Plan of LumiCal and luminosity monitor

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On behalf of CEPC LumiCal team

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Luminosity measurement at CEPC

- Targeted precision of luminosity measurement: $O(10^{-4})$
  - counting the rate of the well-known process

$$L = \int \mathscr{L} \mathrm{d}t = \frac{1}{\epsilon} \frac{N_0}{\sigma_0^{\mathrm{th}}} \qquad \frac{\Delta L}{L} = \frac{\Delta N_0}{N_0} \oplus \frac{\Delta \epsilon}{\epsilon} \oplus \frac{\Delta \sigma_0^{\mathrm{th}}}{\sigma_0^{\mathrm{th}}}$$

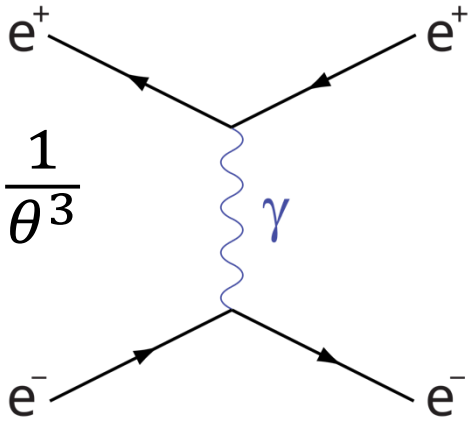
- Small-angle Bhabha scattering (SABS)

  $e^+e^- \rightarrow e^+e^-$, dominant process in e+e- colliders

$$\sigma = \frac{16\pi\alpha^2}{s}\left(\frac{1}{\theta_{min}^2} - \frac{1}{\theta_{max}^2}\right)$$

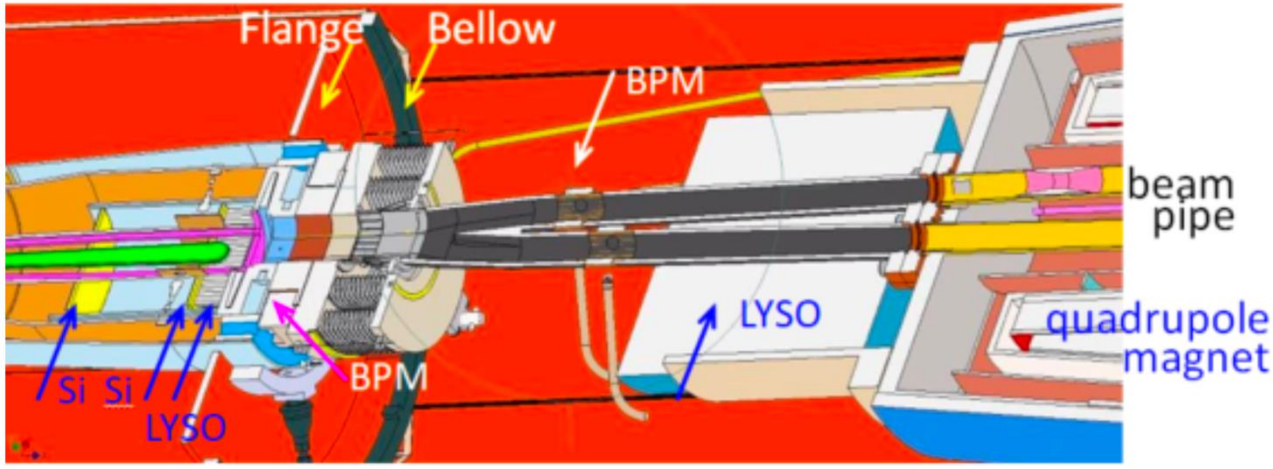
$$= \frac{1040\ \mathrm{nb\ GeV^2}}{s}\left(\frac{1}{\theta_{min}^2} - \frac{1}{\theta_{max}^2}\right)$$

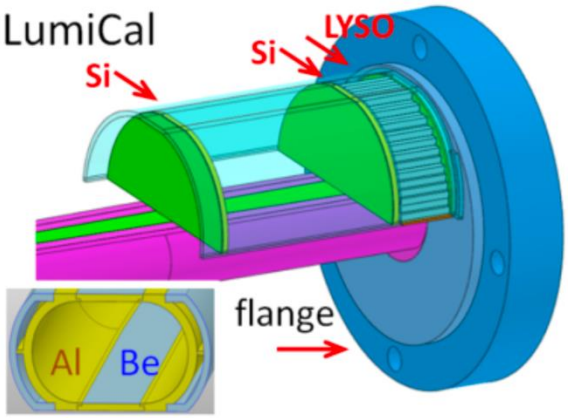
$$\frac{d\sigma}{d\theta} \sim \frac{1}{\theta^3}$$



CEPC LumiCal design

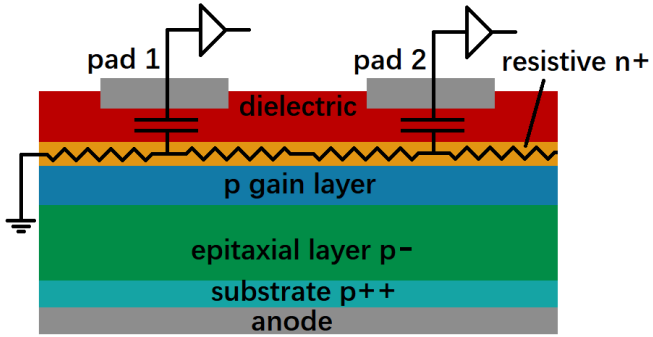
- Dedicated detectors at each side of Interaction Point
  - Low-mass beampipe window: Be 1mm thick, traversing @22 mRad, traversing L= 45 mm, = 0.13 X_0 (Be), 0.50 X_0 (Al)
- Three types of sub-detectors
  1. Si-tracker: photon/electron identification
  2. LYSO+SiPM: energy measurement
  3. Dimond detector: IP position monitor and fast luminosity monitor

