Far-forward / backward update (TIC meeting)

16 Oct 2023

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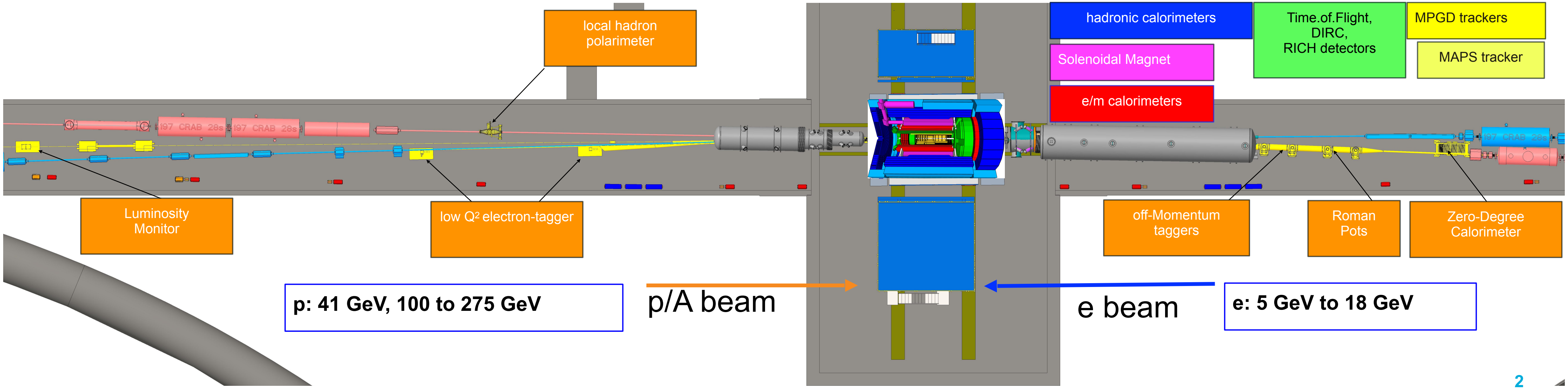
Outline

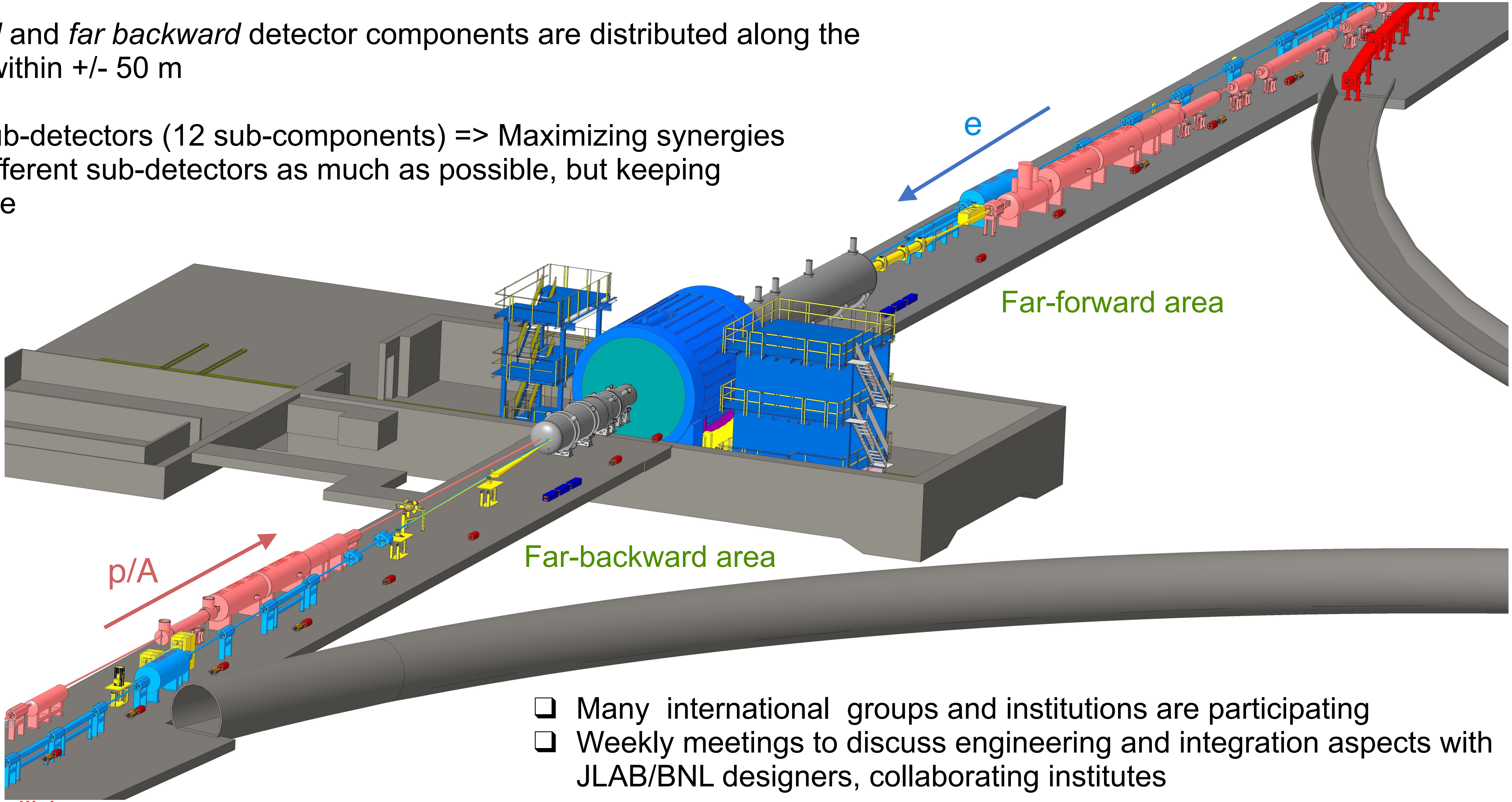
- Requirements & integration aspects
  - Low-Q2
  - Lumi
  - Far-forward



3D view

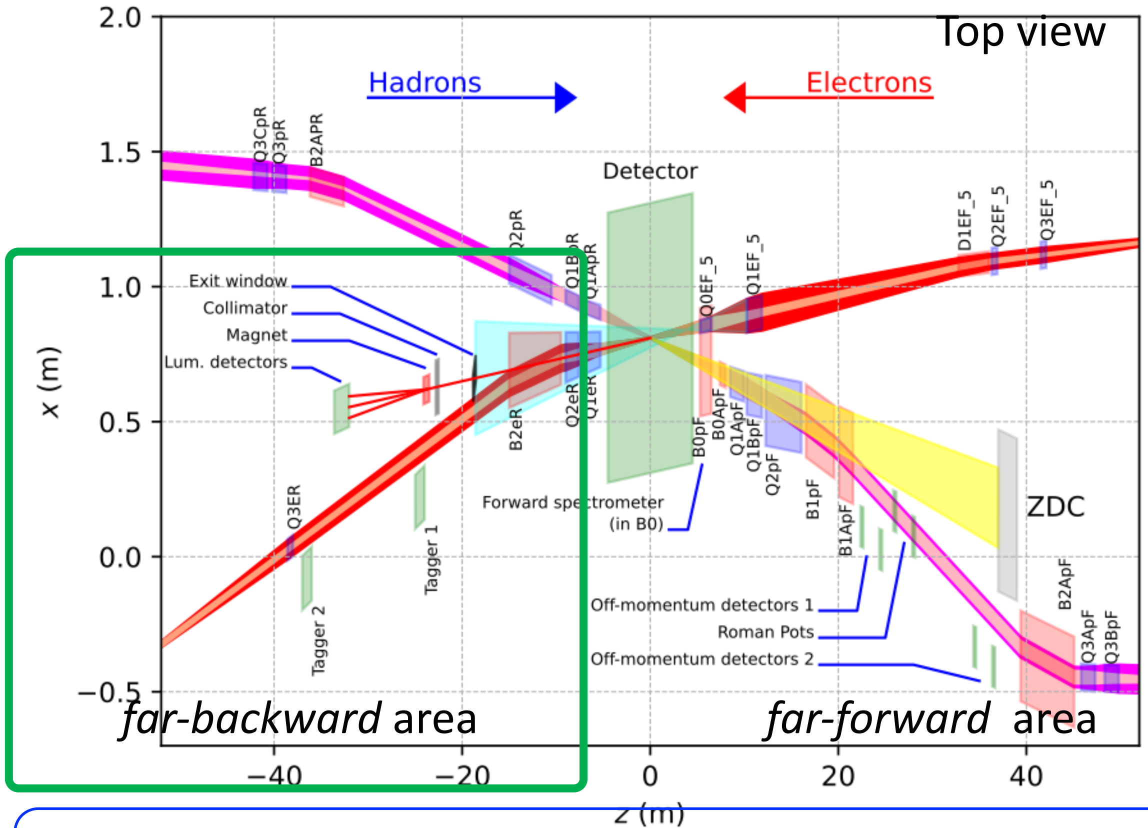
- ❑ F*ar forward* and *far backward* detector components are distributed along the beam line within +/- 50 m

