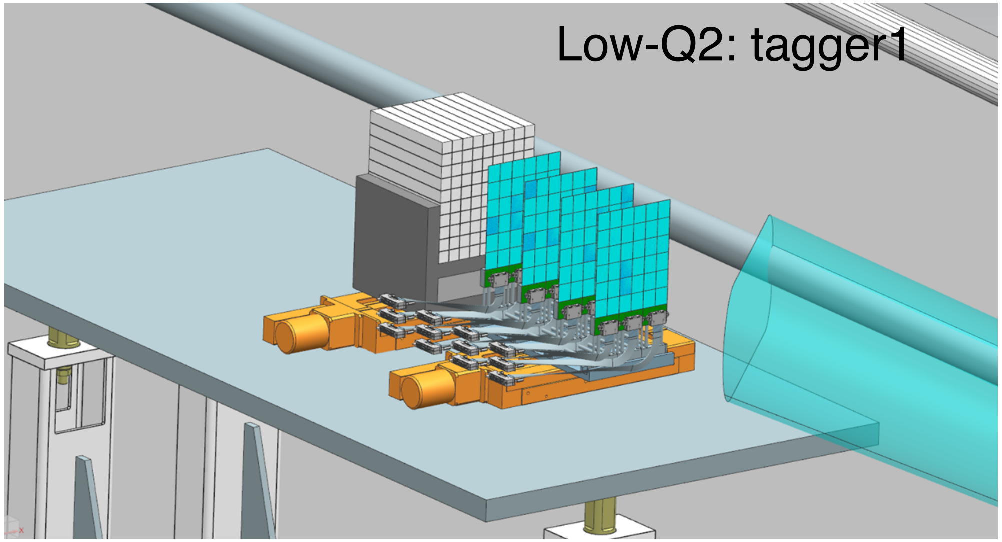
Low-Q2 taggers

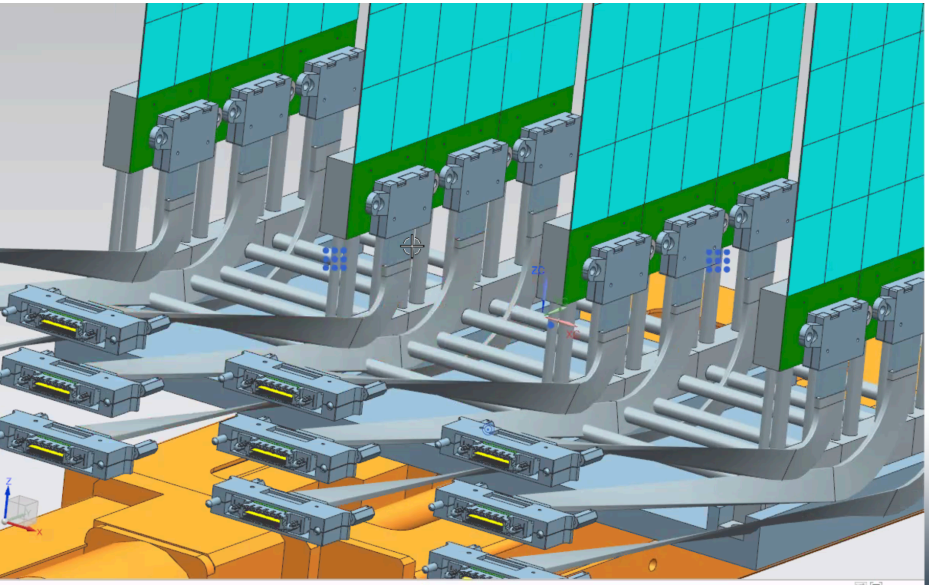
- Two tagger stations with 4 Si-stations 30 cm apart and a calorimeter behind.

Tracker: Timepix technology

- Good timing (~200ps)
- Rate capability is very high ~20kHz per 55um pixel , 10ns shaping time

Calorimeter: $PbWO_4$ (or similar to PS-lumi) — allows essential cross calibration of tracker and luminosity system during low current runs





- CAD layout with dimensions are based on the actual Timepix module design
- Cables and cooling pipes are included
- Support stand and movable station for position adjustments
- Placement : outside of the primary vacuum But Timepix is designed to operate under 10-6mbar vacuum => working on possible setup with detector sitting in the secondary vacuum to minimize the material in front.

Low-Q2: performance and background

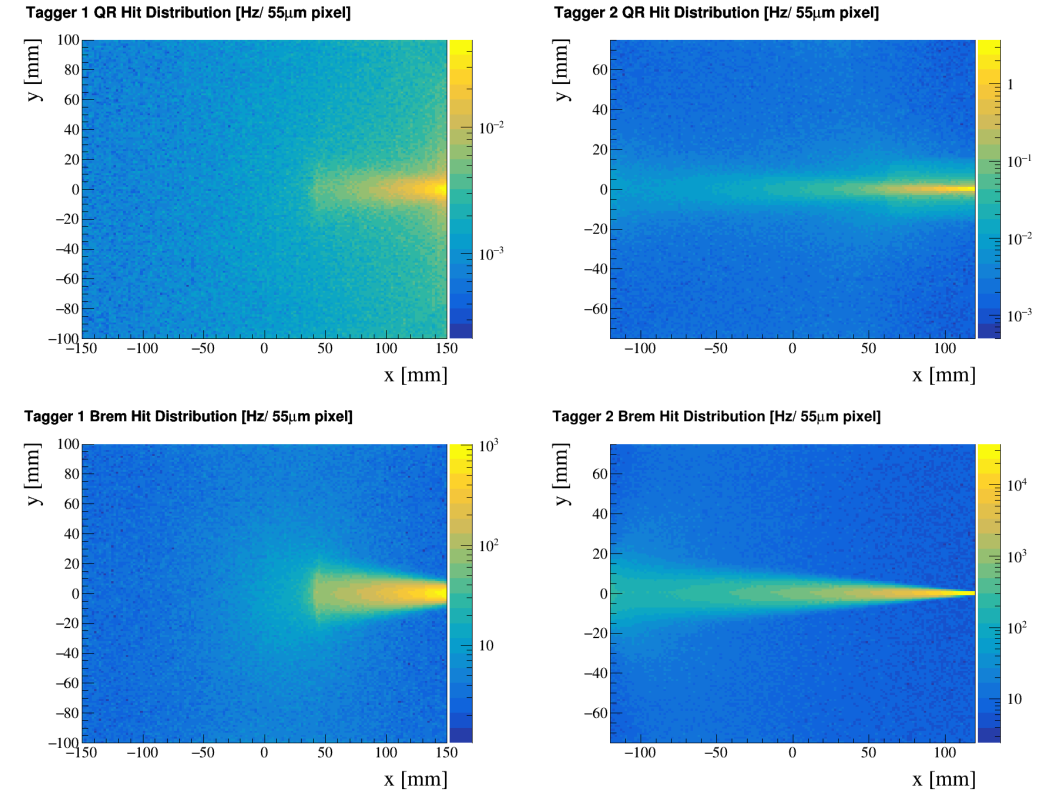
- Energy (dipole), angle => need good position resolution => detector granularity
- Beam smearing (angular, energy) are included into the simulation ; Multiple scattering (exit window)
- Location => minimize a gap between central detector & LowQ2 taggers

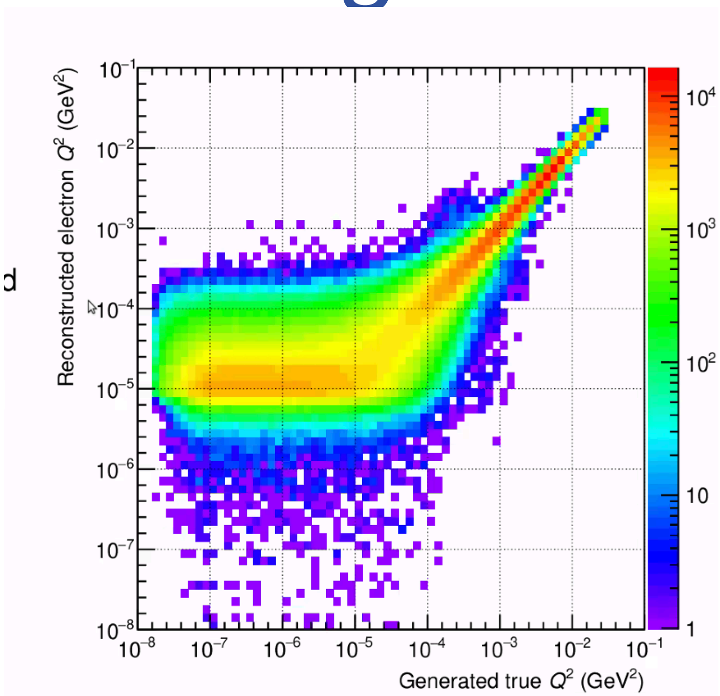
TAGGER 1

TAGGER 2

Quasi-real

Bremsstrahlung





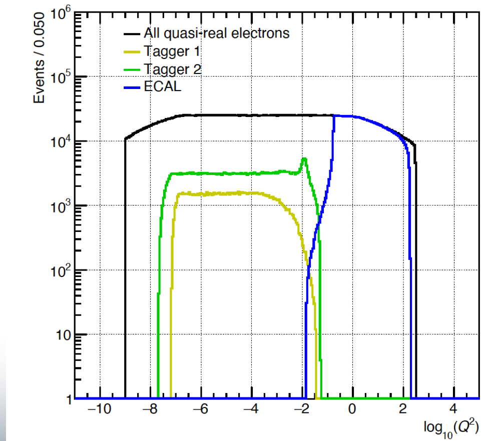


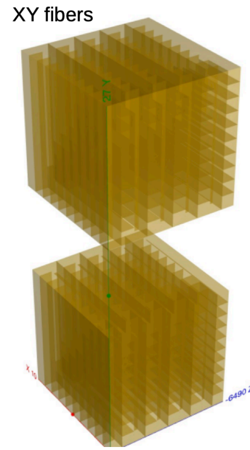
FIG. 16: Coverage in Q^2 for tagger detectors and ECAL.