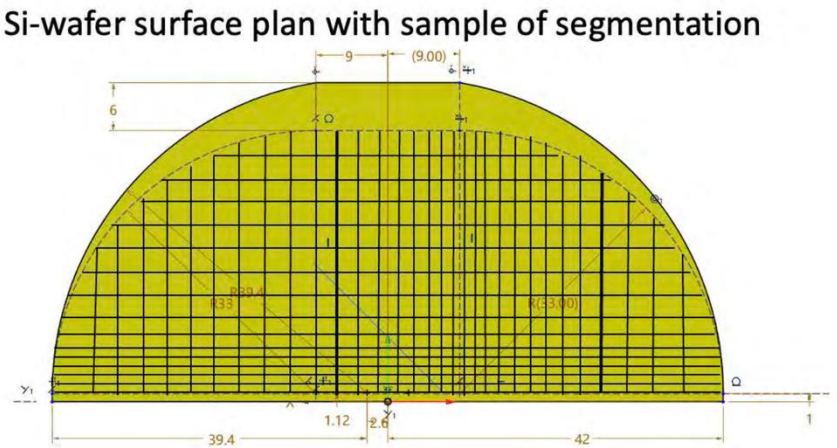


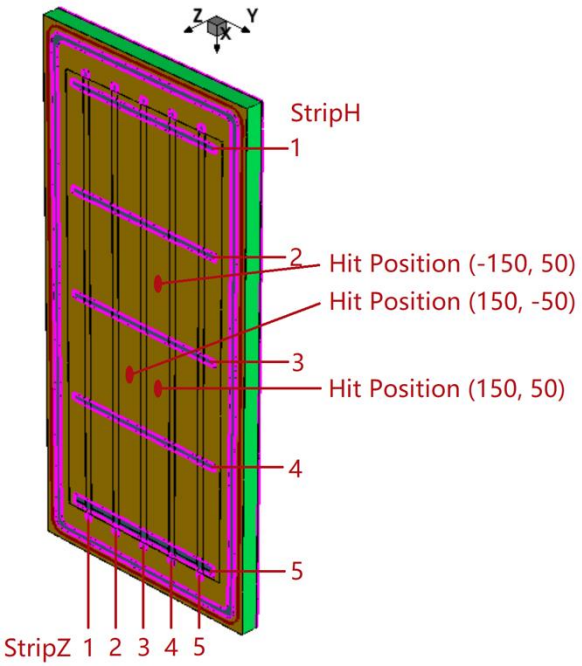


1. Si-tracker

- 2D readout AC-LGAD: a double AC layer configuration
  - Designed by Mei Zhao (from IHEP), together with Xiaoxu Zhang (PhD student from NJU)



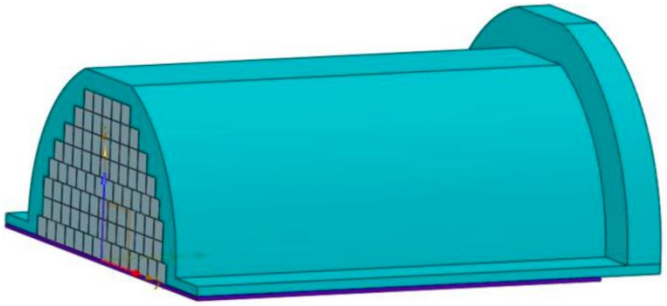


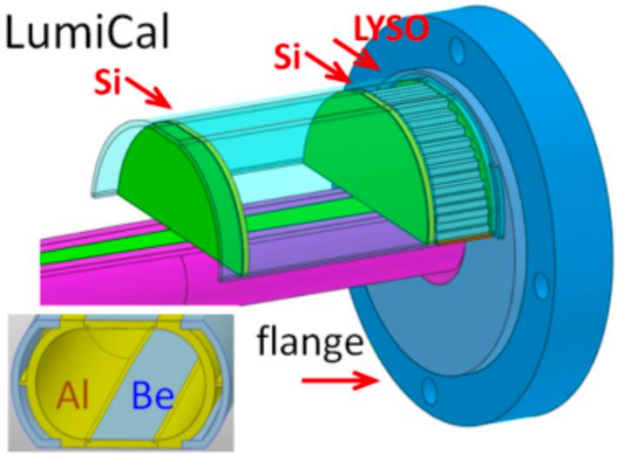


- First 2D AC LGAD sensor manufactured
  - Thanks to OTK group!
  - May need help to setup the test system
- Further iteration needed

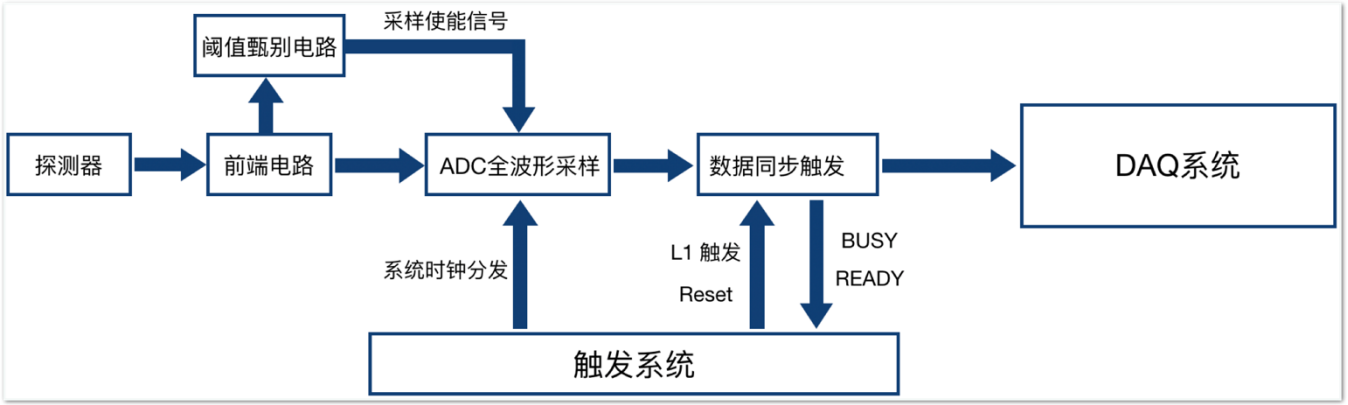
2. LYSO+SiPM calorimeter

- Before flange: 2 X_0 LYSO (23 mm) @ $z = 560 \sim 700$ mm
- After Bellow: 13X_0 LYSO (150 mm) @ $z = 900 \sim 1100$ mm