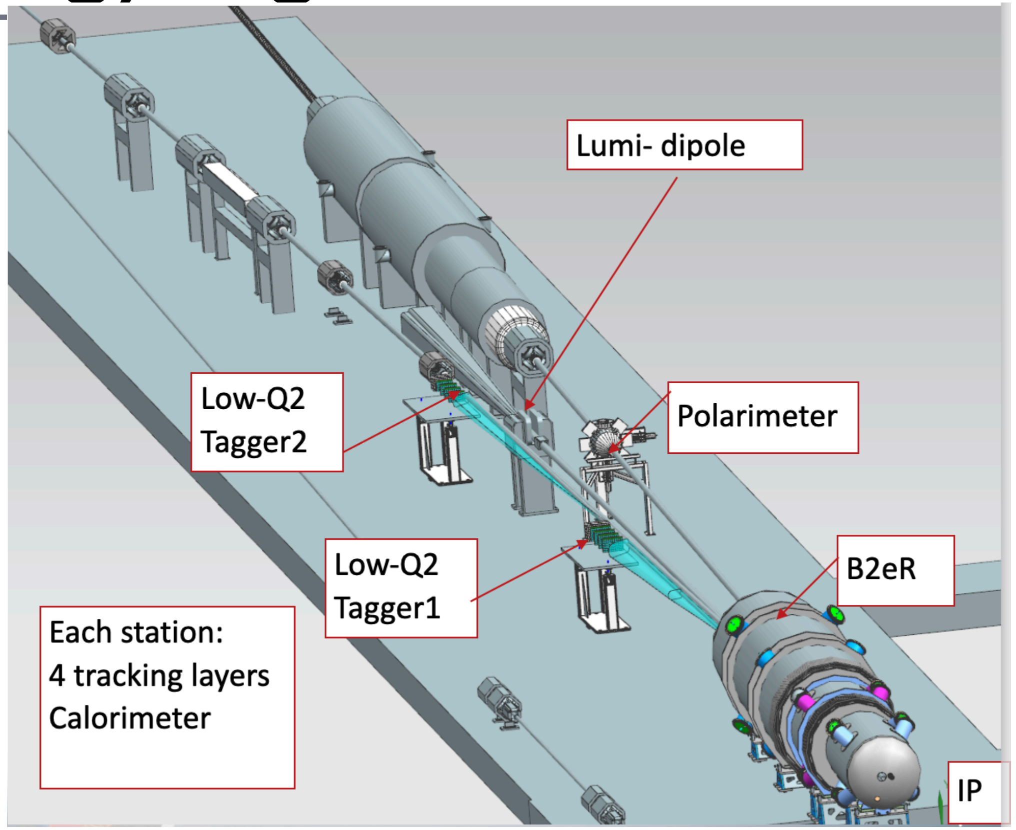
- ❑ In total 7 sub-detectors (12 sub-components) => Maximizing synergies between different sub-detectors as much as possible, but keeping performance



- ❑ Many international groups and institutions are participating
- ❑ Weekly meetings to discuss engineering and integration aspects with JLAB/BNL designers, collaborating institutes

Far-backward (electron-outgoing) region





- ➢ This area is designed to provide coverage for the low-Q^2 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 1GeV²** 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. => two stations to cover the maximum acceptance

- ✓Low-Q2 system should have a **good position resolution**(beam effects are included into the simulation) (momentum resolution < 5 %) => up to 4 Si tracking layers
- ✓Calorimeter shall provide an electron energy resolution: $\sigma(E)/E < 10\%/\sqrt{E} + 3\%$

- ✓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 (10 electrons per bunch crossing)**

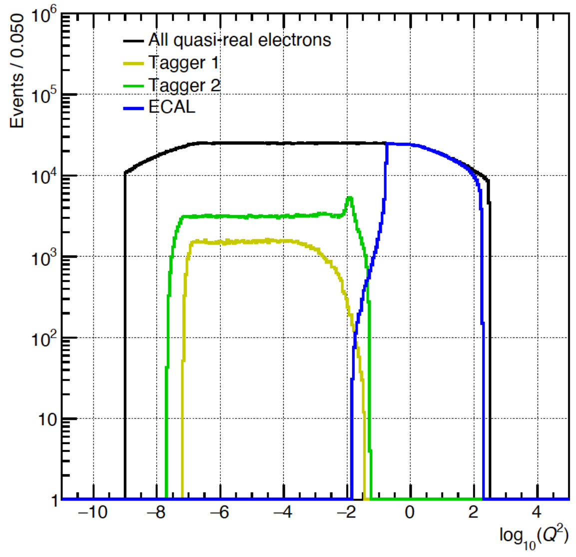
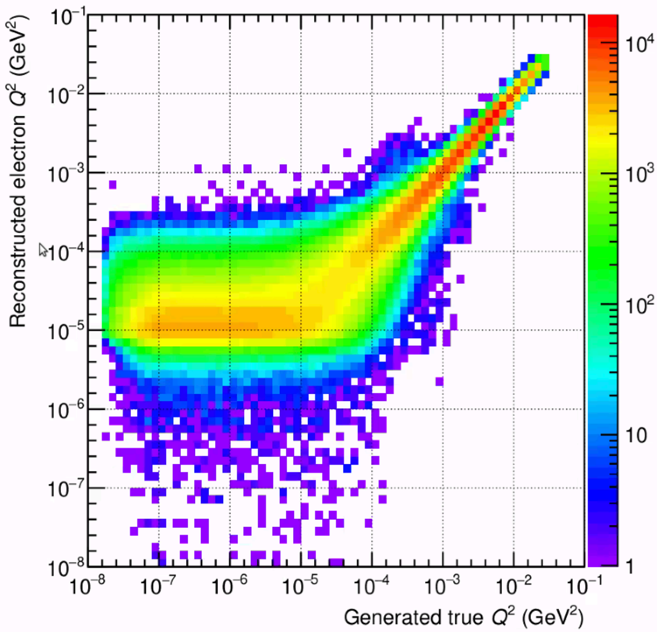


FIG. 16: Coverage in Q^2 for tagger detectors and ECAL.



Low-Q2 detector assumptions.

current P6 configuration

	CD1	Detector proposal 1	Detector proposal 2	ePIC
Dimensions	Tagger1: 40x40 cm^2 Tagger 2: 30x20cm^2	Tagger1: 40x40cm^2 Tagger 2: 30x20cm^2	Tagger1: 40x40 cm^2 Tagger 2: 30x20cm^2	Tagger 1 and Tagger 2 : ca **15x18cm^2**
Tracker technology	LGAD	Tagger 2: 30x20cm^2 Si (AC-LGAD)	AC-LGAD 500um pixels 30ps	Timepix4 **55um pixels** 2ns **high rate capability 20kHz/pixel**
CAL technology	PbWO4 (2x2x20cm^2)	Spaghetti W-calorimeter with radiation-hard scintillating fiber, read out with fast PMTs	PbWO4 (2x2x20cm^2)	W/SciFi (the same as for lumi PS)

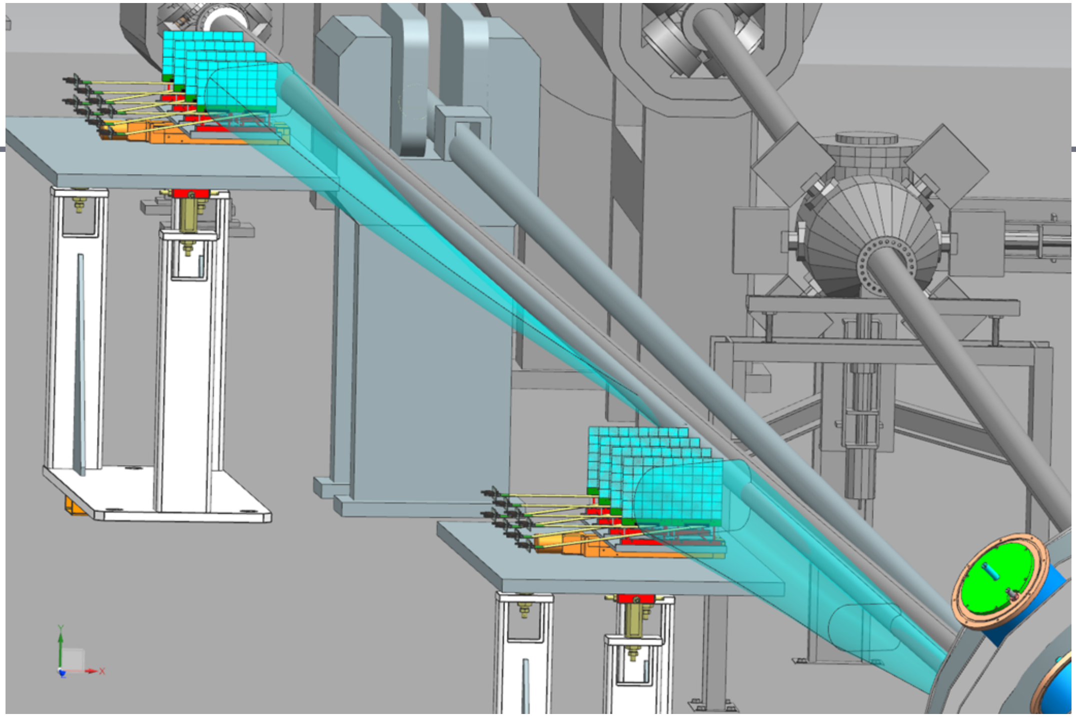
Low-Q2 taggers

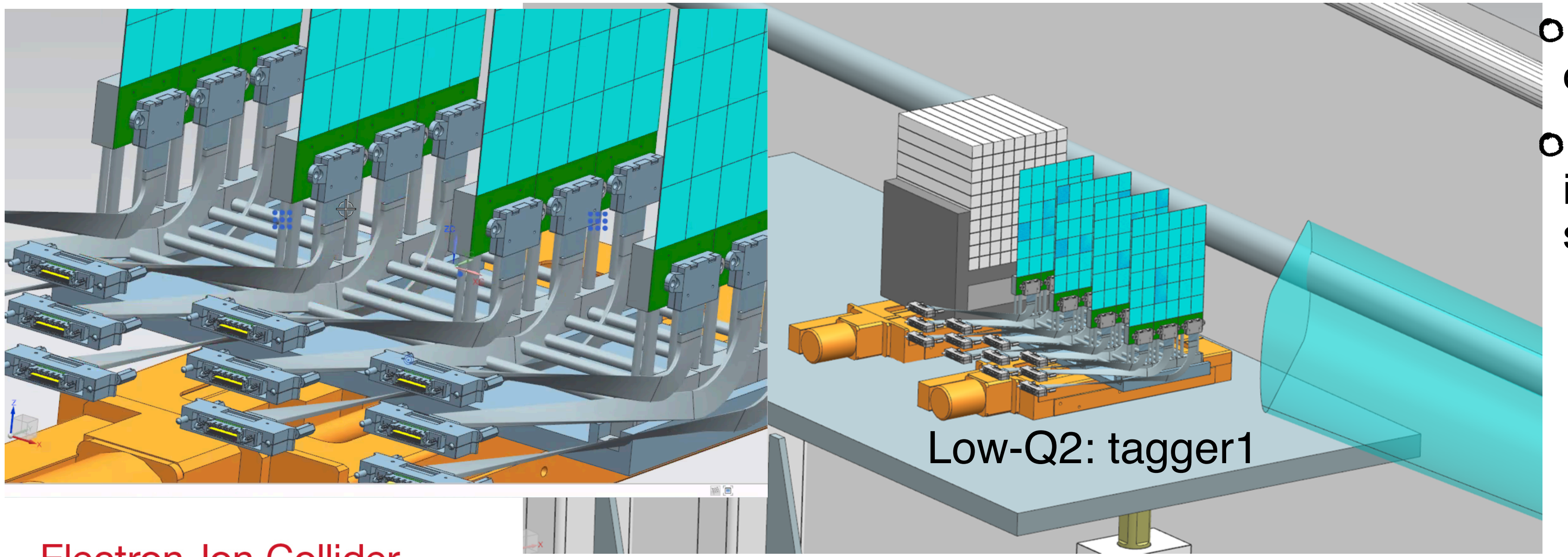
- Two tagger stations with 4 Si-stations 30 cm apart and a calorimeter behind.

