IDEA: a detector concept for FCC

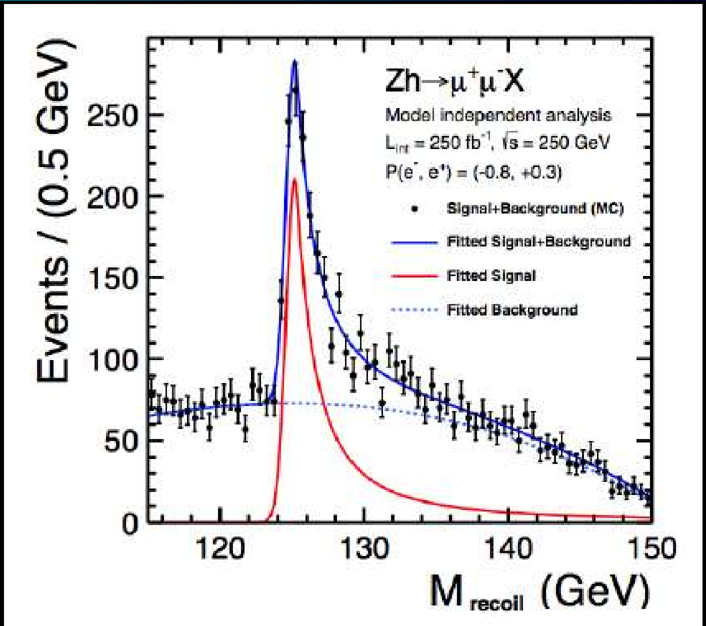
F. Bedeschi
FCC-WG11 meeting,
CERN, March 2018

Outline

- Main physics/technical drivers
- Detector layout
- Conclusions

Physics drivers recap

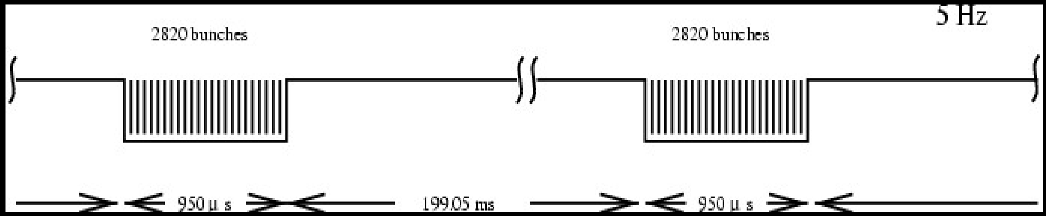
- Physics drivers
  - Higgs:
    - Tracking (recoil mass), vertex (b/c separation), calorimetry (hadronic W/Z, γγ), pre-shower (τ decays with π^0's)
  - Z pole:
    - Mostly covered by above
    - Excellent acceptance determination



Physics Process	Measured Quantity	Critical Detector	Required Performance
$ZH \to \ell^+\ell^- X$	Higgs mass, cross section	Tracker	$\Delta(1/p_T) \sim 2 \times 10^{-5}$
$H \to \mu^+\mu^-$	$\mathrm{BR}(H \to \mu^+\mu^-)$		$\oplus 1 \times 10^{-3}/(p_T \sin\theta)$
$H \to b\bar{b},\ c\bar{c},\ gg$	$\mathrm{BR}(H \to b\bar{b},\ c\bar{c},\ gg)$	Vertex	$\sigma_{r\phi} \sim 5 \oplus 10/(p \sin^{3/2}\theta)\ \mu\mathrm{m}$
$H \to q\bar{q},\ VV$	$\mathrm{BR}(H \to q\bar{q},\ VV)$	ECAL, HCAL	$\sigma_E^{\mathrm{jet}}/E \sim 3-4\%$
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\sigma_E \sim 16\%/\sqrt{E} \oplus 1\%$ (GeV)

Differences with ILC

- B field constrained by beam structure at IR (~ 2T)
  - TPC: issues with transverse diffusion
  - Silicon: can't compensate smaller tracking radius with large field