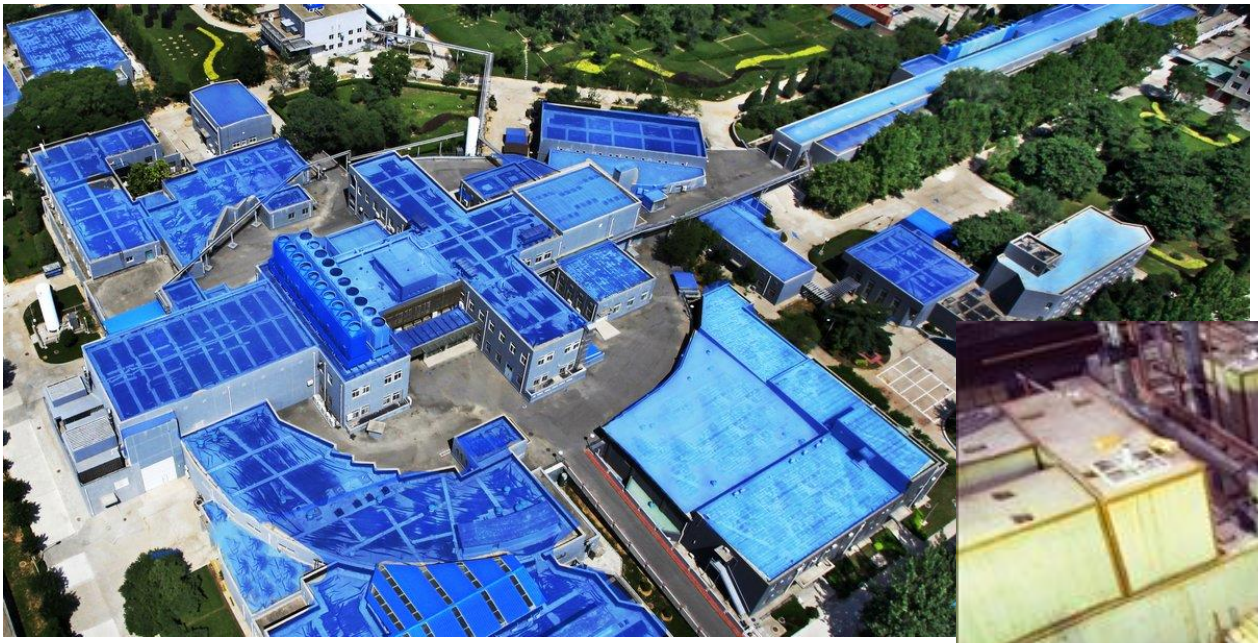


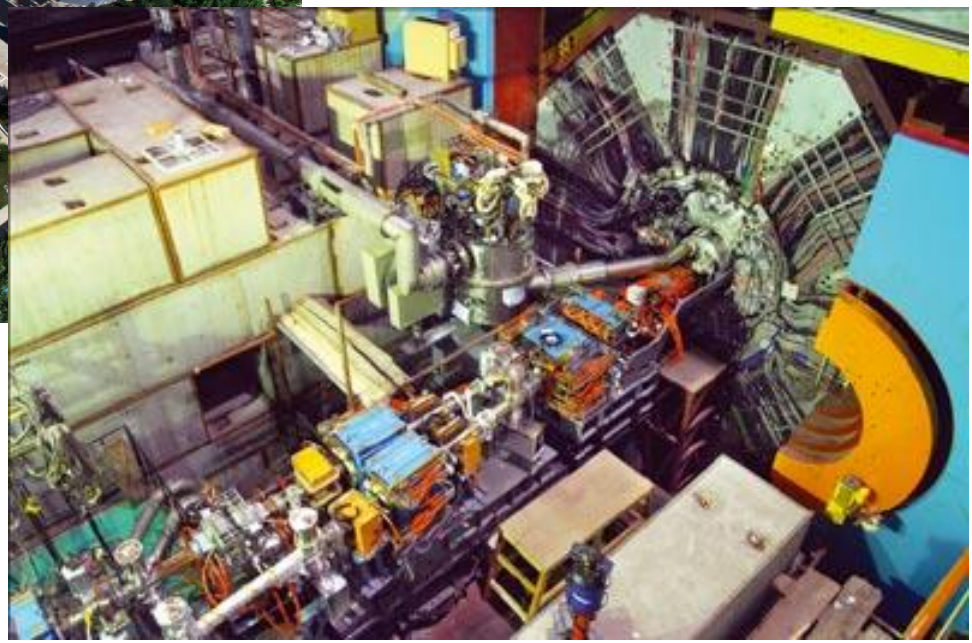
- Plan: middle size prototype
  - 3x5 array of 1x1x3 cm^3 LYSO+SiPM
  - Full chain: detector, electronics, cabling, shielding, Trigger & DAQ and etc.



2. LYSO+SiPM calorimeter

- BEPCII-BESIII experiment
  - e+e- collider, COM energy: ~2-5 GeV, Luminosity: ~$10^{33}cm^{-2}/s$