Tracker: Timepix technology

- Rate capability is very high ~20kHz per 55um pixel

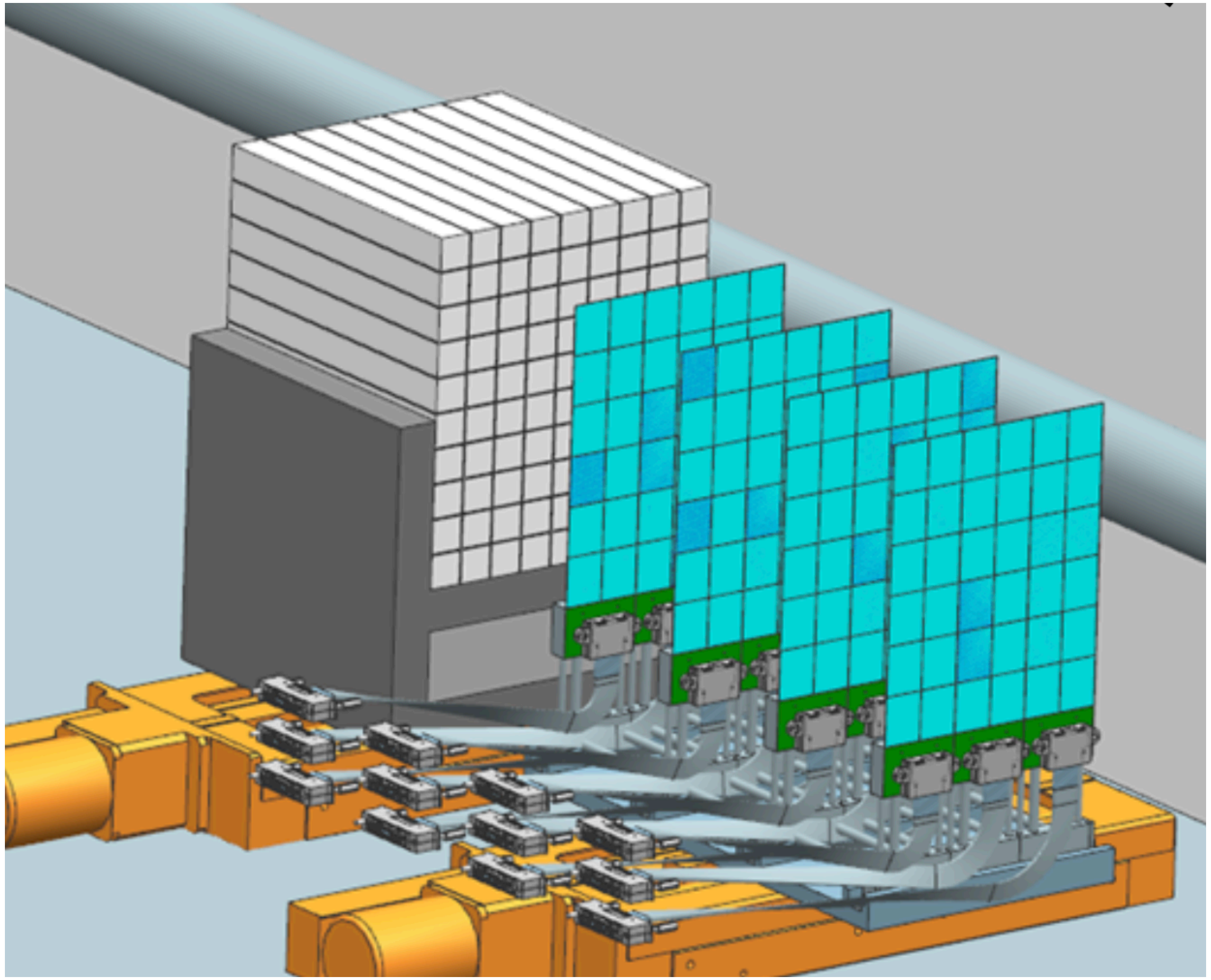
Calorimeter: PbWO4 (or similar to PS-lumi) — allows essential cross calibration of tracker and luminosity system during low current runs





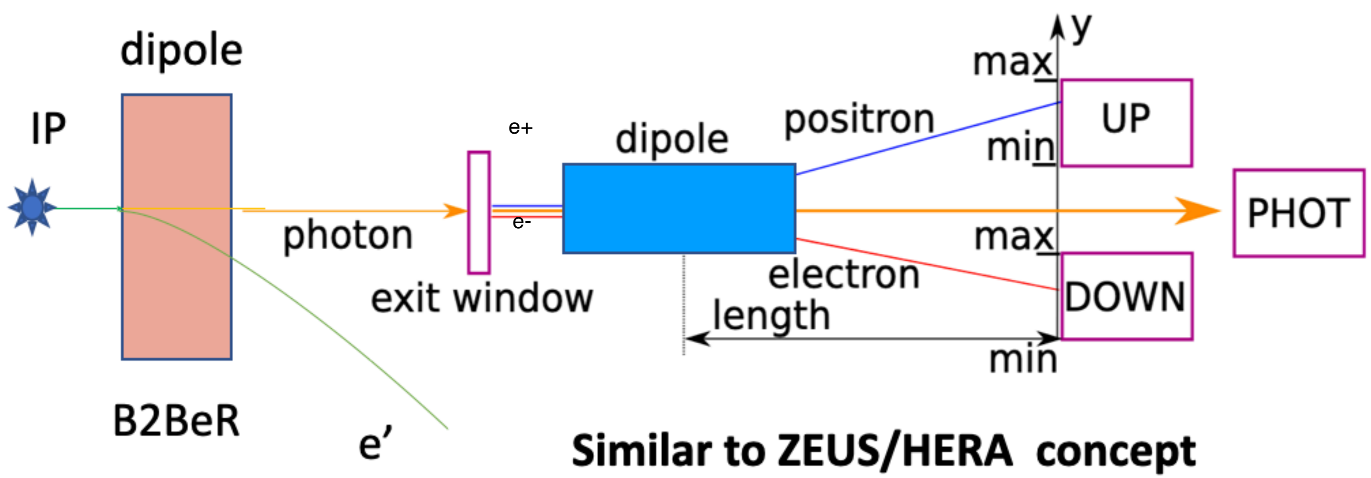
- CAD layout with dimensions are based on the actual Timepix module design
- Cables and cooling pipes are included. Support stand and movable station for position adjustments

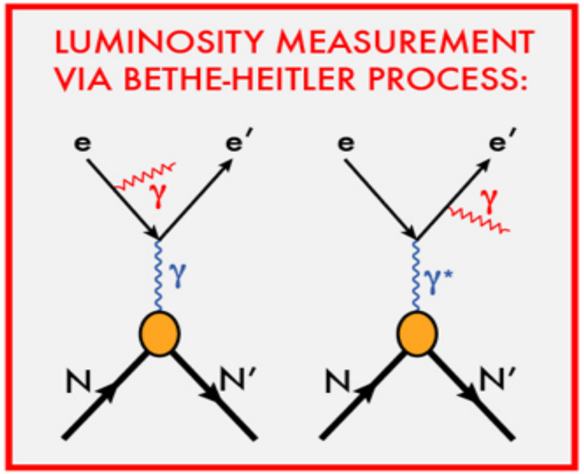
Low-Q2 taggers: integration



- Placement : outside of the primary vacuum
- But Timepix is designed to operate under 10-6mbar vacuum => working on possible setup with detector sitting i**n the secondary vacuum** to minimize the material in front.