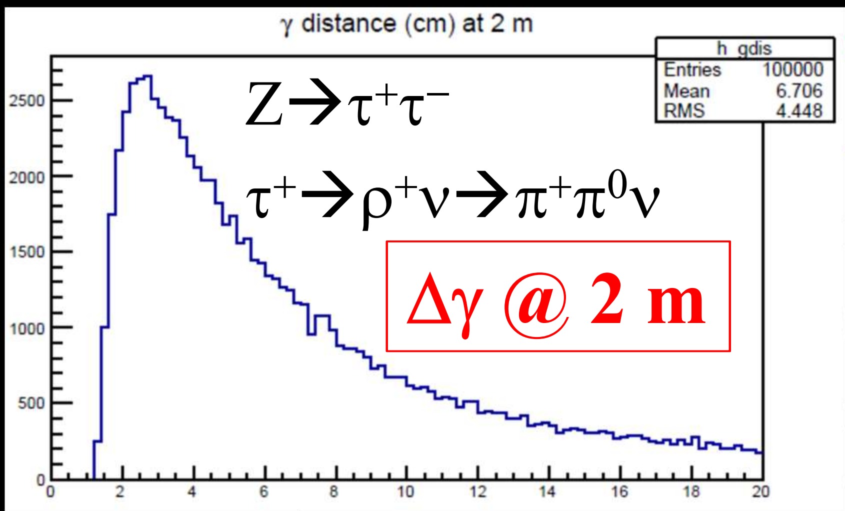


- Beam time structure:
  - Short bunch spacing (~ 20-30 ns Z, ~ 1 μs H)
  - No large time gap
    - Cooling issues for PF calorimeter and vertex detector
    - TPC ion backflow
  - Non-negligible machine backgrounds
    - Fast detector integrates less background in each readout

Other drivers

- Extreme statistical resolution on Z pole
  - Acceptance systematics control is critical
  - Silicon layer after DCH for charged resolution and acceptance
  - Pre-shower with high precision and stability allows μm level acceptance definition for γ
- π^0 important in tau and HF physics
  - No π^0: 35% $\tau \to 1\,(e, \mu)\,\nu\nu$ + 20% $\tau \to (1,3)\pi^{\pm}\,1\nu$
  - 1 π^0: 28% $\tau \to (1,3)\pi^{\pm}\pi^0 1\nu$
  - 2 –3π^0: 10% $\tau \to \pi^{\pm}\,(2,3)\,\pi^0 1\nu$

Other drivers



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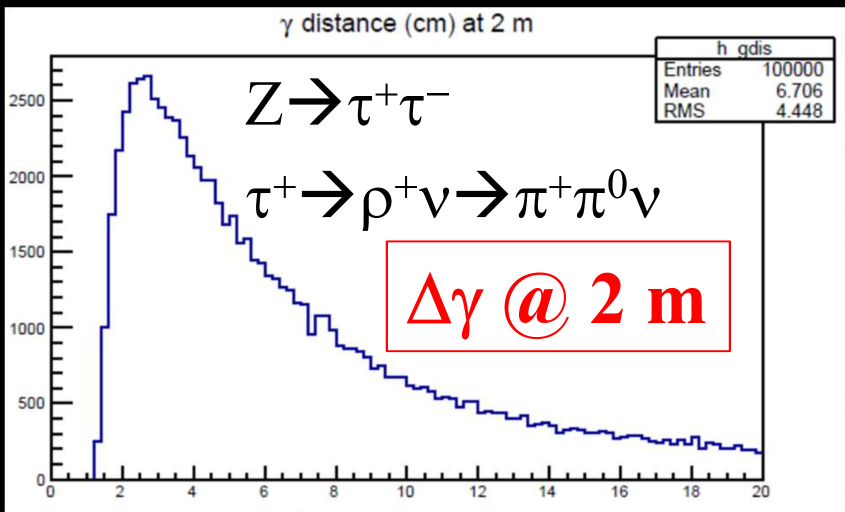
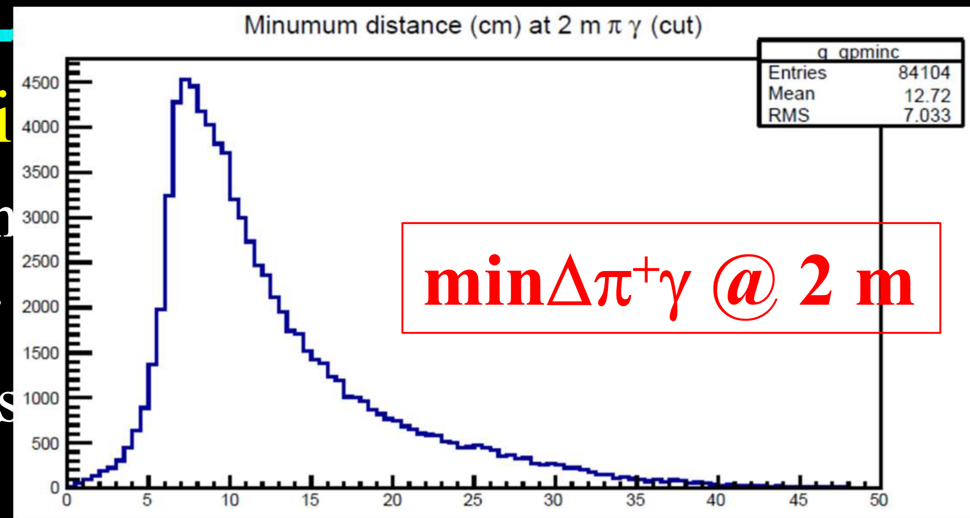
  - 2 –3π^0: $10\%\ \tau \rightarrow \pi^\pm (2,3)\ \pi^0 l\nu$
- Pre-shower improves π^0 identification