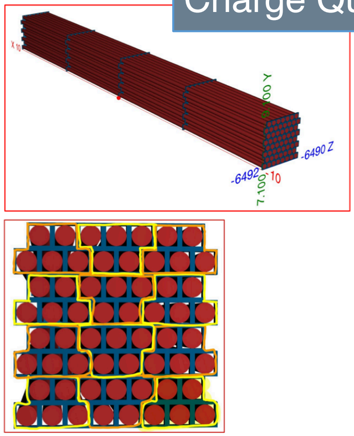
Luminosity monitor

Value engineering on the technology choice is ongoing (synergies with other sub-detectors)

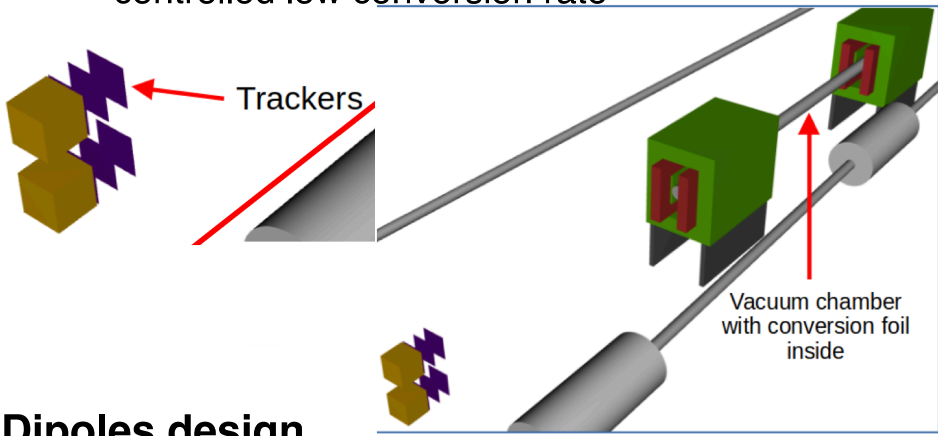
✓**Pair-Spectrometer Calorimeter**

- ➡Technology: W-powder + epoxy infused into a bundle of scintillating fibers (like fECAL).
- ➡Total size 20cmx20cmx20cm
- ➡Module size 2x2x20cm^3
- ➡Fibers- radius 0.1cm
- ➡Five closes fivers are bundled to form a single readout channel





✓ recent design optimization: split second dipole in two: sweeper and analyzed dipoles- allows a controlled low conversion rate

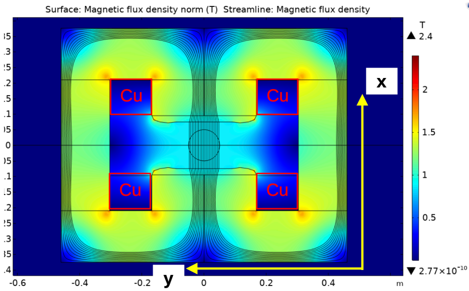


✓**Pair-Spectrometer tracker**

- ➡ Timepix,AC-LGAD, micto-strips,Astropix…
- ➡Benefits from Tracking Planes in front of CALs:
  - Enables standalone detector calibration
  - Better energy resolutions compared to CALs.
  - Well defined acceptance, no "fuzzy" edges as with CALs.
  - Pile-up easily identified and treated.
  - Tracks allow rejection of background particles (beam-gas) and assessments of the electron beam divergence.

Dipoles design properties:

- ✓1.2m long with field reaching about 0.8T
- ✓15cm bore diameter
- ✓Fringe field at electron beam pipe < 4 Gauss



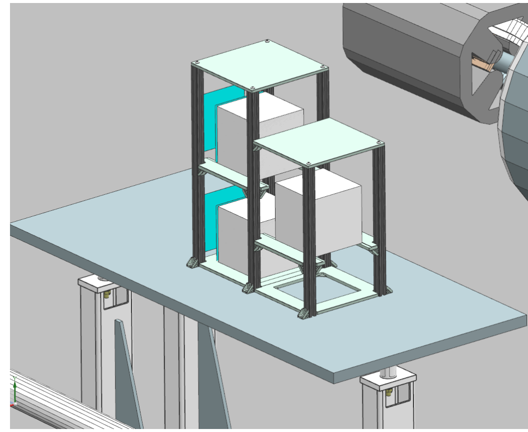
Luminosity monitor: High rate photon Calorimeter

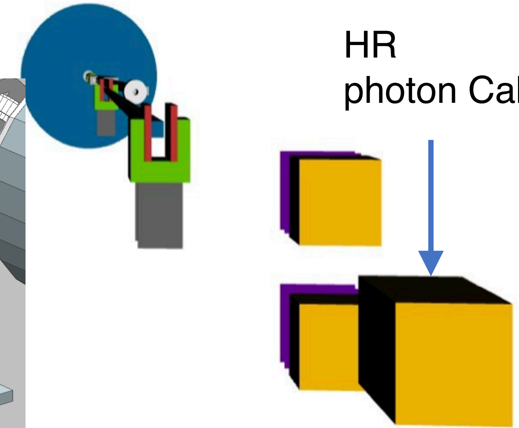
Direct bremsstrahlung photons measurements can provide very simple and precise EIC luminosity measurements: almost 100% acceptance.

Base-line HRC detector choice:

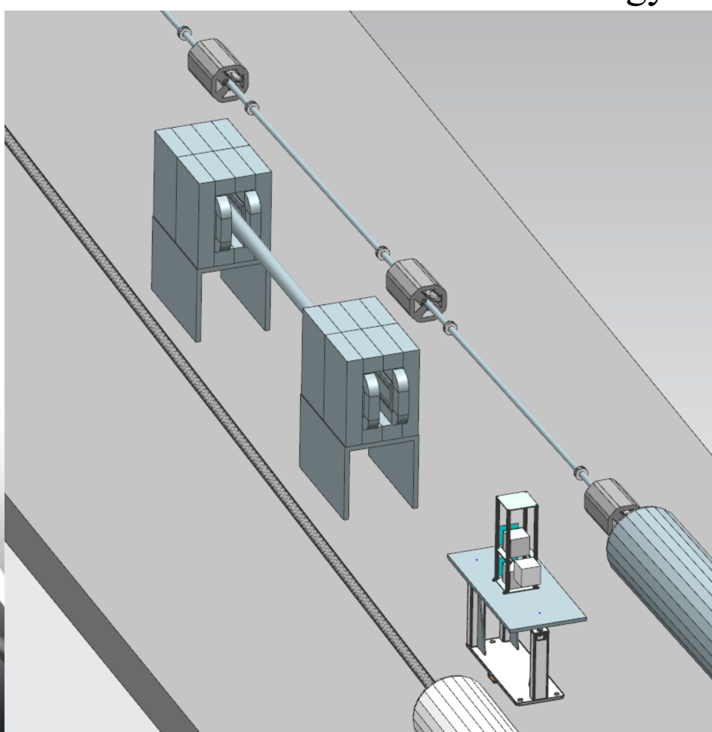
1. **Quartz fiber/tungsten spaghetti** calorimeter for energy flow – maximal **radiation hardness**

2. **Sci fiber/tungsten spaghetti** calorimeter for single photon measurements – maximal **energy resolution**

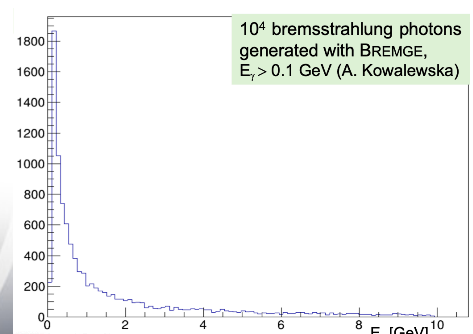


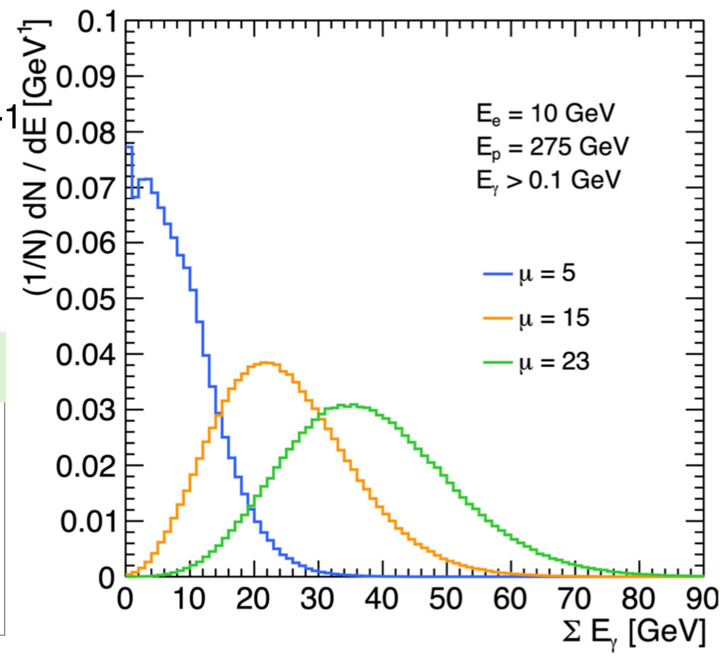


Baseline choice still under consideration due to high rates for eA and high synchrotron load → balance radiation hardness with energy resolution