Luminosity system: requirements





- ➢ 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 PS CAL energy resolution for electrons shall be σ(E)/E < 15%/sqrt(E)
- ➢The PS CALs, direct CAL, and trackers shall all provide timing resolution sufficient to resolve 10ns beam buckets
- ➢The calorimeters are outside of the primary synchrotron radiation fan

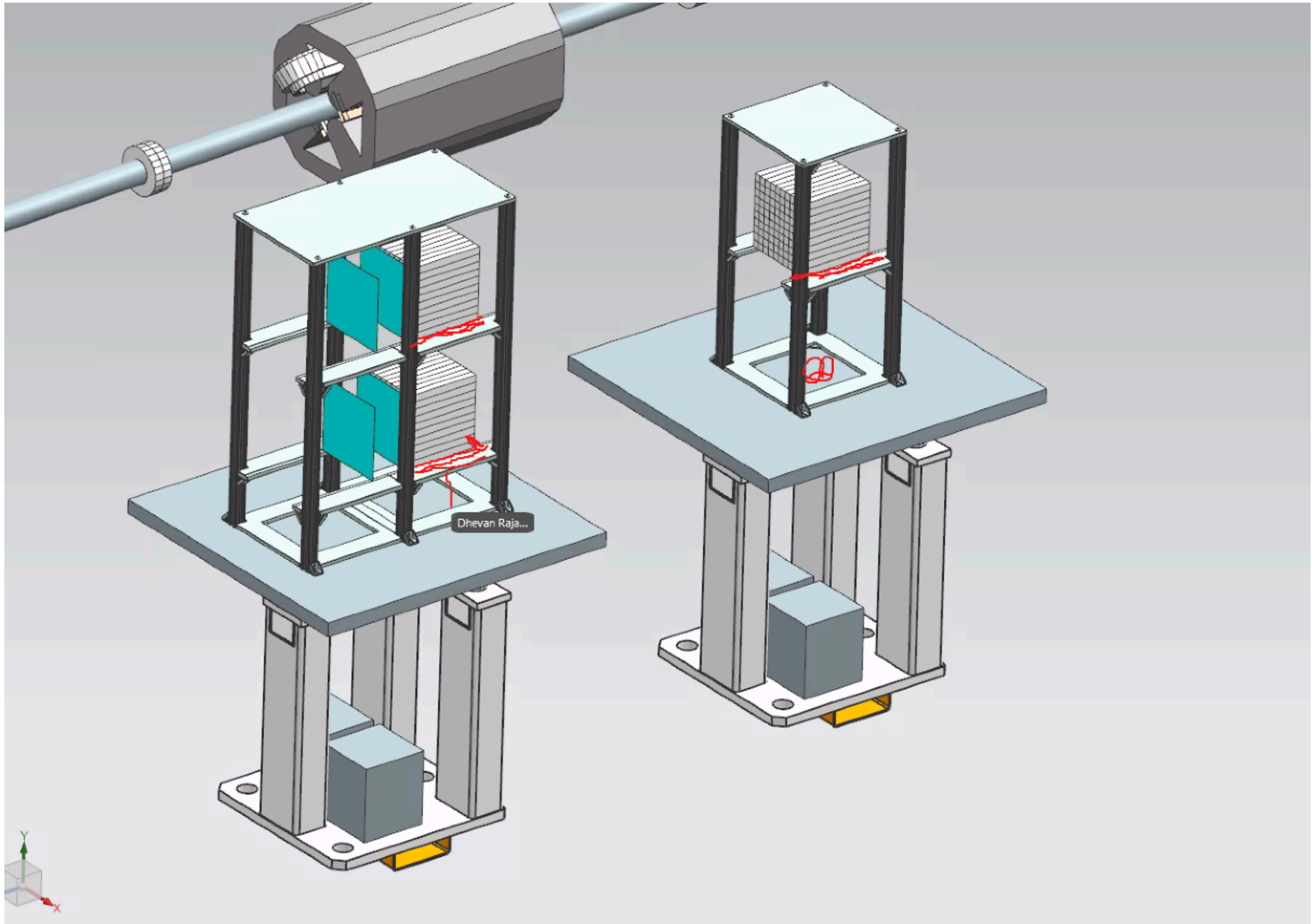
zero degree photon calorimeter
- ➢high rate
- ➢Fast feedback for machine tuning
- ➢measured energy proportional to # photons
- ➢ the CAL energy resolution for electrons shall be σ(E)/E < 15%/sqrt(E)
- ➢subject to synchrotron radiation

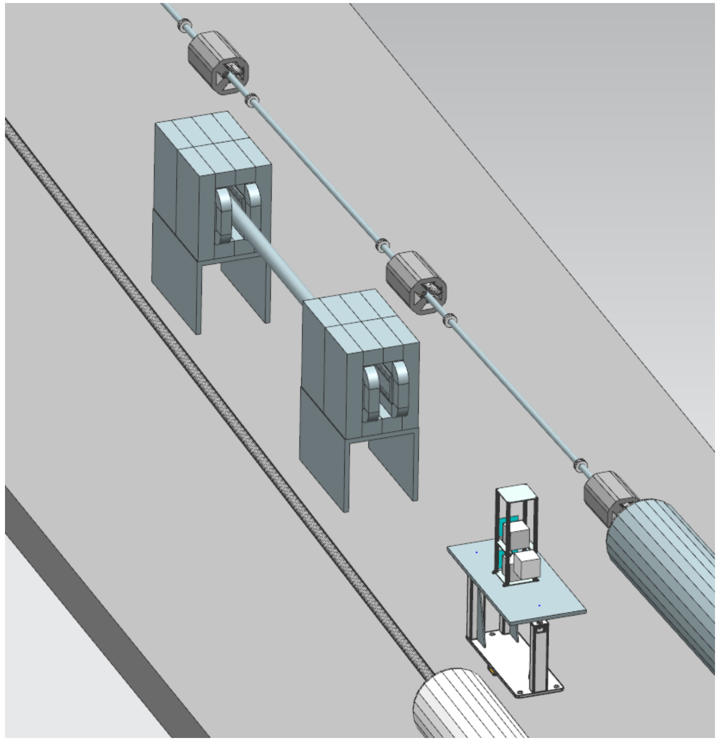
Lumi detectors

current P6 configuration

	CD1	Detector proposal 1	Detector proposal 2	ePIC
Dimensions	15x15x20cm^3 analyzing dipole	20x20x20cm^3 analyzing dipole	16x16x20cm^3 analyzing dipole	18x18x20cm^3 swiping and analyzing dipoles
PS-tracker	Si strip detector	Hodoscope 4 planes of Sci -fi (?)	AC-LGAD tracking, 8x16 cm^2 (52 sensors, 208 channels)	AC-LGAD - strip (as barrel TOF)
PS- CAL	W/SciFi with 140 channels	Spaghetti W-calorimeter with radiation- hard scintillating fiber (PMT readout)	PbWO4 (8x16x20cm^3) cells 2x2x20cm^2 2x32 channels	W-powder +epoxy infused into a bundle of scintillating fibers (like forward ECAL)
Direct Photon Cal	W/SciFi with 140 channels	Cherenkov-radiating quartz fibers read out by SiPMs	PbWO4 (16x16x20cm^3) cells 2x2x20cm^2 64 channels	Sci-fiber/tungsten spaghetti or Quartz fiber/tungsten spaghetti 100 channels

Luminosity system: integration





Far- Forward detectors

current P6 configuration

	CD1	Detector proposal 1	Detector proposal 2	ePIC
B0 tracker	ITS3- 2 layers AC-LGAD pixel 2 layers	ITS3- 2 layers AC-LGAD pixel 2 layers	ITS3- 1 layers AC-LGAD pixel - 3 layers	all 4 layers AC-LGAD pixels
B0 CAL	Pre-shower Pb + Si	Pre-shower Pb + Si	PbWO4 2x2x20cm^2	PbWO4 2x2x7cm^2 or LYSO
RPOT/OMD	AC-LGAD 2 stations /2 layers + 2 stations /2 layers (OMD)	AC-LGAD 2 stations /2 layers + 2 stations /2 layers (OMD)	AC-LGAD 2 stations /2 layers + 2 stations /2 layers (OMD)	AC-LGAD 2 stations /2 layers + 2 stations /2 layers (OMD)