Other drivers





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  - Overlap with π^+ may require longitudinal segmentation

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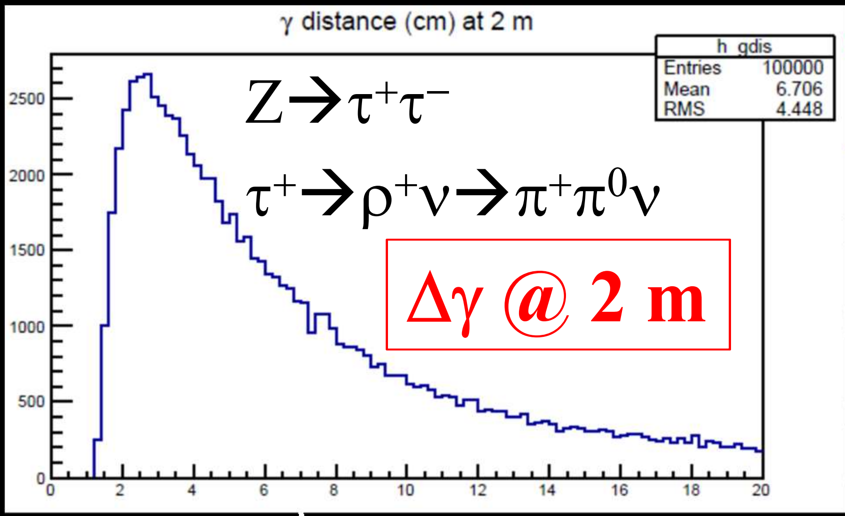