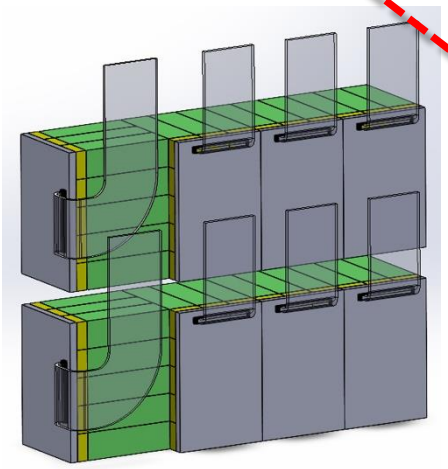


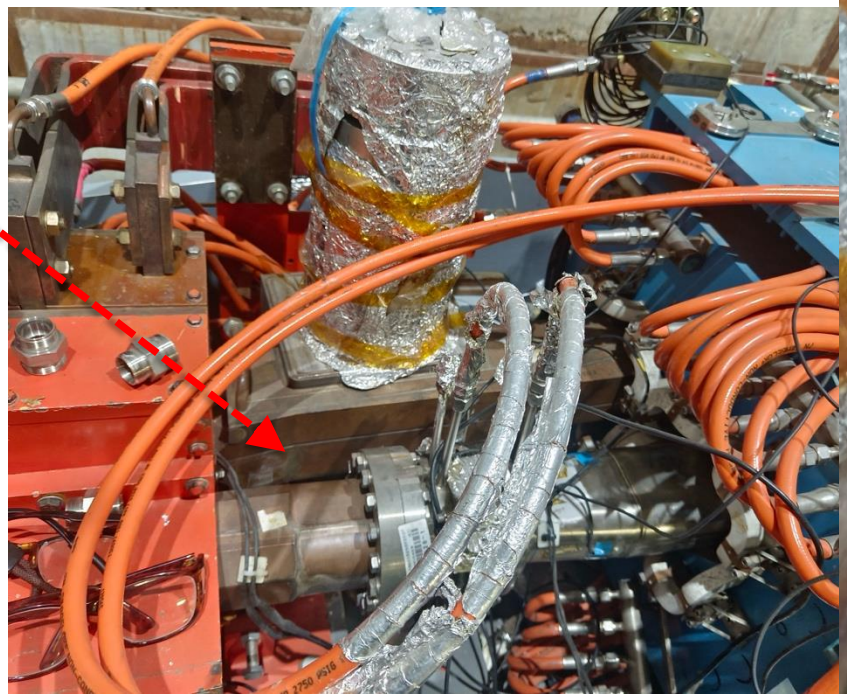
2. LYSO+SiPM calorimeter

- BEPCII-BESIII experiment
  - e+e- collider, COM energy: ~2-5 GeV, Luminosity: ~$10^{33}cm^{-2}/s$
  - Zero Degree Region: fast luminosity and ISR photon
  - LYSO+SiPM array, 240 channels in total

- Single detector module test

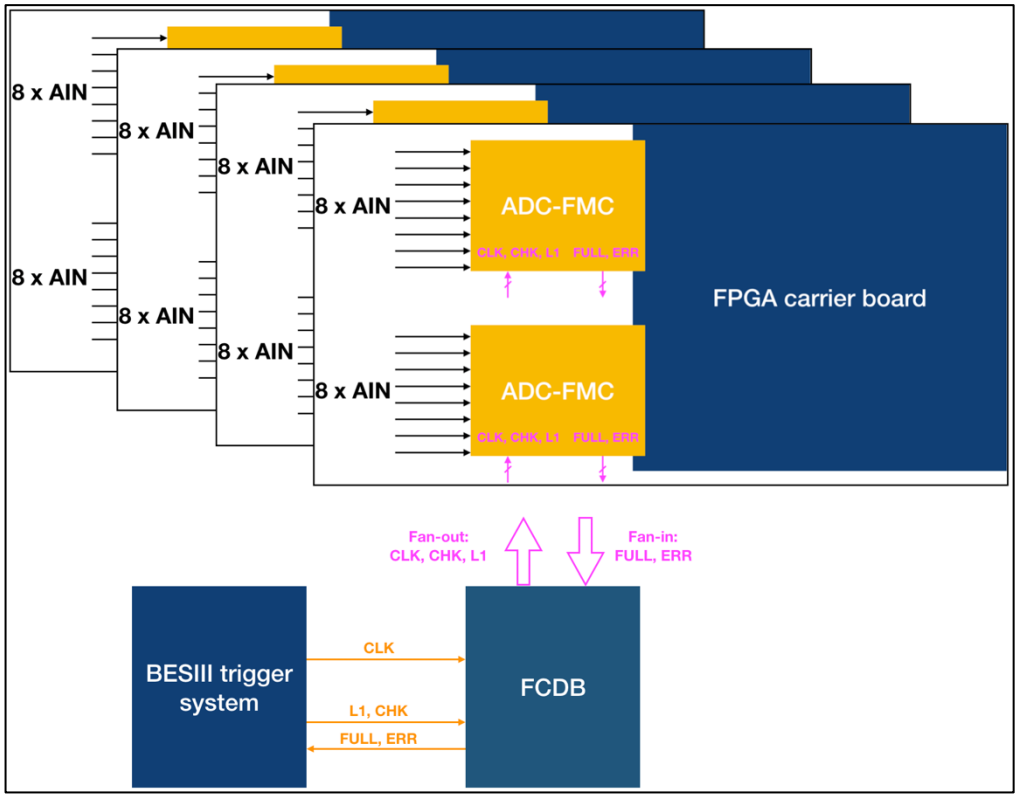
- 3.3m <z<3.5 m, θ=0 in CMS frame





2. LYSO+SiPM calorimeter

- Readout electronics design
  - Trigger board(FCDB): Interface to BESIII trigger system
  - ADC board(ADC-FMC): Carrier board through FMC connector

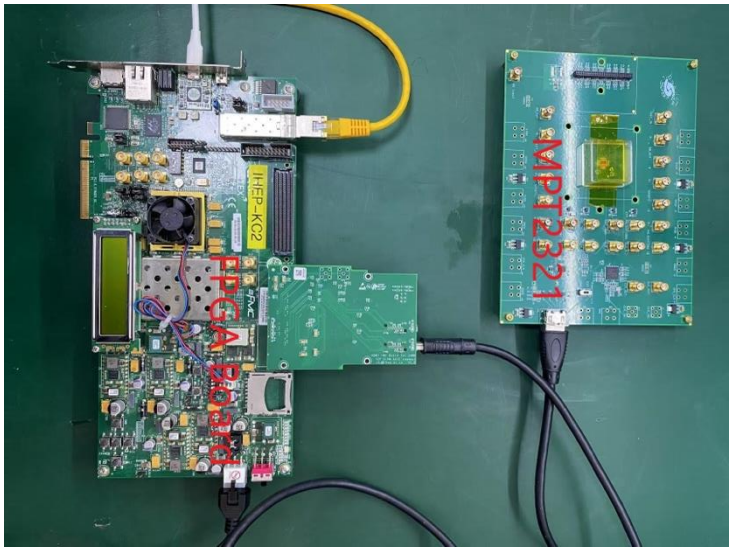


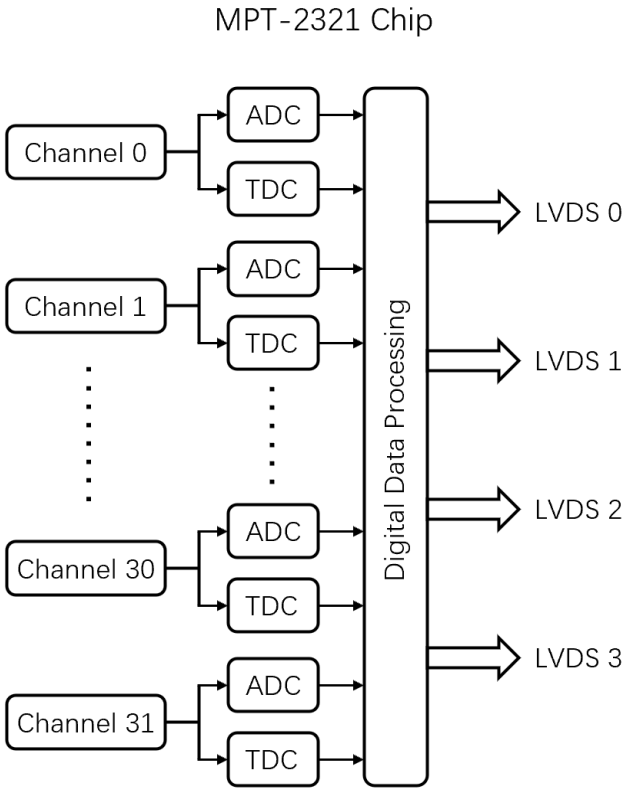
- FPGA carrier board: Process digitized signal from ADC, send to DAQ