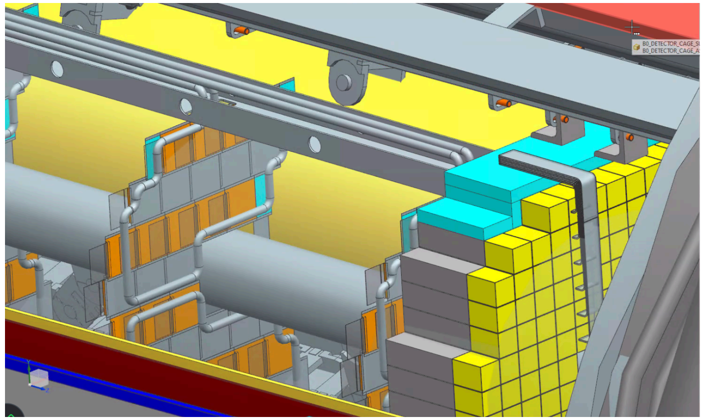
ZDC

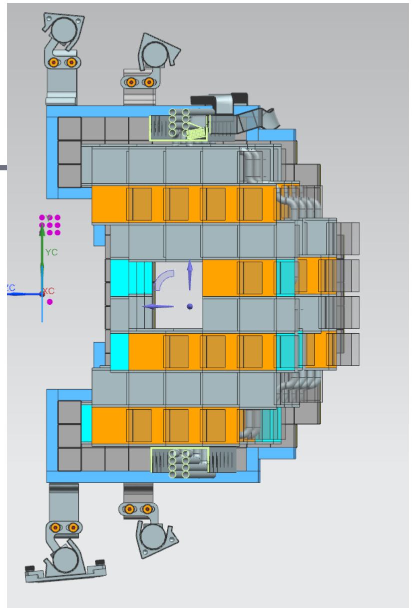
current P6 configuration

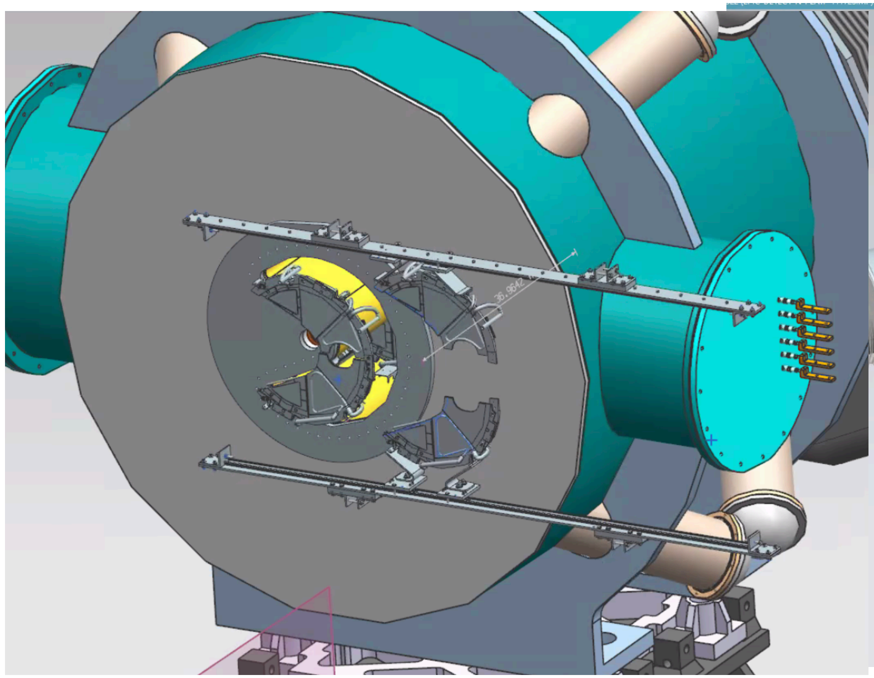
	CD1	Detector proposal 1	Detector proposal 2	ePIC
Dimensions	60x60x200cm^3		60x60x200cm^3	
VETO	no	1 layer Si	Si - LowG pads - 2 layers HGCROC	Si -LG pads 56x54 cm^2
EMCAL	PbWO4 with SiPMs 2x2x20 cm^3	W/SciFi 2.5 × 2.5 cm towers, 17 cm long	PbWO4 with APD $3x3x7cm^3$ 20x20	PbWO4 (with APD) 56x54 cm^2 $2x2x7cm^3$ 28x27 or LYSO ?
EMCAL-imaging	no	no	Si- LowG pads - 20 layers Si-HighG pads -3 layers W alloy 3.5mm - 22 layers	(56x54 cm^2) - 20 layers
HCAL -imaging	no	no	Si-LowG pads 12 layer , HGCROC Pb- 3.5cm -12 layers	no
HCAL	Pb/Sci Pb: 3cm 3 stations	Pb/Scintillator 120 layers of 1 cm Pb and 0.25 cm scintillator	Pb/Sci - 2 stations Pb- 3cm -15 layers Sci-10cmx10cmx2mm	Pb/Sci ? Or as Insert

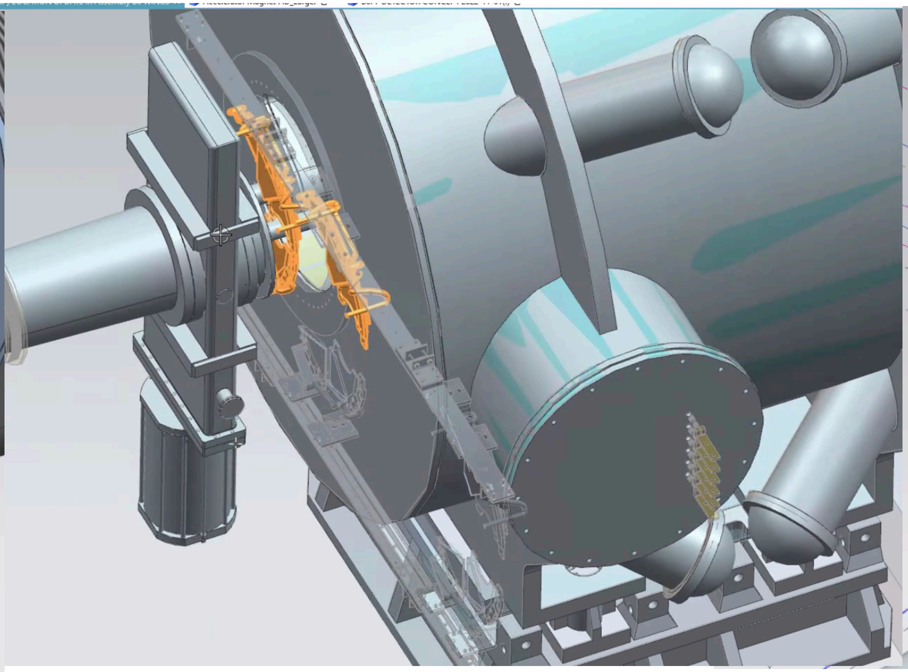
B0-detectors- integration

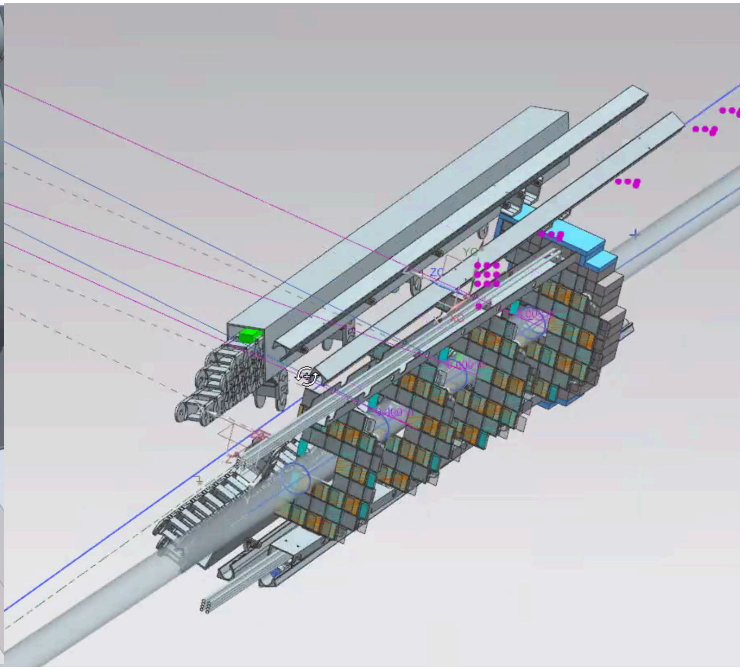
- Mechanical integration (all AC-LGAD + PbWO4 (7cm) CAL)
- Installation and maintenance
- Cooling/cabling