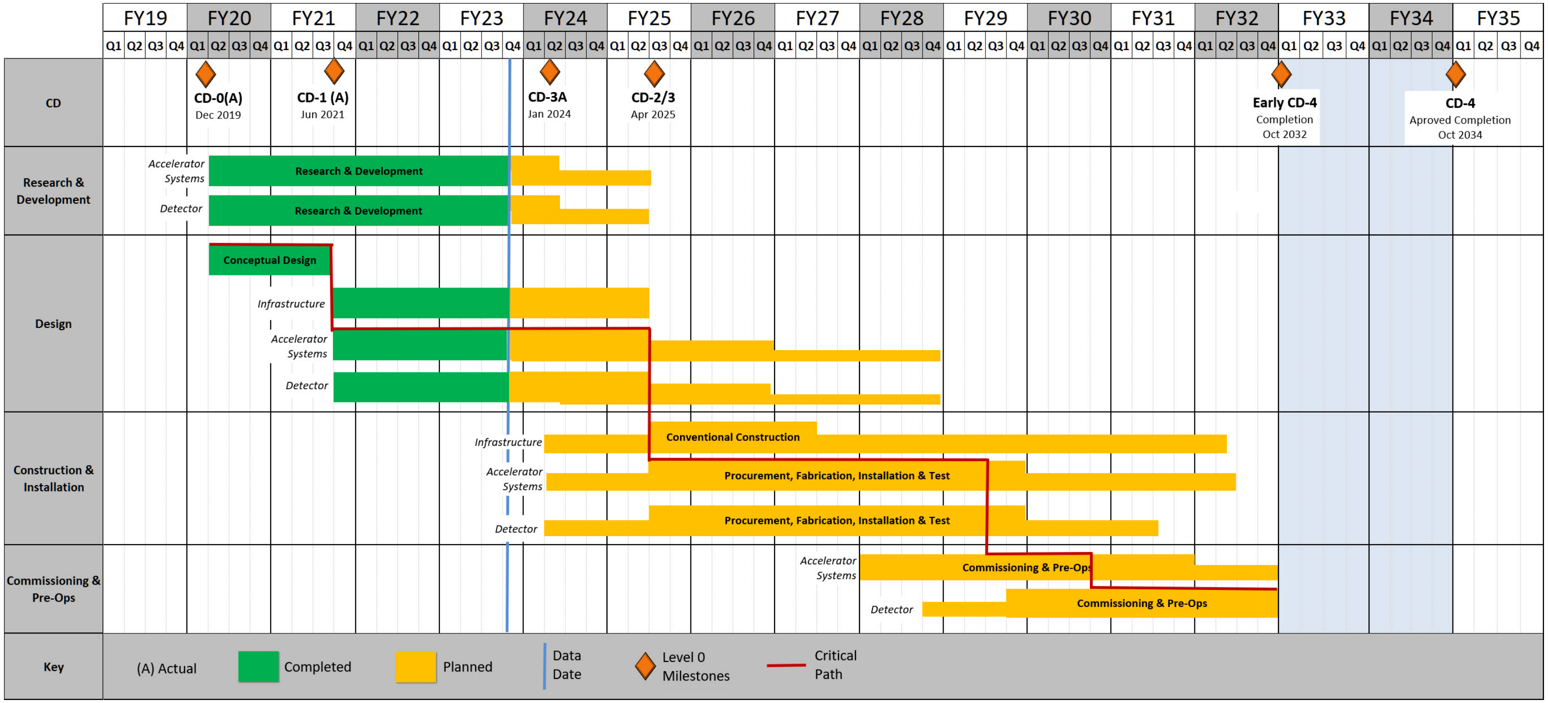


At nominal L = 10^34 cm-2s-1 about 23 hard photons on average will be emitted for each bunch crossing





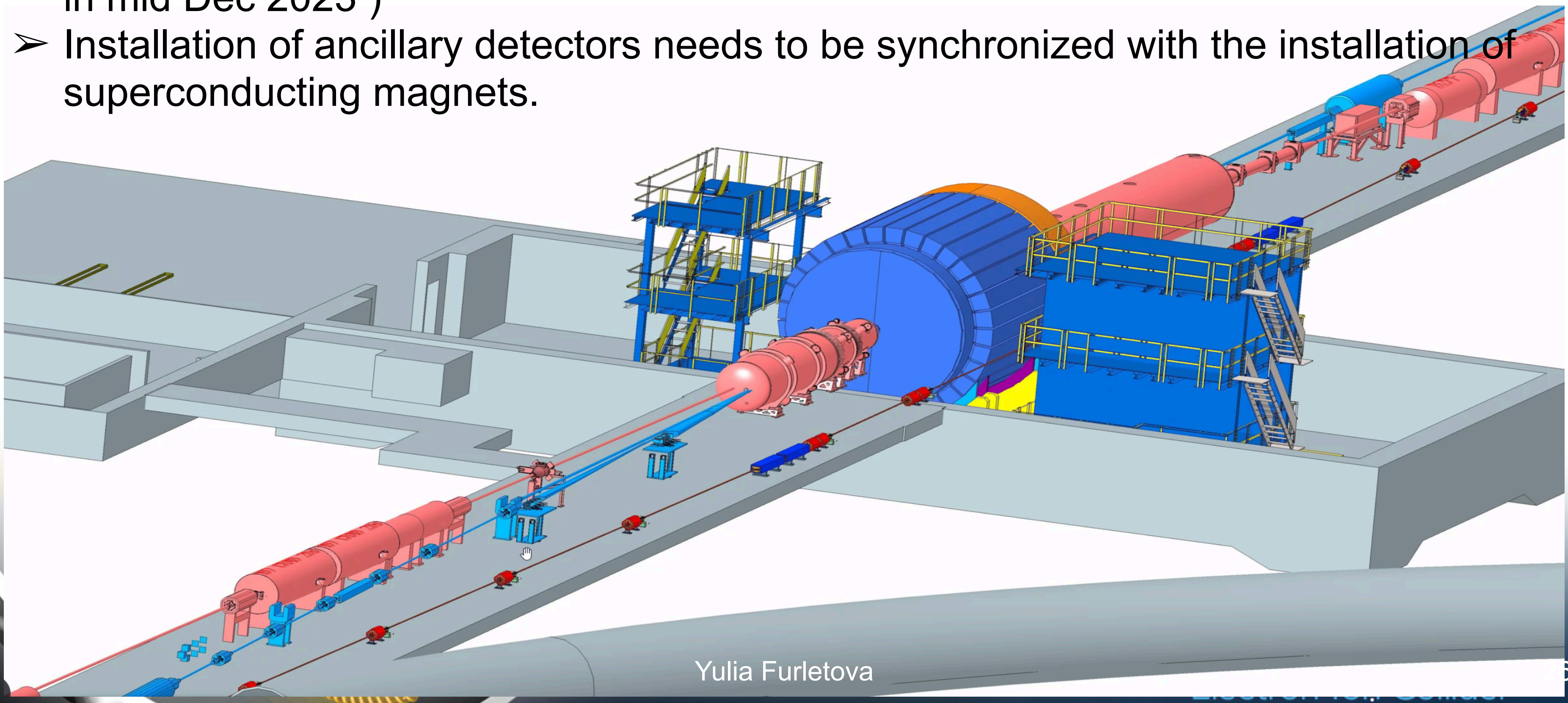
Timeline



- ➢ Preliminary design review of ANC detectors in mid Dec 2023
- ➢ The installation of far-forward equipment is at later stage and synchronized with commissioning activities. All scattering chambers that house detectors will be installed from the start of pre-ops. The detector packages will be installed later, after achieving a stable operation of the accelerator
- ➢ Luminosity detectors has to be at start of pre-ops.
- ➢ Working on the interface and requirements documents (see example in backup)

Summary

- ➢ Physics requirements drive the design of Far-forward and Far-backward regions and the current configuration satisfies the requirements.
- ➢ The detailed detector layout and configuration are driven by the ongoing EIC community efforts and will be further improved.
- ➢ Keeping a close contact with accelerator group
- ➢ Work on the detector support structure, services, detector installation and maintenance (CAD) is ongoing and approaching preliminary design level (review in mid Dec 2023)
- ➢ Installation of ancillary detectors needs to be synchronized with the installation of superconducting magnets.



Backup

Interface document- example for Low-Q2

Type	*RelatedSystemID*	*InterfaceName*	Description
COOL	DET-INF-COOL	Process Cooling	Either a liquid or gas cooling system will be required to remove heat from the calorimeter, tracking and readout electronics, to maintain them at room temperature.
ELEC	DET-ELEC	Low Voltage	The detector will receive DC power provided by the Detector Electronics group.
ELEC	DET-ELEC	Bias Voltage	The detector will receive DC power provided by the Detector Electronics group to support electronics.
ELEC	DET-ELEC	High Voltage	The detector will receive DC power provided by the Detector Electronics group to support silicon sensors and calorimeter.
CONTROL	DET-COMP-ONLINE	Slow Controls	Network connection from the DAQ system to the detector's slow controls interface.
DATA	DET-COMP-ONLINE	Data Transfer and Control Interface	Fiber connection from the DAQ system to the detector's RDO to perform configuration, control, and data acquisition.
DATA	DET-COMP-ONLINE	Timing Interface	Fiber connection from the DAQ system to the detector's RDO used for timing synchronization.

Type	*RelatedSystemID*	*InterfaceName*	Description
MECH	DET-INF-MECH	LowQ2 Support	The LowQ2 detector is supported by a freestanding platform that is adjacent to the outgoing electron beam.
SPACE		Forward Space Constraint	The LowQ2 detector must be downstream in the electron direction from the B2ER magnet.
SPACE		Backward Space Constraint	The LowQ2 detector must be upstream in the electron direction from the Q3ER magnet.
SPACE		Vertical Space Constraint	The LOWQ2 detector must be at the same level as the electron beamline.
SPACE		LowQ2 Beamline Proximity	The LowQ2 detector must be positioned as close as possible electron beam pipe in order to detector particles at a shallow angle from the electron beam.
ENV		Lumi-Dipole Interference	The LowQ2 detector should be position such that it receives minimal magnetic interference and secondary scattering from the Lumi-Dipole.
ENV		Beam pipe Exit Window	The performance of the LowQ2 detector will depend on the thickness and shape of the electron beam pipe exit window.

Requirements and spec. for ANC set. - example for low-Q2

GENERAL REQUIREMENTS

Low-Q2 System	
G-DET-ANC-LOWQ2.1	The Low- Q^2 detectors will measure the energy and position of the scattering electrons with Q^2 below 1 GeV^2 in the far-backward directions.