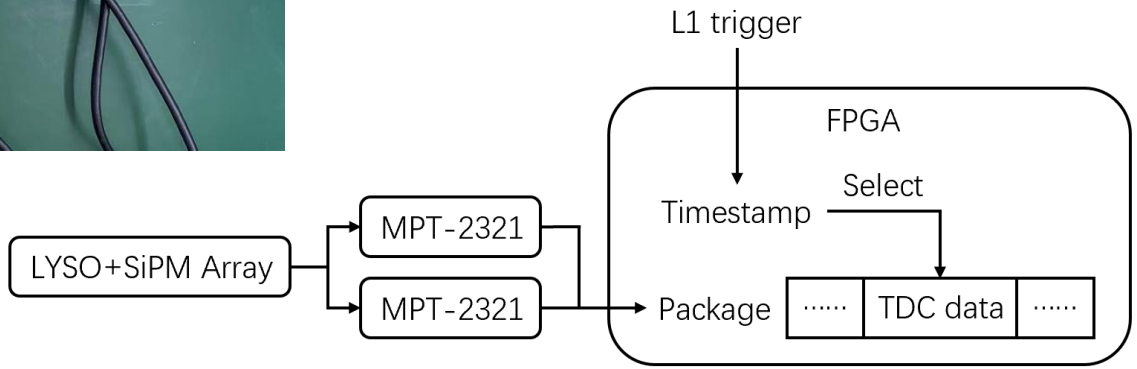
Trigger&data flow

2. LYSO+SiPM calorimeter

- Future upgrade: ASIC based readout
- MPT-2321: SiPM Signal Processing Chip
  - 32 input channels
  - 12-bit ADC, 20-bit TDC with 50ps resolution

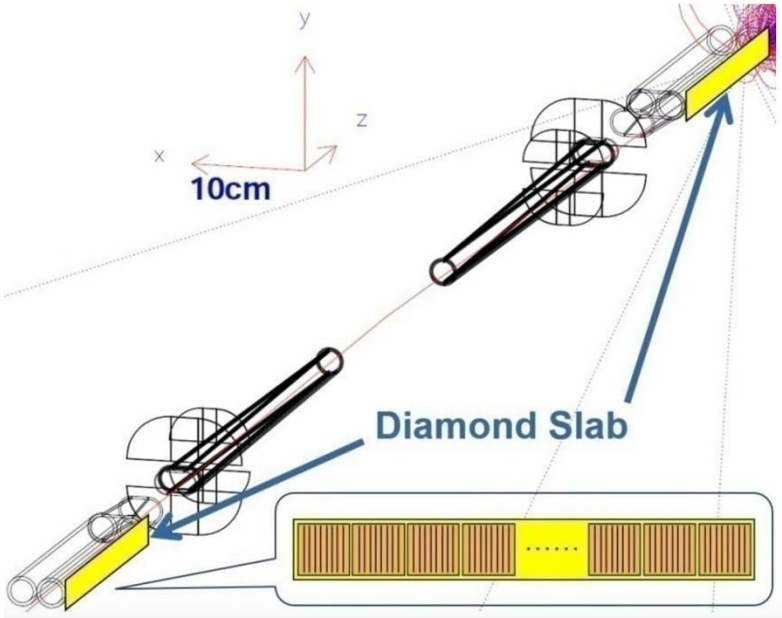


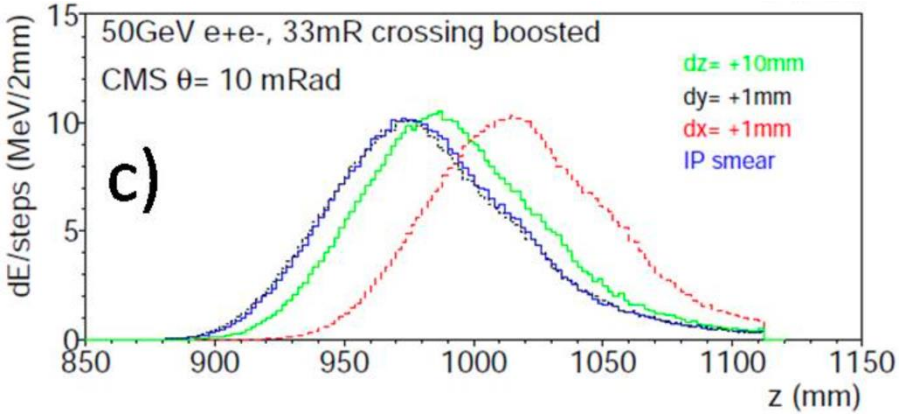




3. Diamond detector

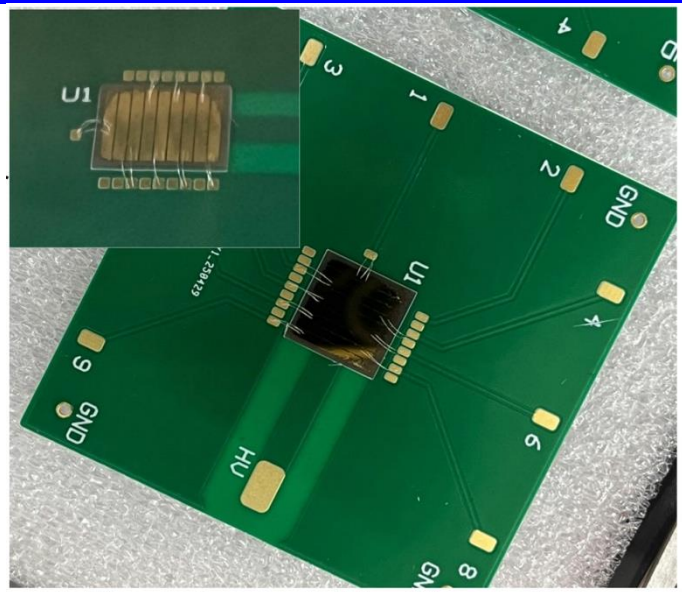
- IP measurement along z-axis and Fast luminosity monitor
  - |z|= 855~1110 mm diamond slab, on sides of beampipe
  - Monitoring small angle Bhabha electrons
  - Differing event rates on +z and -z sides for IP offset