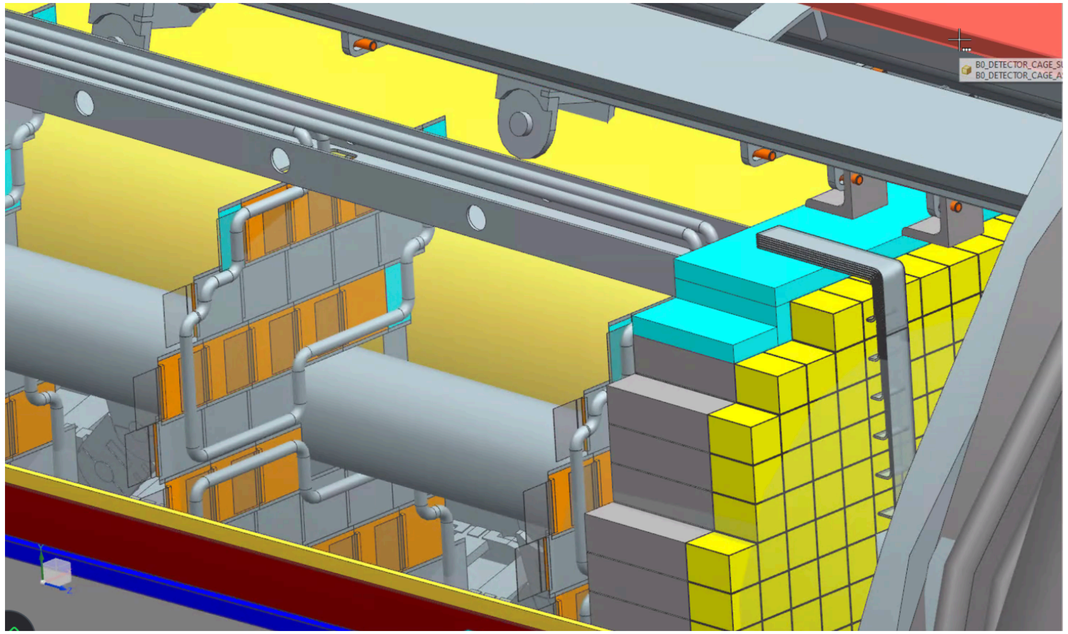


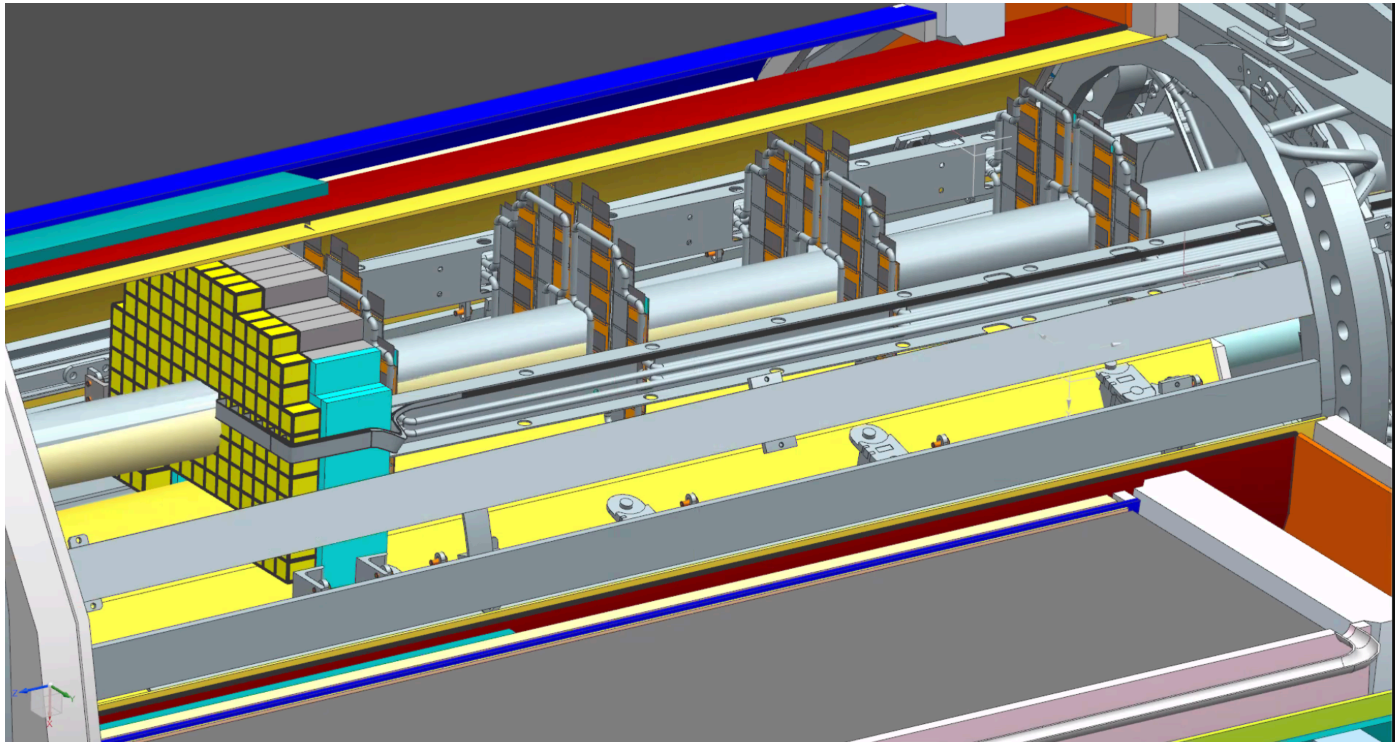




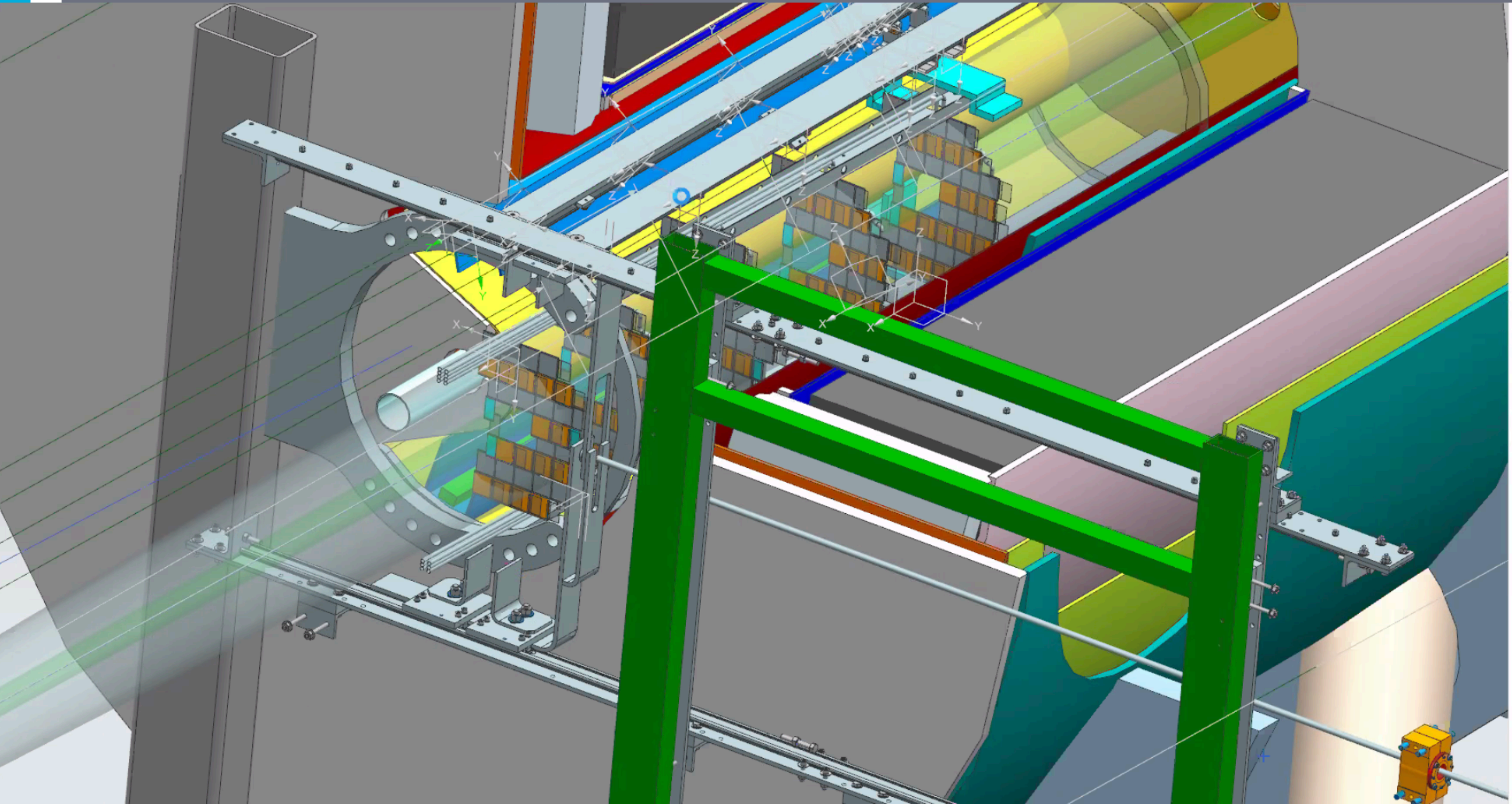


B0: integration



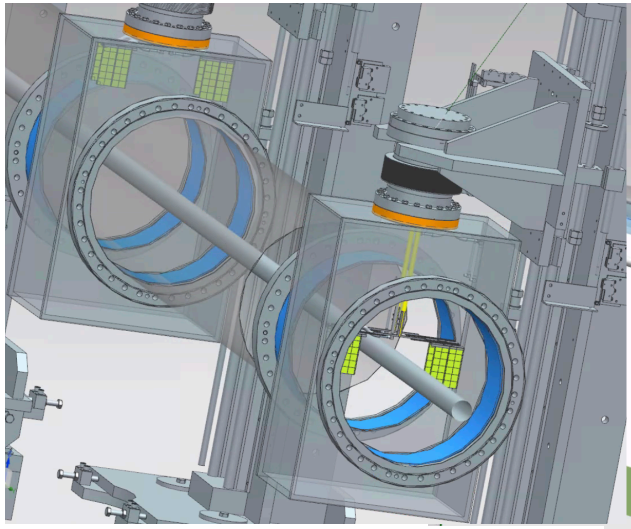


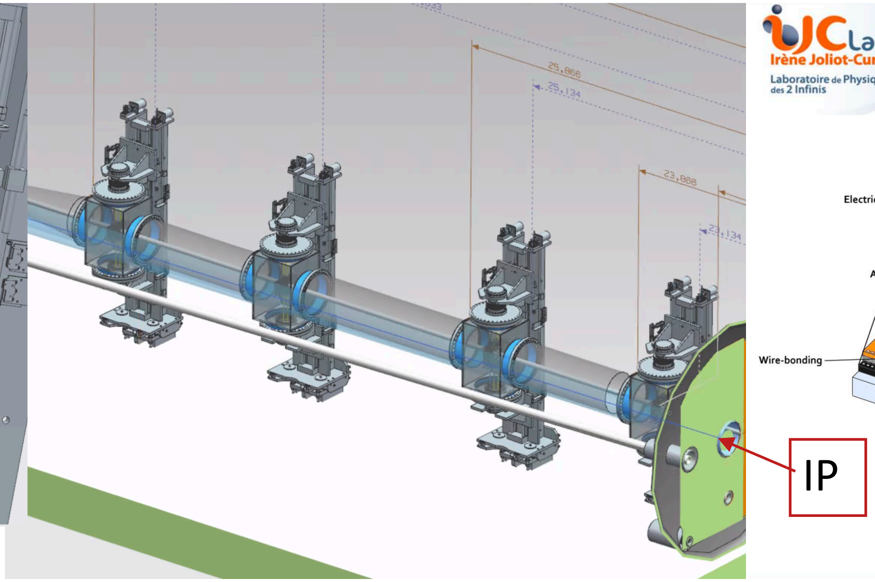
B0: integration

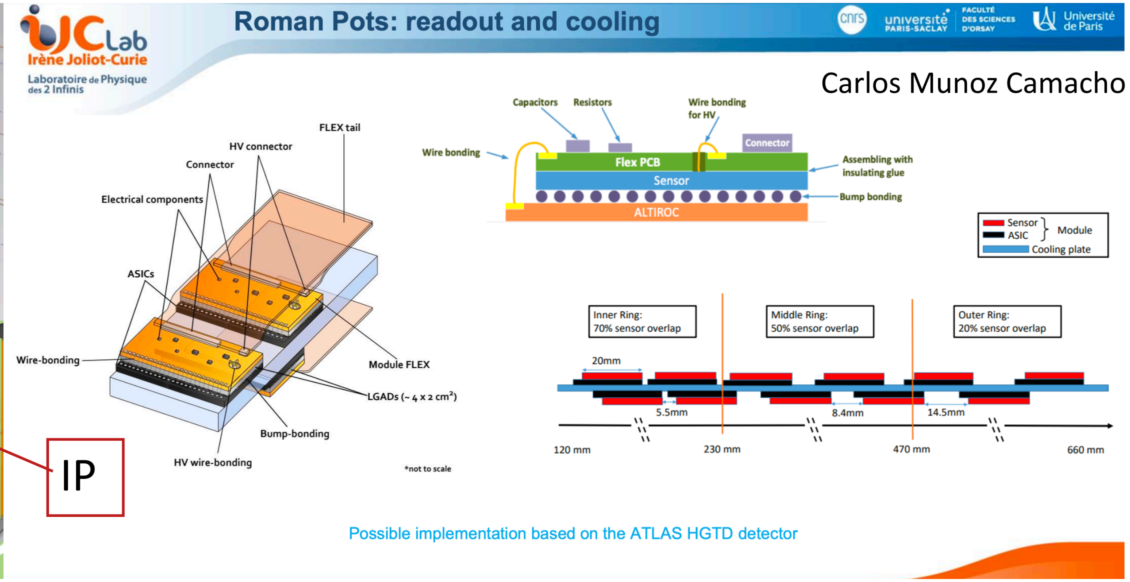


Roman Pots: readout, cooling, integration

- 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.
- Support structure, integration and RF -shielding - it is an iterative process , in collaboration with accelerator and vacuum team (impact on the accelerator)
- Exit window for the neutron cone -> minimize an amount of material on the way of neutrons.