FUNCTIONAL REQUIREMENTS

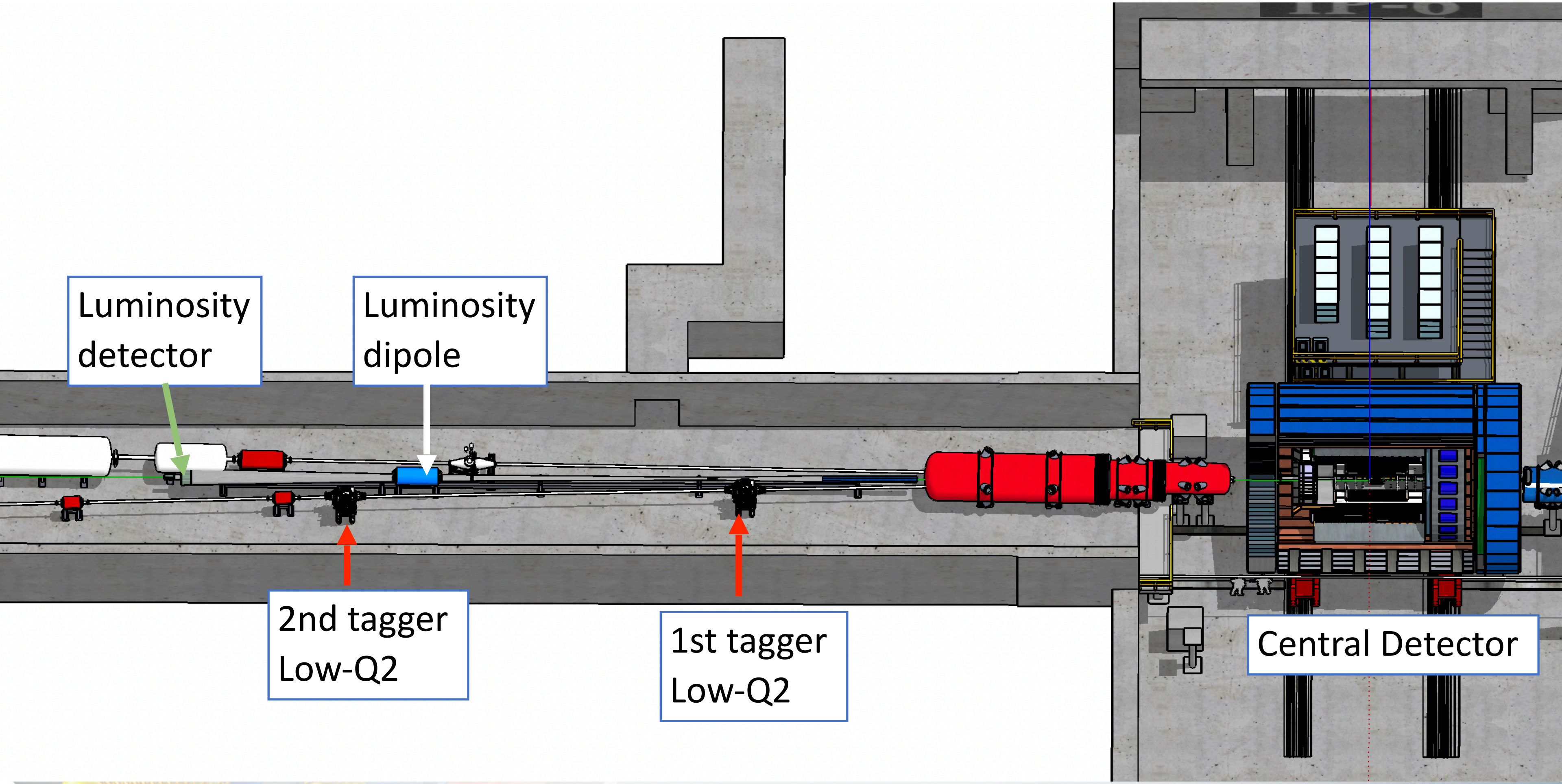
Low-Q2 System		
F-DET-ANC-LOWQ2.1	The acceptance for the low- Q^2 tagger should complement the central detector to reach the coverage close to the limit given by the divergence of the beam.	G-DET-ANC-LOWQ2.1
F-DET-ANC-LOWQ2.2	The Low- Q^2 calorimeter will be used to measure the energy of the scattered electrons.	G-DET-ANC-LOWQ2.1
F-DET-ANC-LOWQ2.3	The tracking system will be used to determinate a position and angle of the scattered electron.	G-DET-ANC-LOWQ2.1
F-DET-ANC-LOWQ2.4	Low- Q^2 tagger will be located along the outgoing electron beam, after the B2eR dipole (20 -40 m away from the IP).	G-DET-ANC-LOWQ2.1
F-DET-ANC-LOWQ2.5	Low- Q^2 tagger will have at least two stations positioned next to the beam-pipe.	G-DET-ANC-LOWQ2.1
F-DET-ANC-LOWQ2.6	LowQ2 system must operate at a full projected EIC luminosity and must be resistant to extreme background conditions (synchrotron radiation, bremsstrahlung events and slow neutrons in particular) at the levels specified by the simulation studies	G-DET.9 G-DET.10

PERFORMANCE REQUIREMENTS

Low-Q2 System		
P-DET-ANC-LOWQ2.1	Low-Q2 will have 2 tagger stations	F-DET-ANC-LOWQ2.1 F-DET-ANC-LOWQ2.4 F-DET-ANC-LOWQ2.5
P-DET-ANC-LOWQ2.2	each Low-Q2 stations will have 4 layers of tracking and 1 calorimeter	F-DET-ANC-LOWQ2.2 F-DET-ANC-LOWQ2.3
P-DET-ANC-LOWQ2.3	The Low-Q2 tracking system shall provide a momentum resolution < 5%.	F-DET-ANC-LOWQ2.3
P-DET-ANC-LOWQ2.4	Low- Q^2 tagger1 tracker shall provide timing resolution (to be determined)	F-DET-ANC-LOWQ2.1 F-DET-ANC-LOWQ2.3
P-DET-ANC-LOWQ2.4	Low- Q^2 tagger1 tracker will have dimensions XX in X and XX in Y (to be determined)	F-DET-ANC-LOWQ2.1 F-DET-ANC-LOWQ2.3
P-DET-ANC-LOWQ2.4	Low- Q^2 tagger2 tracker will have dimensions XX in X and XX in Y (to be determined)	F-DET-ANC-LOWQ2.1 F-DET-ANC-LOWQ2.3
P-DET-ANC-LOWQ2.3	Low- Q^2 tracker will provide	F-DET-ANC-LOWQ2.2
P-DET-ANC-LOWQ2.3	Low- Q^2 calorimeter will have granularity (cell size) XX (to be determined)	F-DET-ANC-LOWQ2.2
P-DET-ANC-LOWQ2.2	Low-Q2 calorimeter energy resolution for electrons shall be s(E)/E < 10%/sqrt(E) + 3%.	F-DET-ANC-LOWQ2.2
P-DET-ANC-LOWQ2.4	Low- Q^2 tagger 1 calorimeter will have dimensions XX in X and XX in Y (to be determined)	F-DET-ANC-LOWQ2.3
P-DET-ANC-LOWQ2.4	Low- Q^2 tagger 2 calorimeter will have dimensions XX in X and XX in Y (to be determined)	F-DET-ANC-LOWQ2.3
P-DET-ANC-LOWQ2.4	Must handle a data rate and operate reliably at a full projected EIC luminosity.	F-DET-ANC-LOWQ2.2 F-DET-ANC-LOWQ2.6

Next step:
Detector Specifications

Far-Backward (electron-going) region : 3D layout



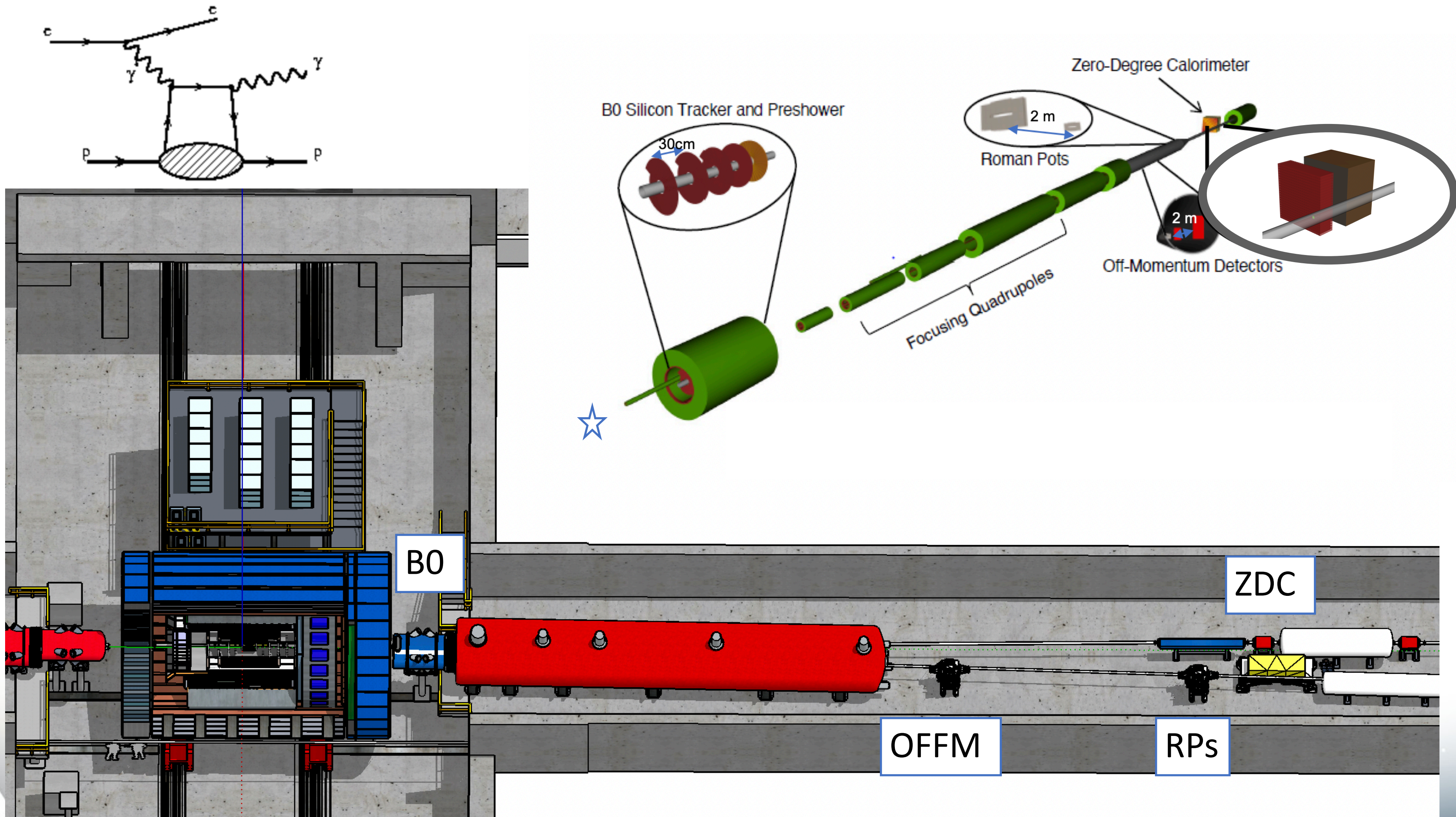
IR-related physics requirements

Table 2.2: Summary of the requirements from the physics program on the overall IR design.