3. Diamond detector

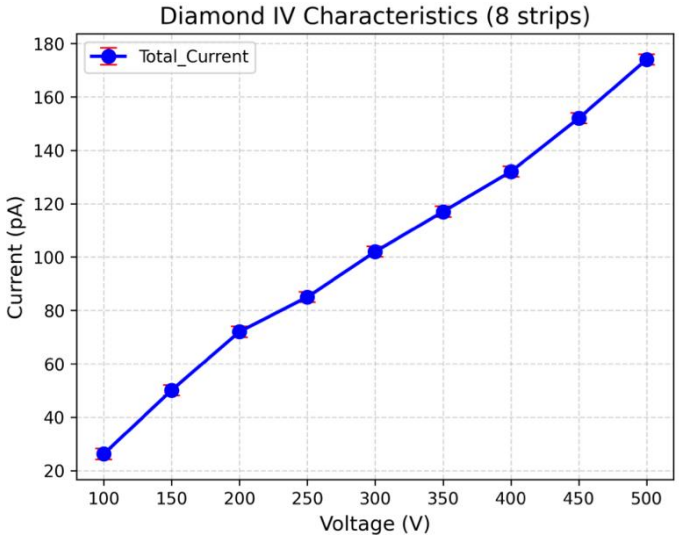
- Strip electrode
  - Full surface process chain
- Plan
  - Need new high quality diamond for further studies, e.g. MIP response, etc.

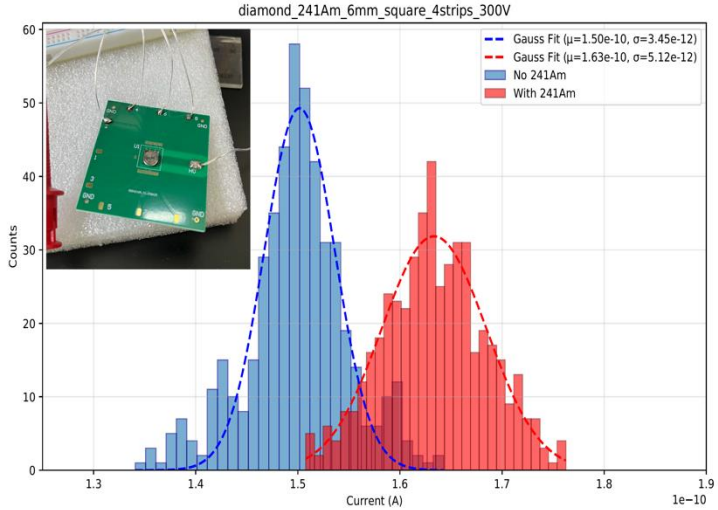


2. Diamond sensor 9 strips 10 mm × 10 mm

Preliminary tests with source meter:

- I-V, Alpha radioactive source





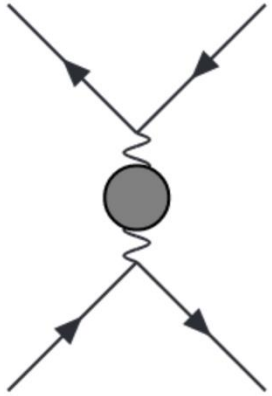
Summary

- CEPC LumiCal system design finished
- Extensive detector R&D performed
  - Si tracker: first version of novel 2D AC-LGAD sensor produced
    - Need help to setup the test system and resources for future iterations
  - LYSO+SiPM calorimeter: get support from BEPCII luminometer upgrade,
    - Prototyping and tests at collider
  - Daimond: surface process tested with an old diamond chip
    - Need high quality diamond for further R&D

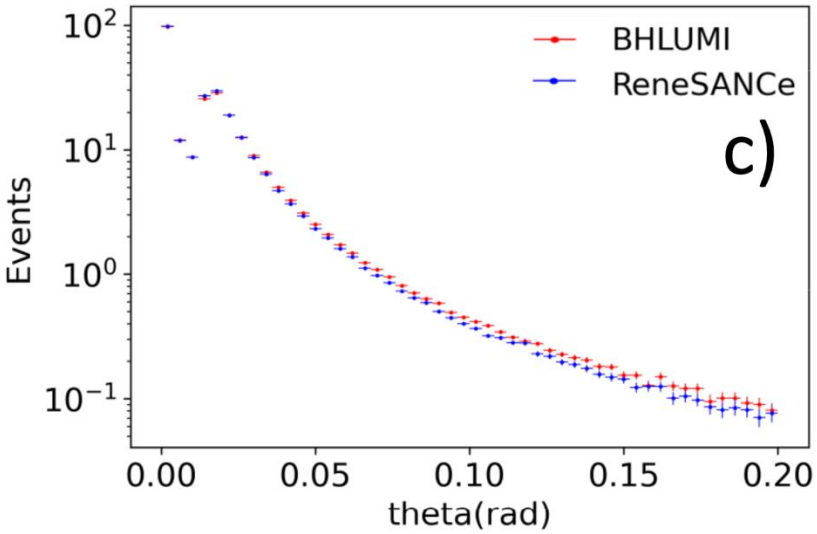
The end

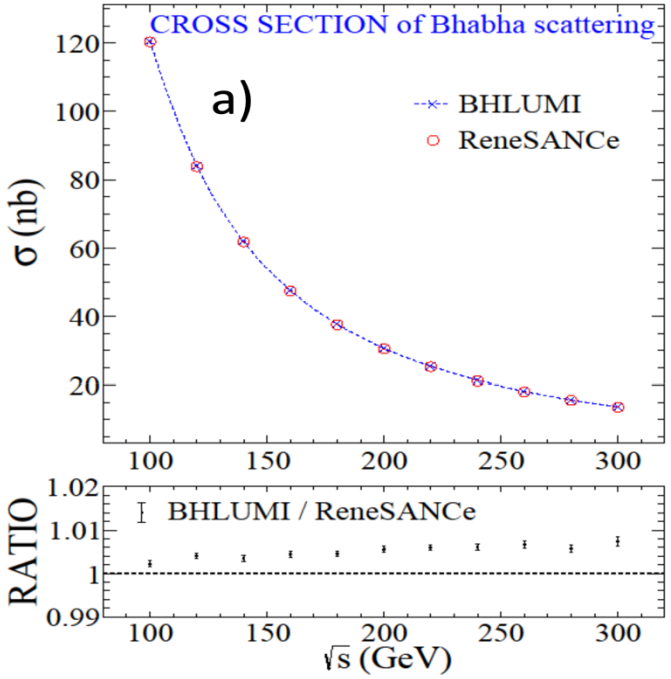
(backup)Theoretical challenges

- Hadronic vacuum polarisation contribution
  - Extracted from data for e^+e^-→hadrons or from lattice QCD
  - Data-driven from (BelleII, BESIII, CMD-3, SND), expected the uncertainty to be reduced below 10^{-4} level