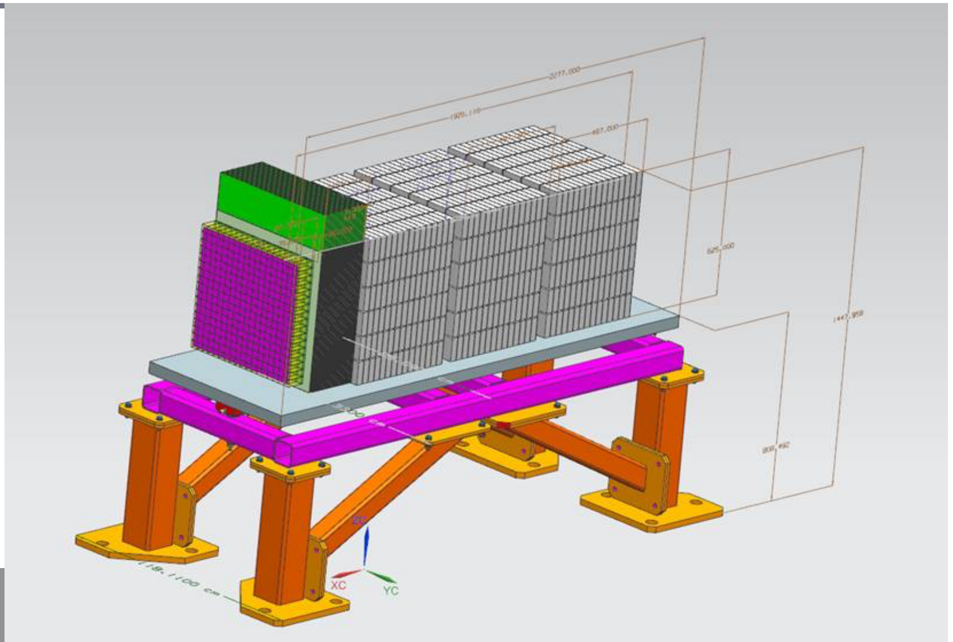


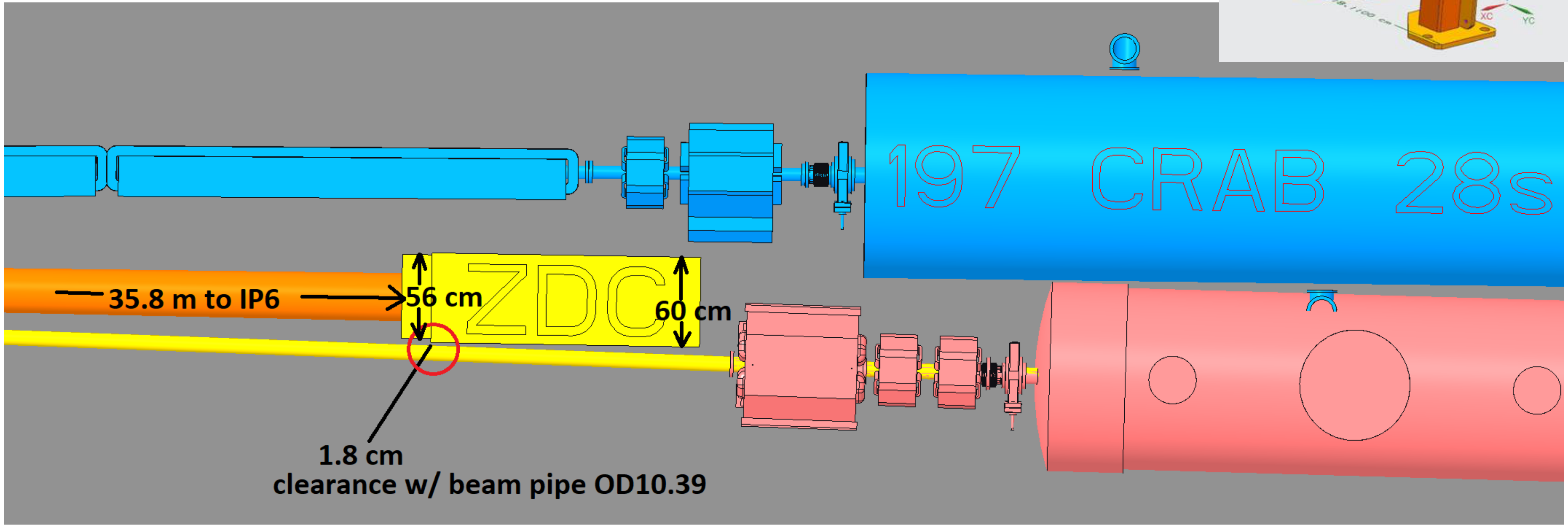


ZDC engineering design and integration

1. Readout and Cooling

2. ZDC integration with accelerator lattice:
z-location 35.8 m,
stay-clear zone around the hadron beam-pipe





Requirements and Interface documents - 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

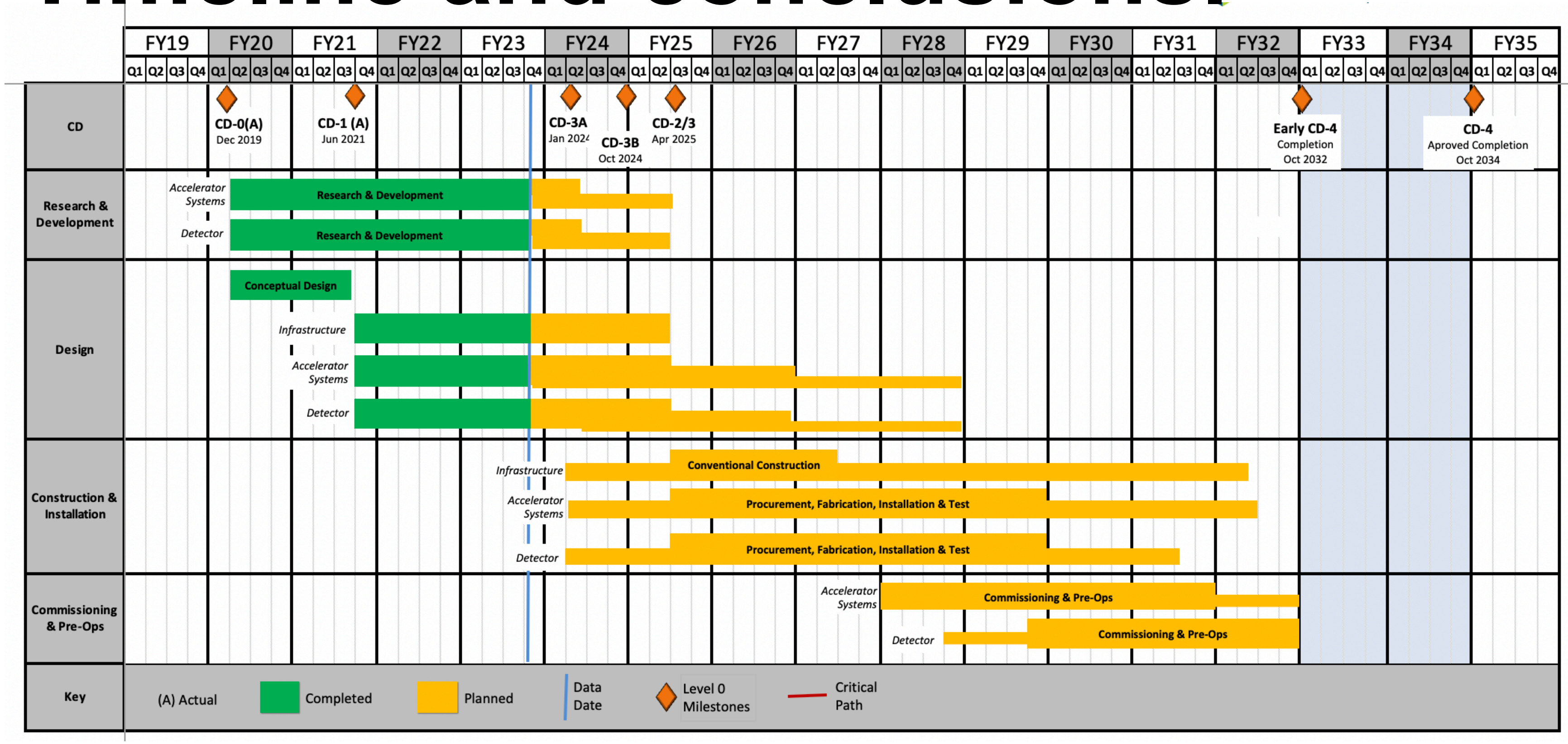
PERFORMANCE REQUIREMENTS

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

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.

Next step: detector specification

Timeline and conclusions.