	Hadron	Lepton
Machine element free region	$\pm 4.5\,\text{m}$ main detector beam elements $< 1.5°$ in main detector volume	
Beam Pipe	Low mass material, i.e. Beryllium	
Integration of detectors	Local Polarimeter	
Zero Degree Calorimeter	60cm x60cm x 2m $@s = 30\,\text{m}$	
scattered proton/neutron acc. all energies for e+p	Proton: $0.18\,\text{GeV/c} < p_T < 1.3\,\text{GeV/c}$ $0.5 < x_L < 1 (x_L = E'_p / E_{Beam})$ Neutron: $p_T < 1.3\,\text{GeV/c}$	
scattered proton/neutron acc. all energies for e+A	Proton and Neutron: $\theta < 6\,\text{mrad}$ (for $\sqrt{s} = 50\,\text{GeV}$) $\theta < 4\,\text{mrad}$ (for $\sqrt{s} = 100\,\text{GeV}$)	
Luminosity	Relative Luminosity: $R = L^{++/--} / L^{+-/-+} < 10^{-4}$	
		γ acceptance: $\pm 1\,\text{mrad}$ $\rightarrow \delta L/L < 1\%$
Low Q^2-Tagger		Acceptance: $Q^2 < 0.1\,\text{GeV}$

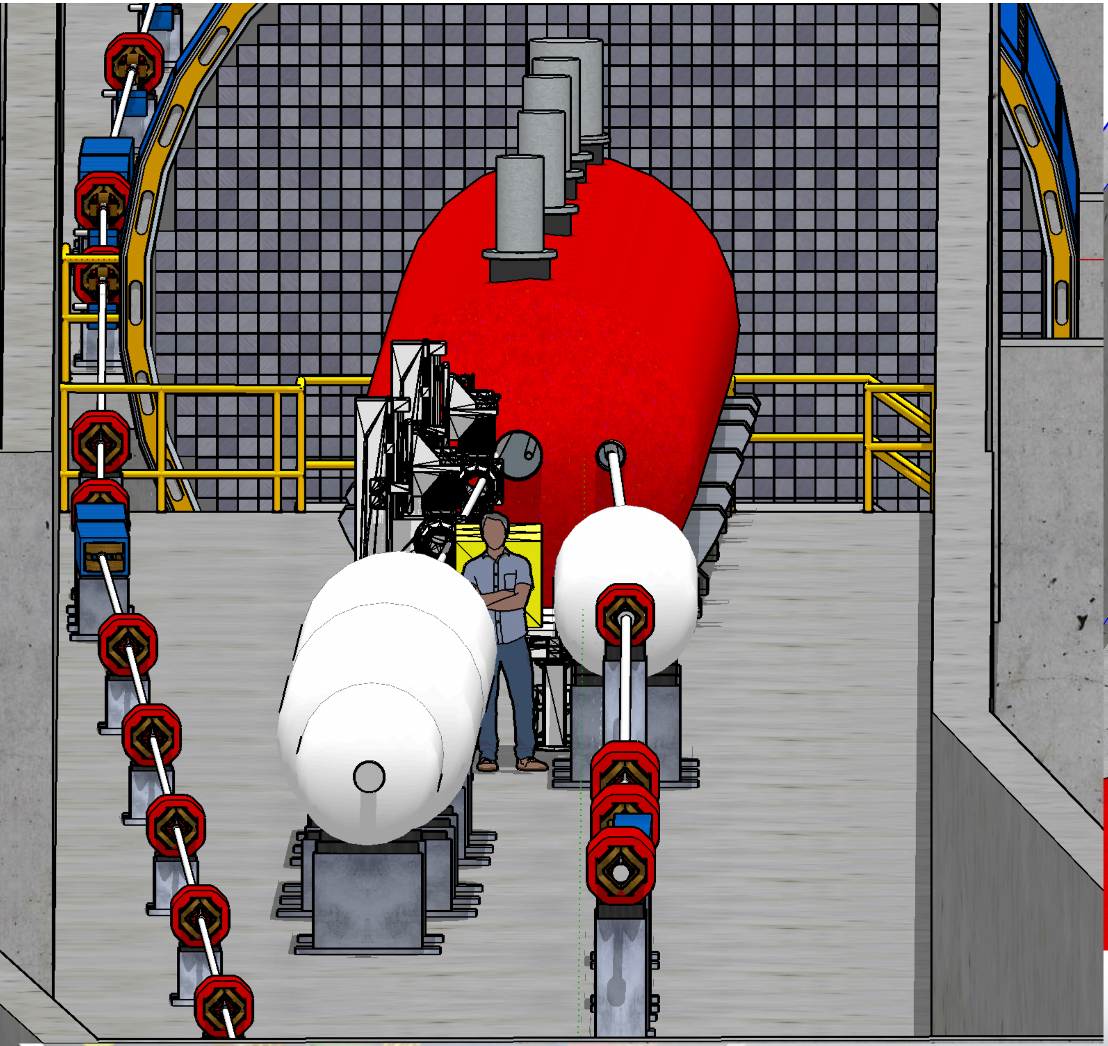
Roman Pots

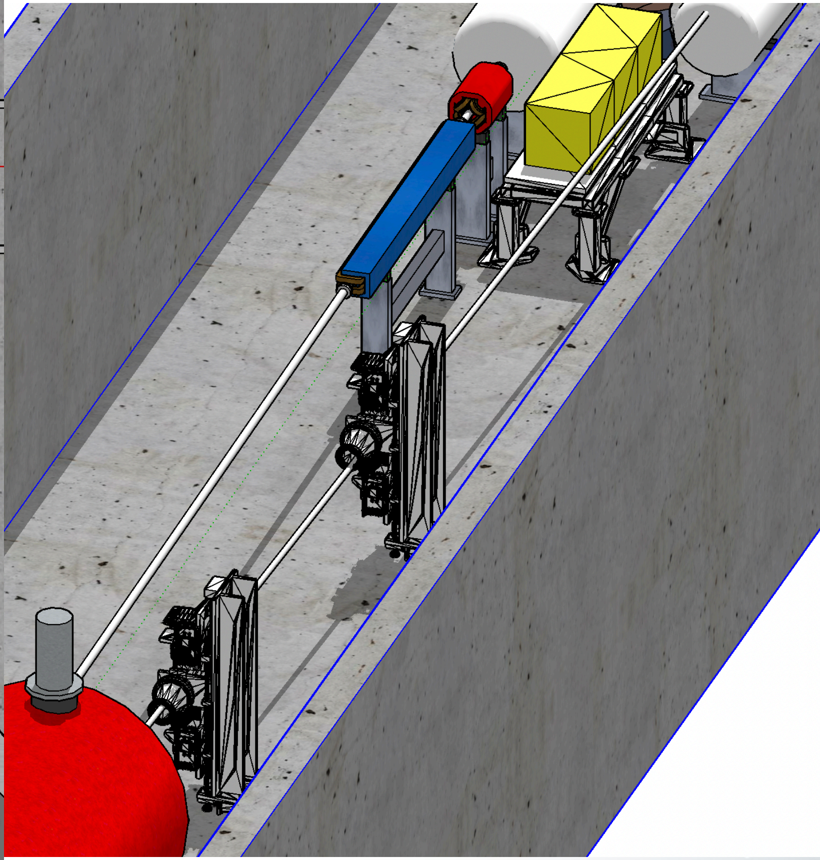
$0.0^{*}\ (10\sigma cut) < \theta < 5.0$ mrad -- small |t| value



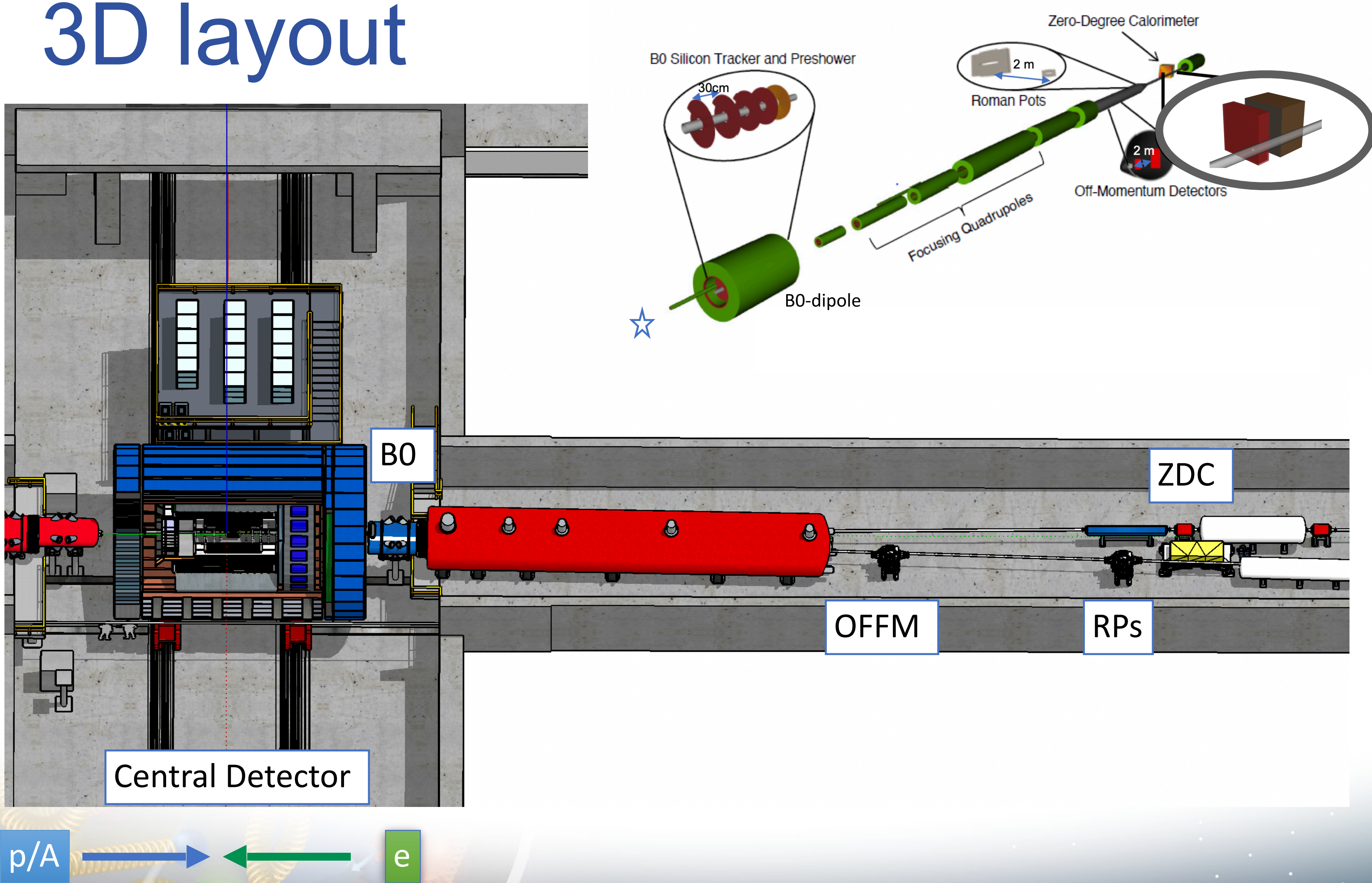
RP Location: Station 1 @ z = 26m, station 2 at z = 28m