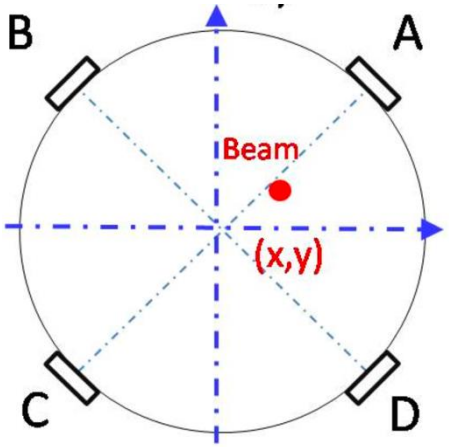
- Generator studies
  - BHLUMI 4.04 S. Jadach, 0.037% precision [PLB 803 (2020) 135319]
  - ReneSANCe, a recent NLO generator [CPC 256 (2020) 107455]





Beam Position Monitor

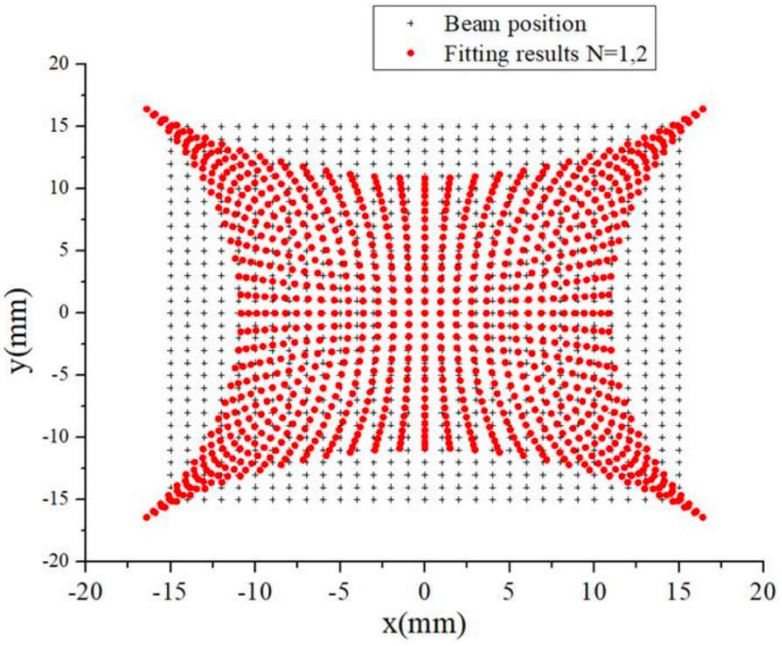
- Survey/monitoring, for Beam IP position
  - Beam Probe Monitor BPM , IP x,y to 1 μm
  - Position monitoring, Flange dx,dy ~1 μm, dz~ 50 μm