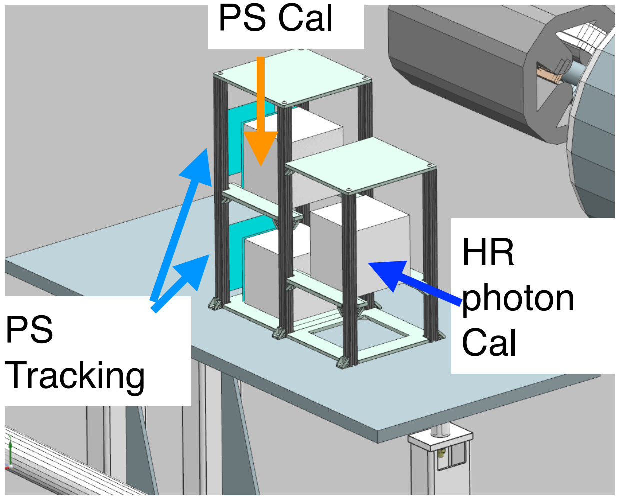


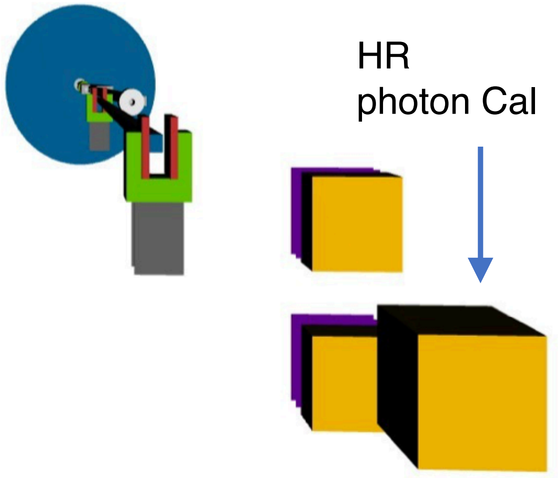
- ➢ Preliminary design review of ANC detectors in Dec 2023 - Jan 2024
- ➢ Need to select default configuration and update P6 cost and schedule before the review.
- ➢ Final design review end of 2024 (early 2025) + TDR (started a draft of TDR for low-Q2, but not for other subsystems)
- ➢ The installation 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.

Backup

Luminosity monitor: High rate photon Calorimeter

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

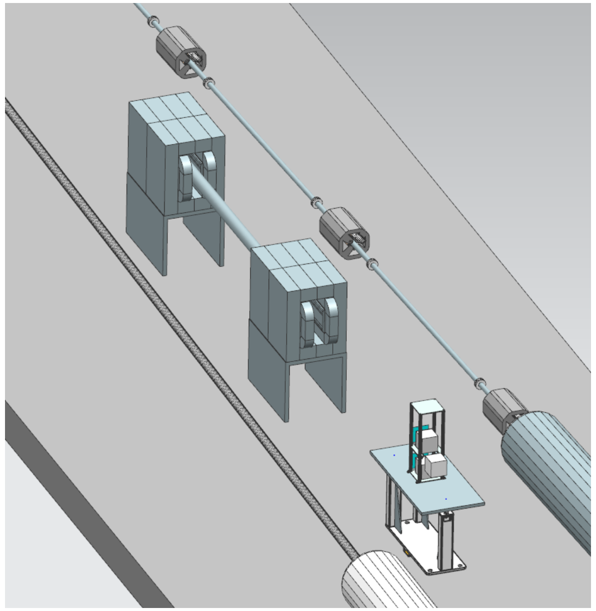




Base-line HRC detector choice:

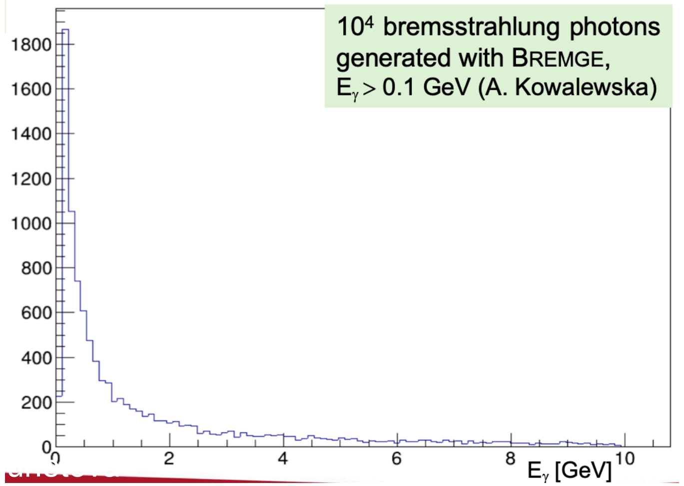
1. **Quartz fiber/tungsten spaghetti** calorimeter for energy flow – maximal **radiation hardness**

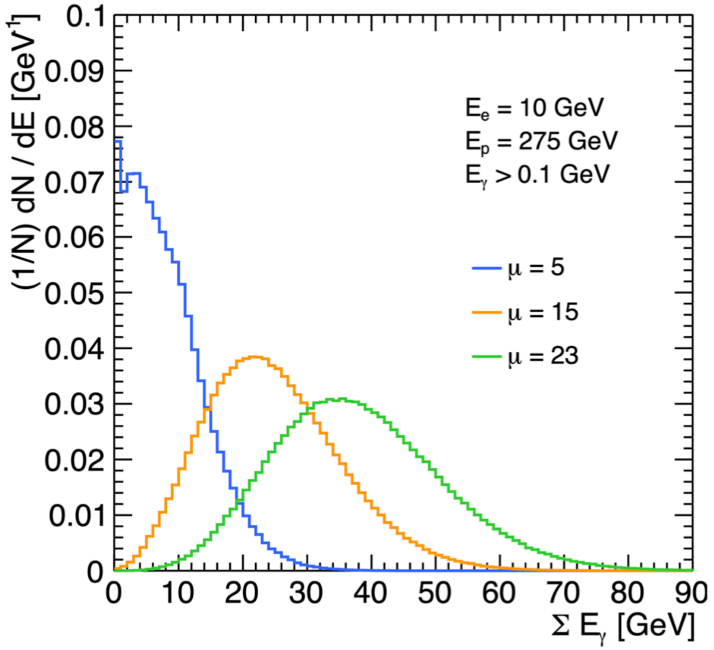
2. **Sci fiber/tungsten spaghetti** calorimeter for single photon measurements – maximal **energy resolution**



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





Luminosity monitor: Pair Spectrometer

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

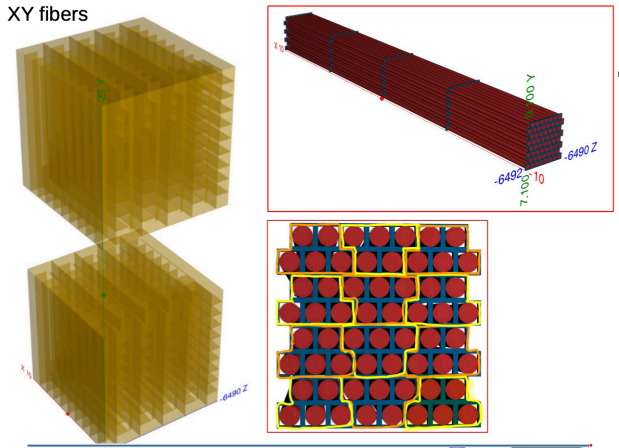
✓**Pair-Spectrometer Calorimeter**

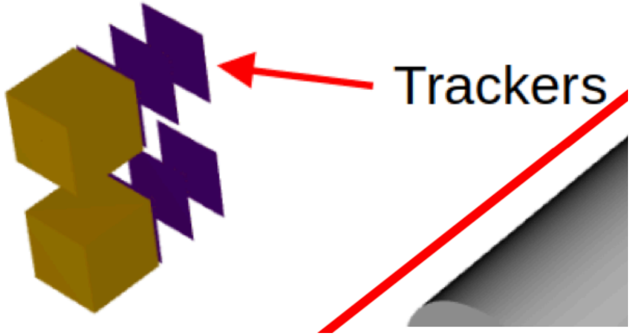
- ➡Technology: W-powder + epoxy infused into a bundle of scintillating fibers (like fECAL).
- ➡Total size 20cmx20cmx20cm
- ➡Module size 2x2x20cm^3
- ➡Five fibers (radius 0.1cm) are bundled to form a single readout channel

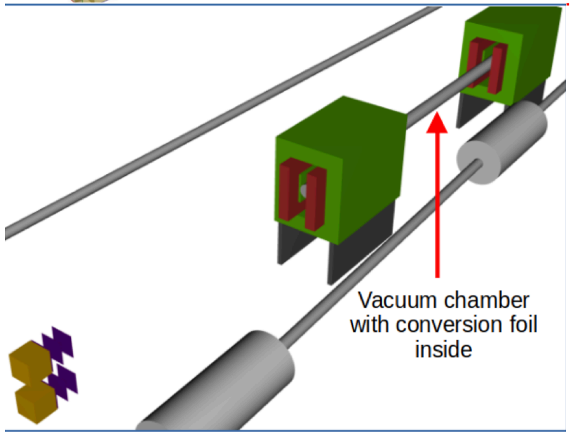
✓**Pair-Spectrometer tracker**

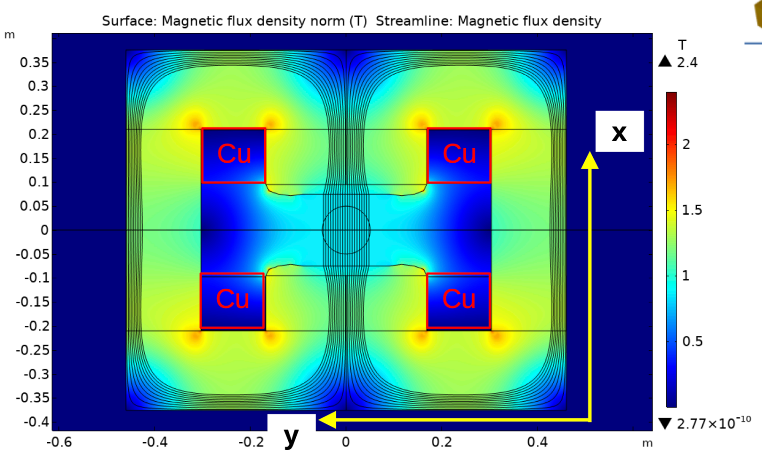
- ➡ AC-LGAD strips as for barrel TOF
- ➡Benefits from Tracking Planes in front of CALs:
  - Enables standalone detector calibration
  - Better energy resolutions
  - Well defined acceptance, no "fuzzy" edges as with CALs.
  - Rejection of background

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









Dipoles design properties:

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