ZDC integration

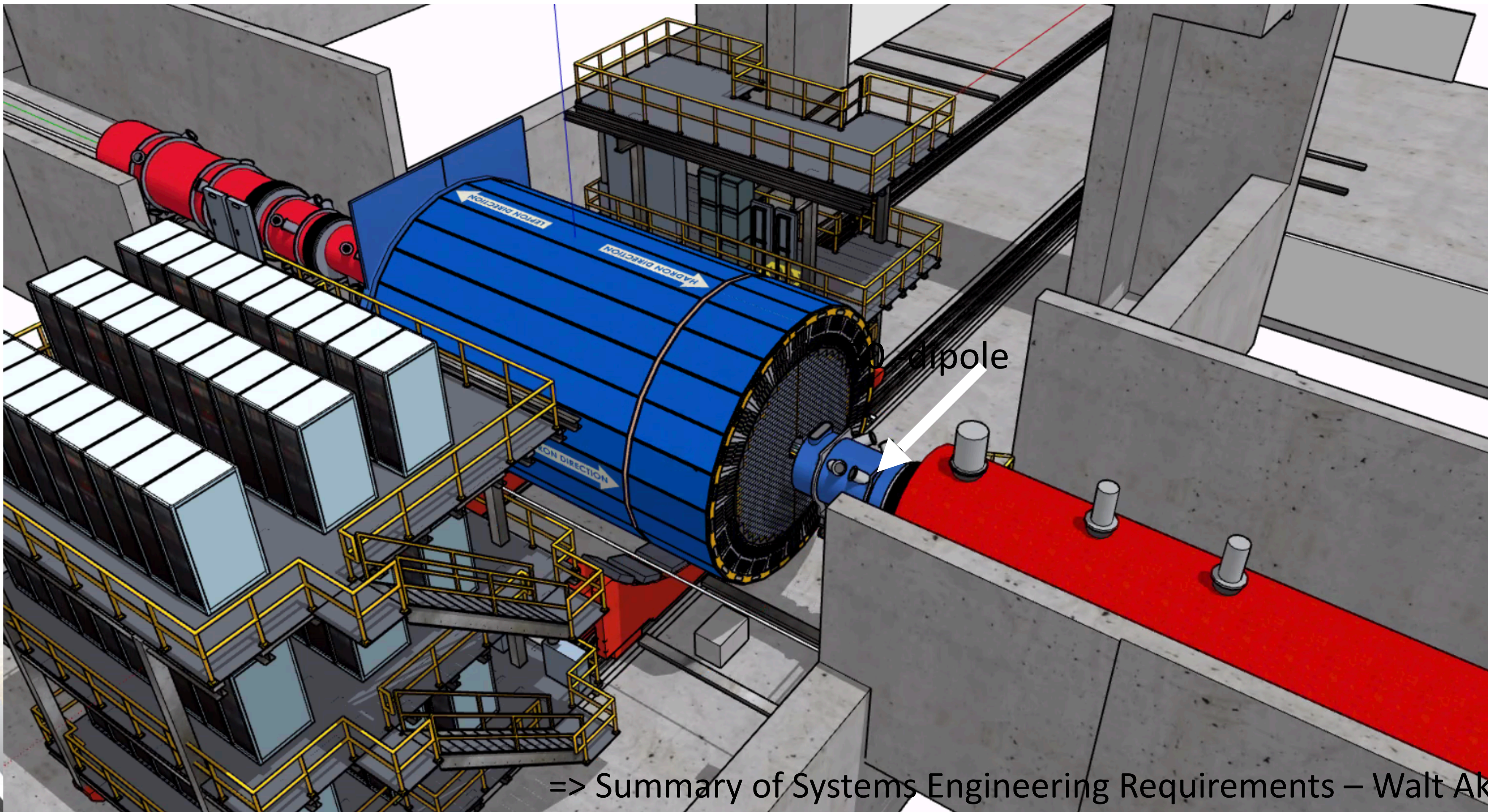




3D layout


Zero-Degree Calorimeter
B0 Silicon Tracker and Preshower
30cm
2 m
Roman Pots
2 m
Off-Momentum Detectors
Focusing Quadrupoles
B0-dipole
B0
ZDC
OFFM
RPs
Central Detector
p/A
e

3D layout: close look to the experimental hall



=> Summary of Systems Engineering Requirements – Walt Akers

Contributions/ detector selection process

Many thanks to all who contributed !

Joint EIC community effort

(Scientists from theory and experimentalists ,

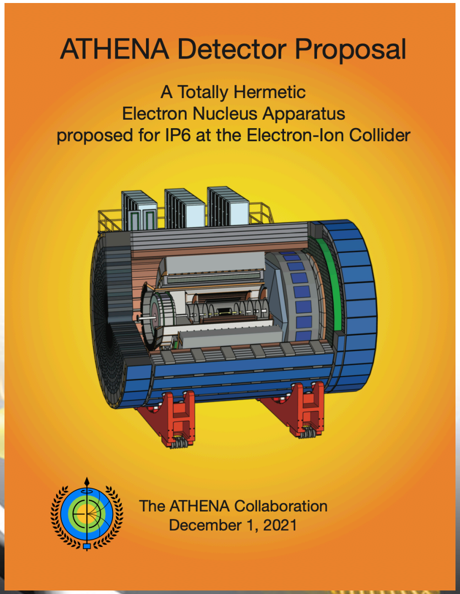
Engineers and Designers, Accelerator colleagues)