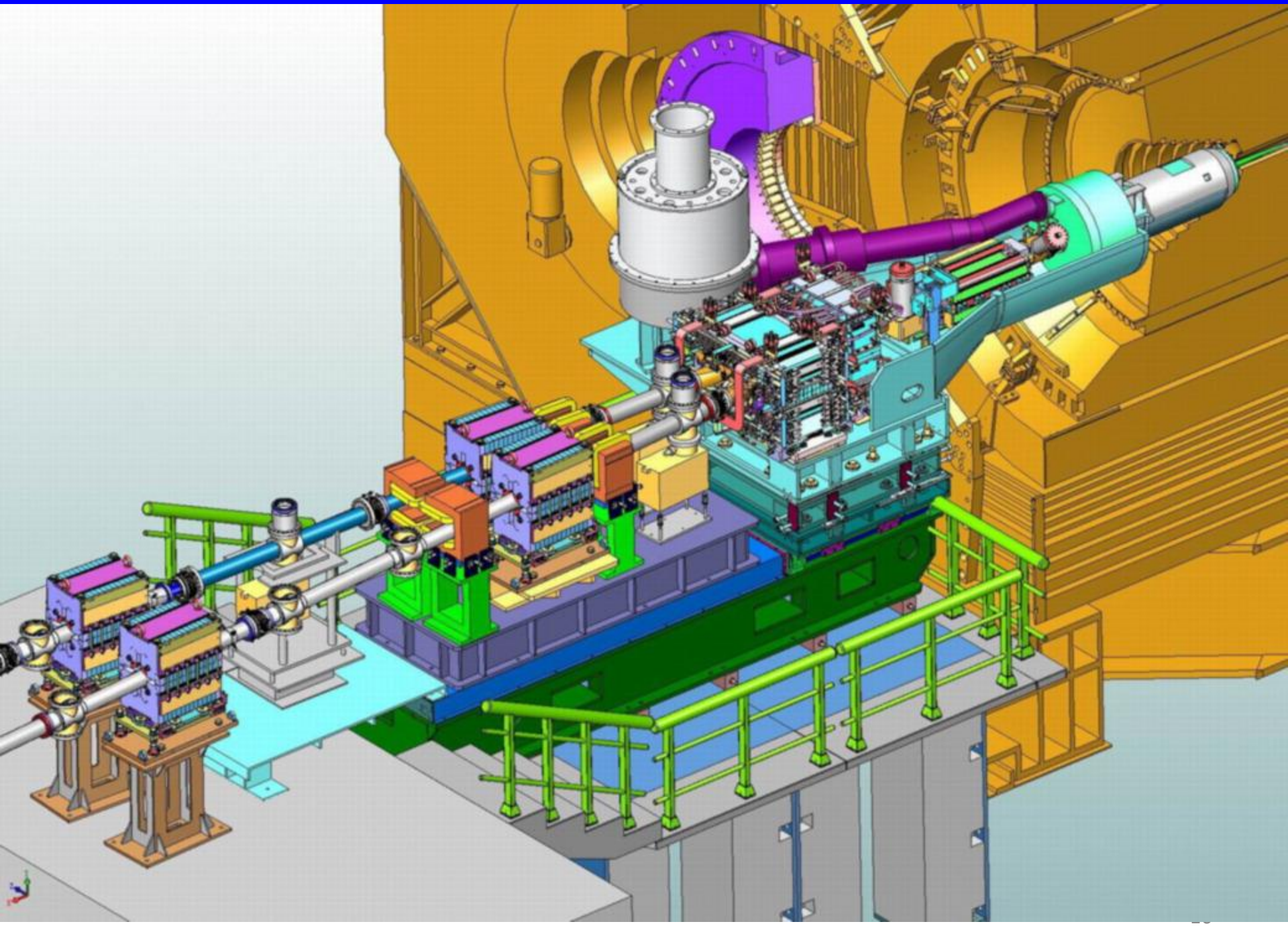


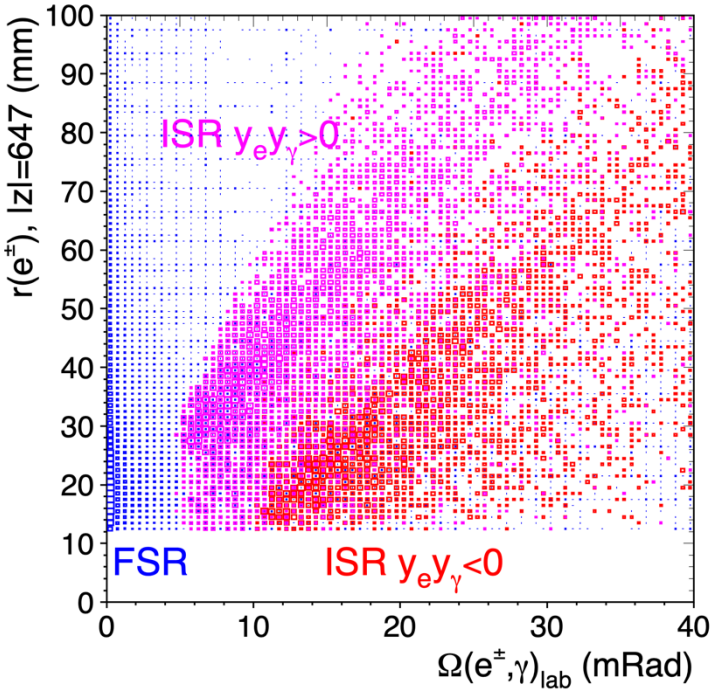
$$x, y = f(x_{raw}, y_{raw})$$

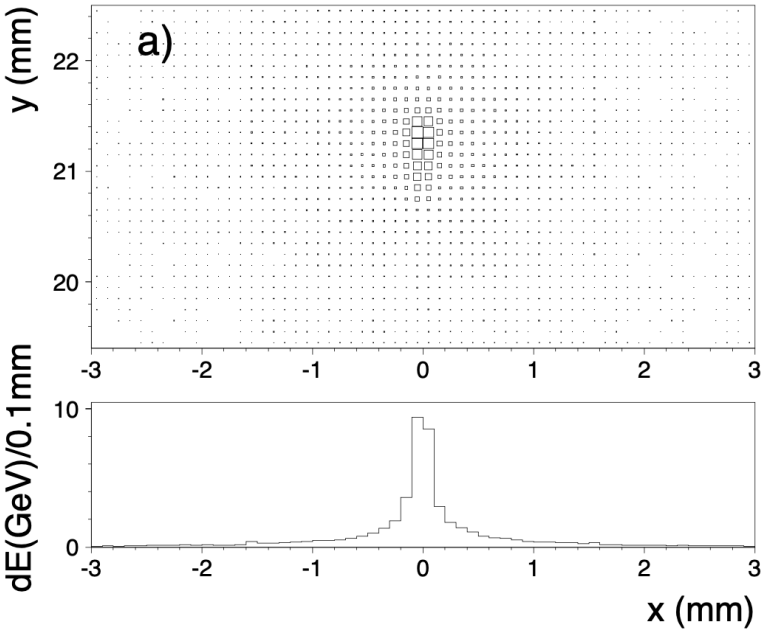
$$x_{raw} = \frac{Va + Vd - Vb - Vc}{Va + Vb + Vc + Vd}$$

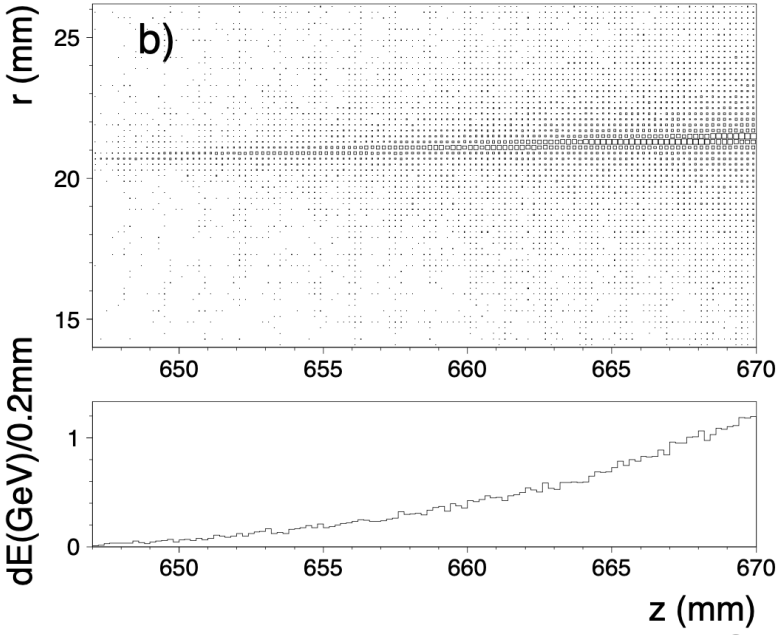
$$y_{raw} = \frac{Va + Vb - Vc - Vd}{Va + Vb + Vc + Vd}$$






r(e±), |z|=647 (mm)
ISR $y_e y_\gamma$>0
FSR
ISR $y_e y_\gamma$<0
Ω(e±,γ)lab (mRad)


a)
y (mm)
dE(GeV)/0.1mm
x (mm)


b)
r (mm)
dE(GeV)/0.2mm
z (mm)