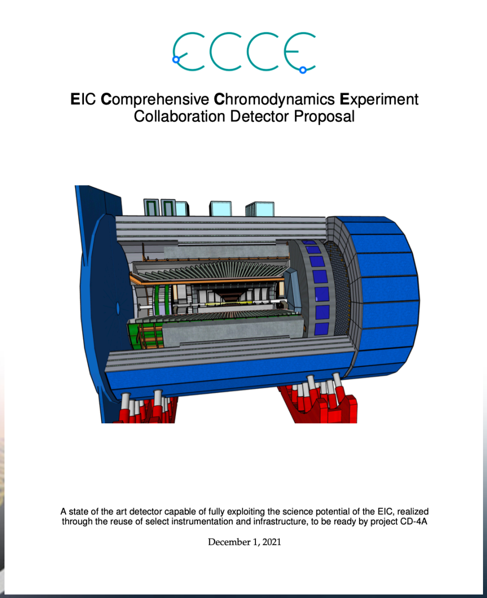
Contributions from

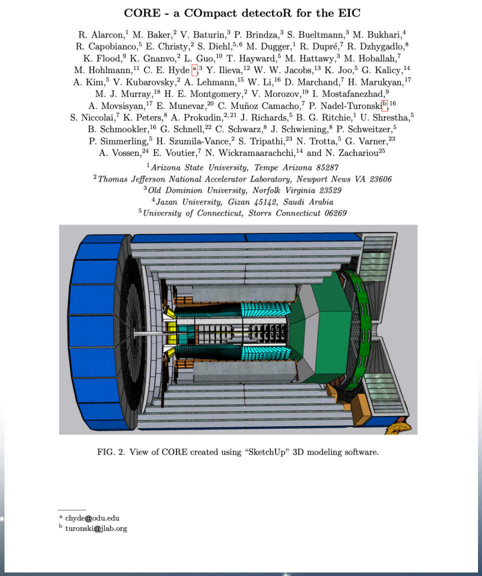
the EIC Yellow Report,

Detector selection process (ECCE, ATHENA,CORE),

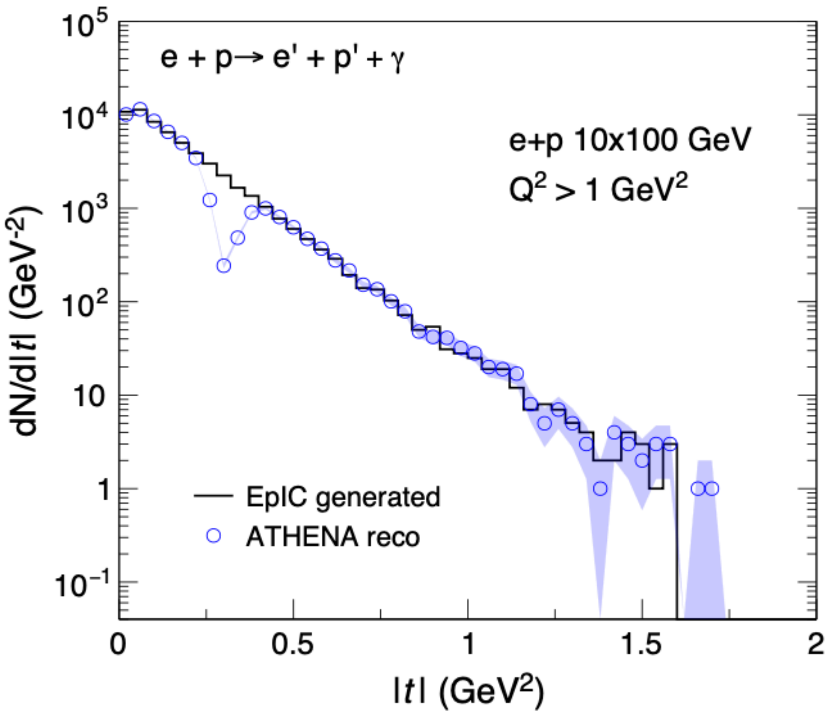
EIC Project

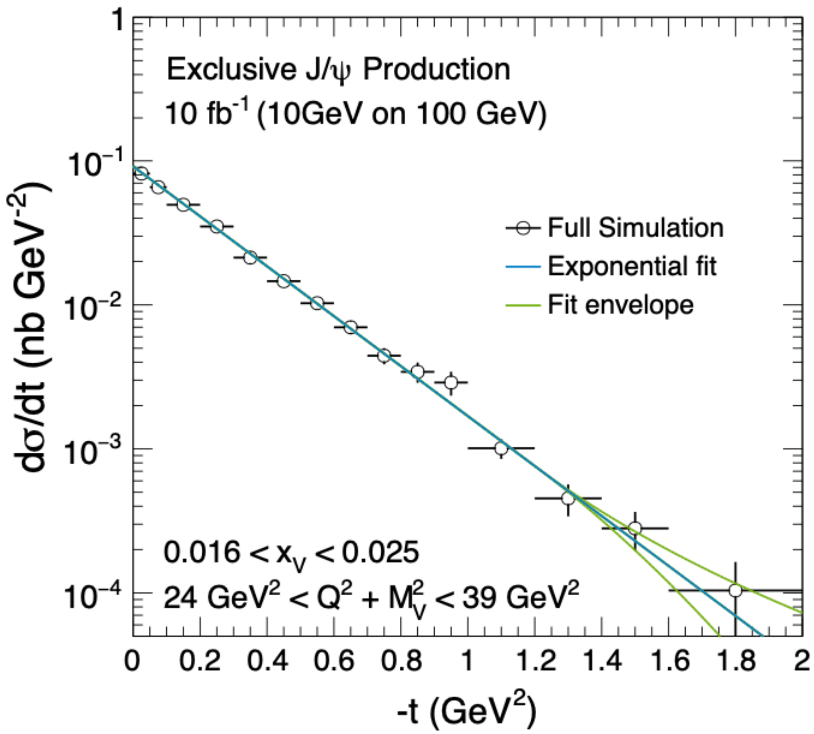




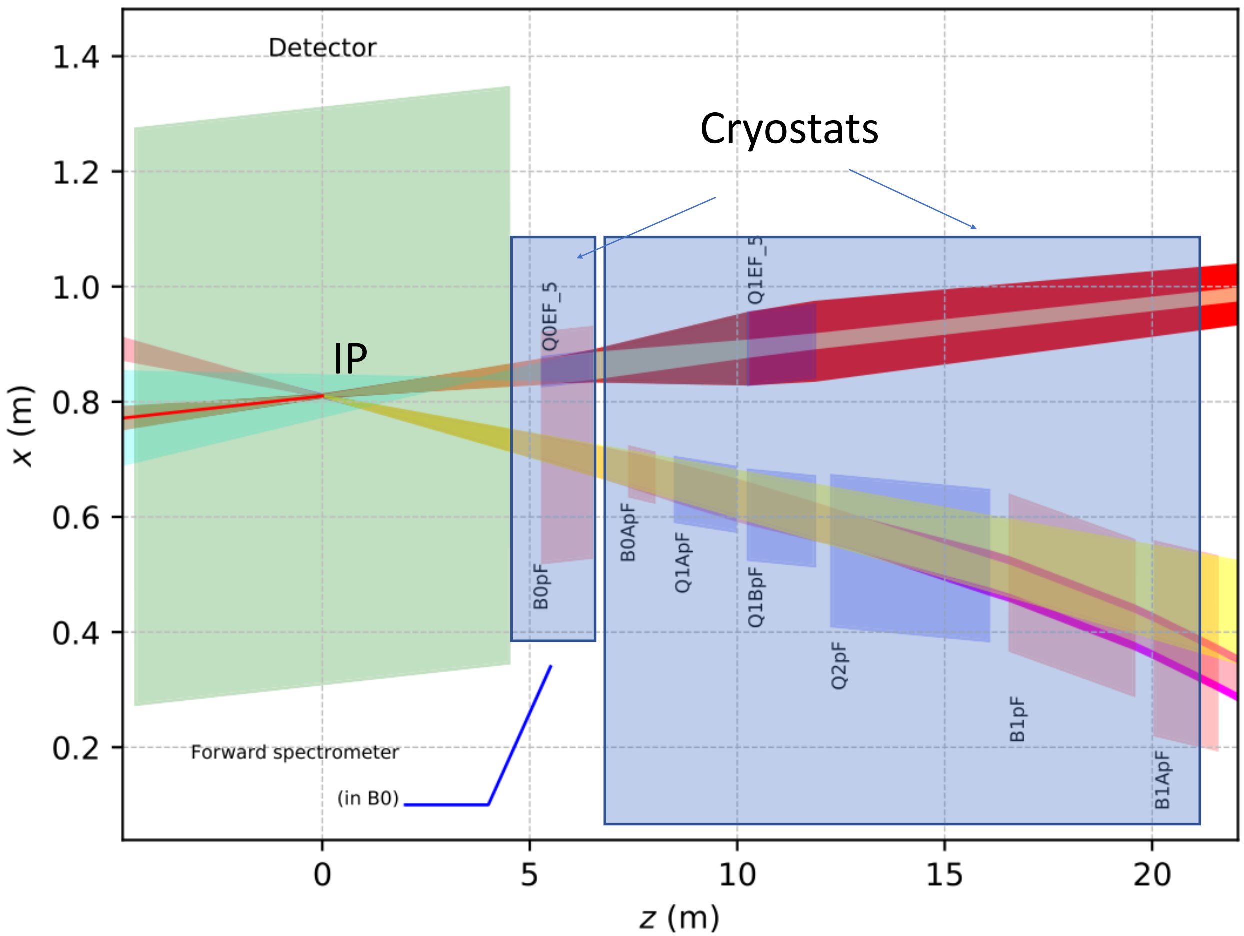


|t| -distribution for DVCS and DVMP





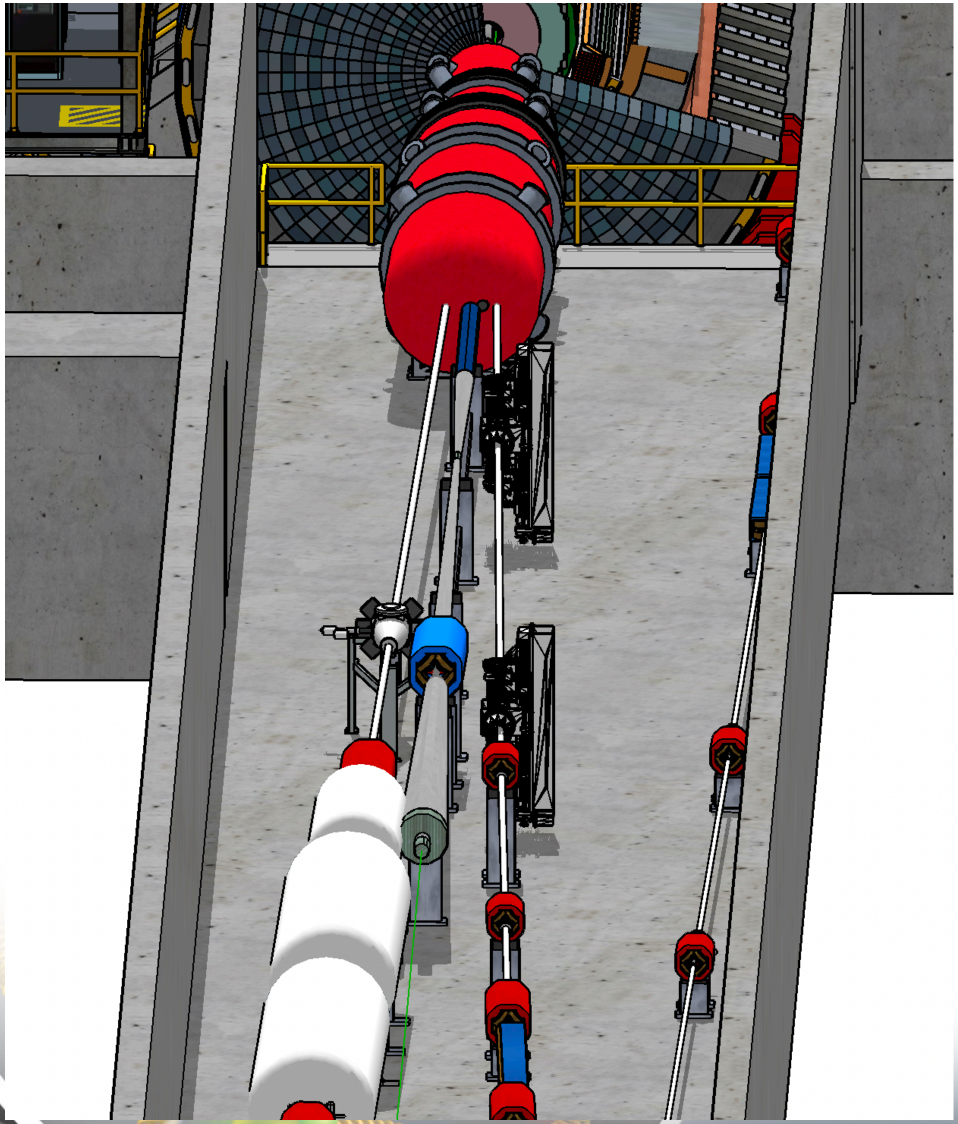
EIC IR: Forward Direction

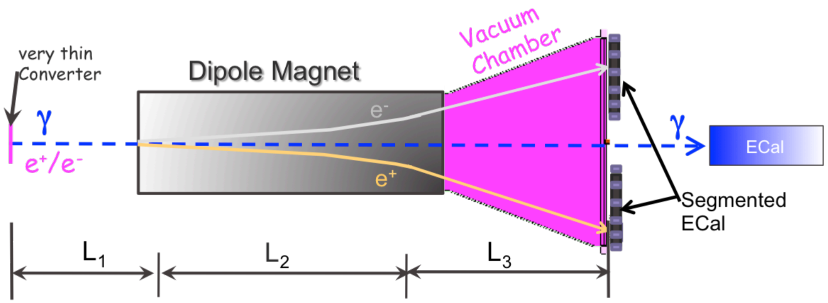


Name	R1	length	B	grad	B pole
	[m]	[m]	[T]	[T/m]	[T]
B0ApF	0.043	0.6	-3.3	0	-3.3
Q1ApF	0.056	1.46	0	-72.608	-4.066
Q1BpF	0.078	1.61	0	-66.18	-5.162
Q2pF	0.131	3.8	0	40.737	5.357
B1pF	0.135	3	-3.4	0	-3.4

Electron-Ion Collider

Luminosity monitor





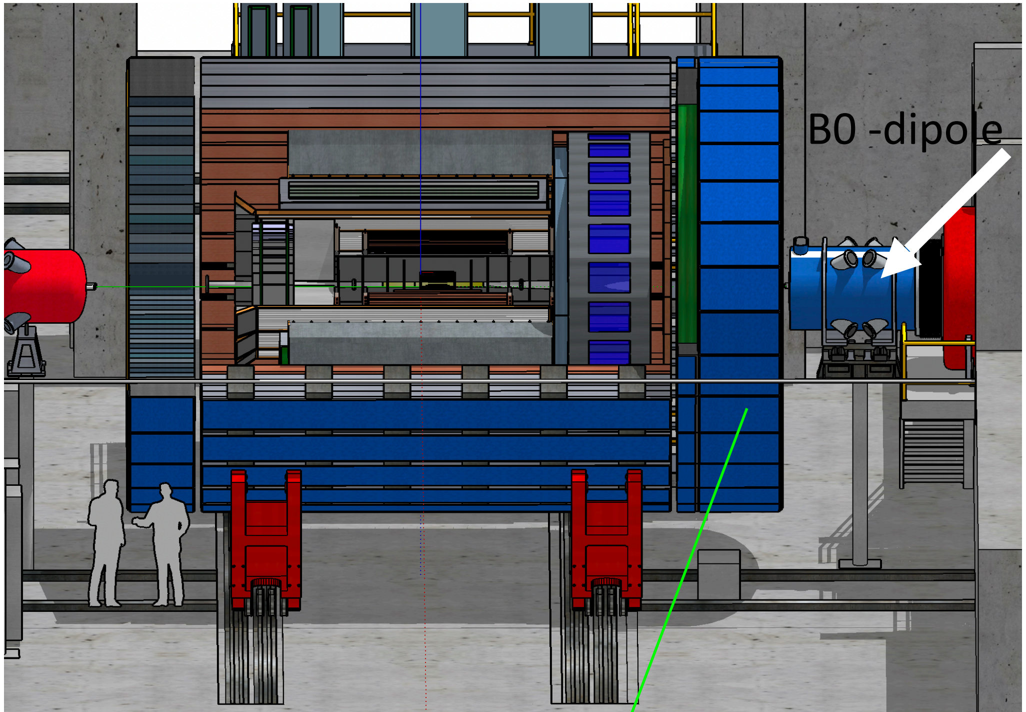
pair spectrometer:

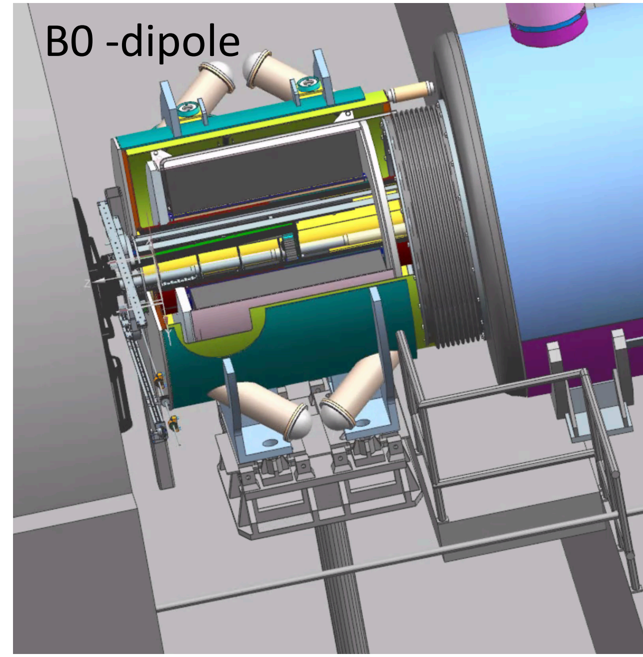
- Low rate (due to conversion)
- High precision measurement for physics analysis
- The calorimeters are outside of the primary synchrotron radiation fan

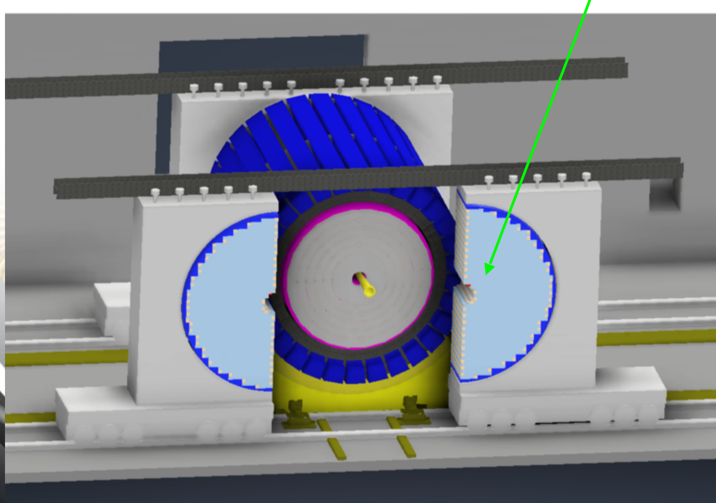
zero degree photon calorimeter

- high rate
- Fast feedback for machine tuning
- measured energy proportional to # photons
- subject to synchrotron radiation

B0-detectors

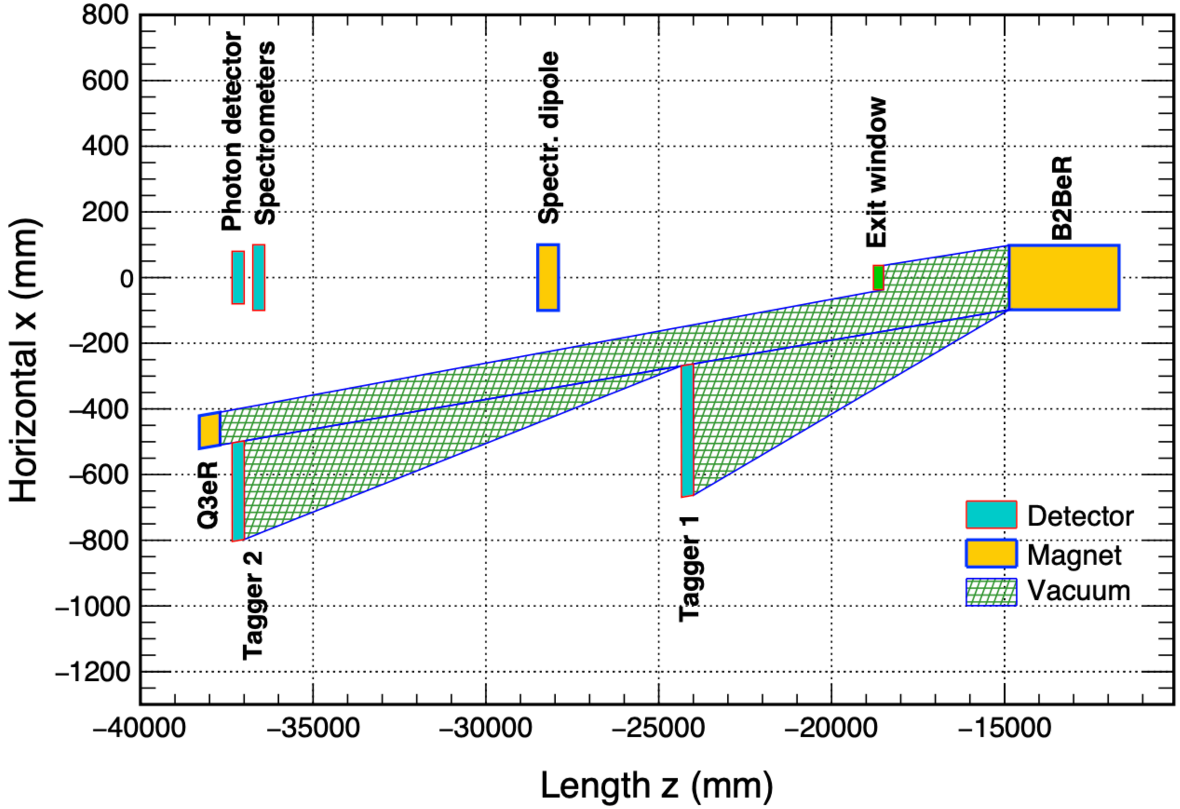






- ➡ Dipole field 1.3T: for momentum reconstruction . Design is on the way (length ~1.5m)
- ➡ B0 placement - after HCAL
  - ✦ Limited space
  - ✦ Access to B0-detectors only from one side (after opening HCAL) ~ 15cm (!)
  - ✦ Vacuum pumps
  - ✦ Beam-pipes: crossing angle

Far-backward



Far-backward