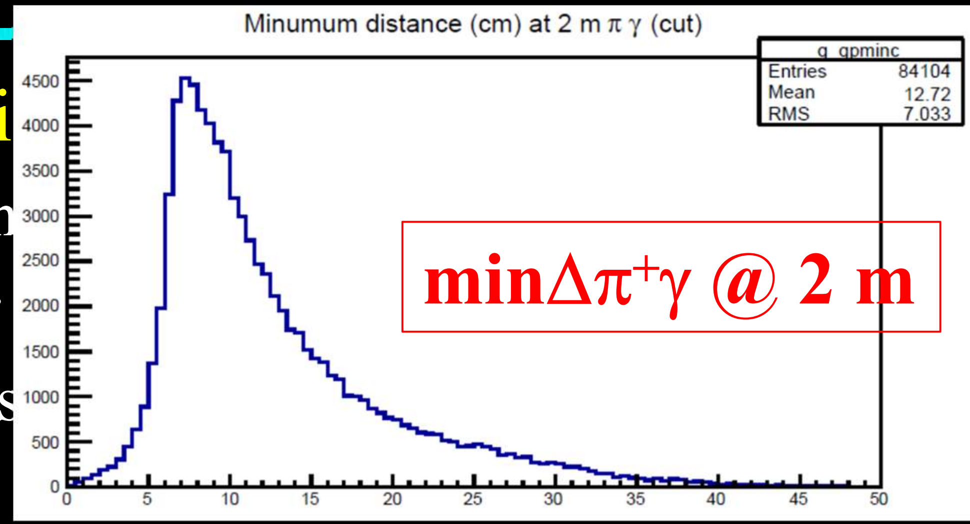

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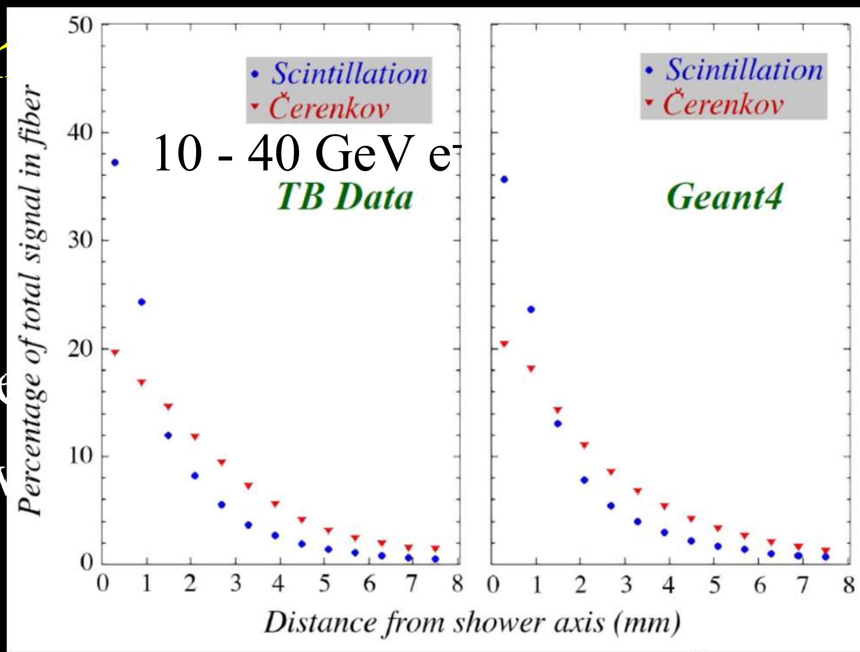
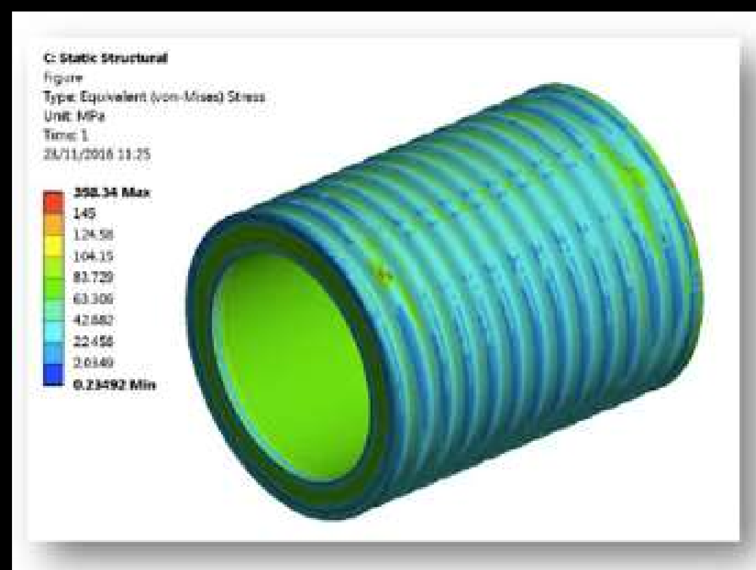


Detector solenoid

❖ 2T field solenoid – Rin = 2 m

- Can be made very thin ~30 cm total = 0.74 X_0 (0.16 λ) at $\theta = 90^{\circ}$
  - Calorimeter can be located outside coil
- Small yoke thickness 50-100 cm Fe
  - Scales with B R^2 → cost reduction over large coil

Property	Value
Magnetic field in center [T]	2
Free bore diameter [m]	4
Stored energy [MJ]	170
Cold mass [t]	8
Cold mass inner radius [m]	2.2
Cold mass thickness [m]	0.03
Cold mass length [m]	6



Courtesy of H. ten Kate et al.

Detector layout

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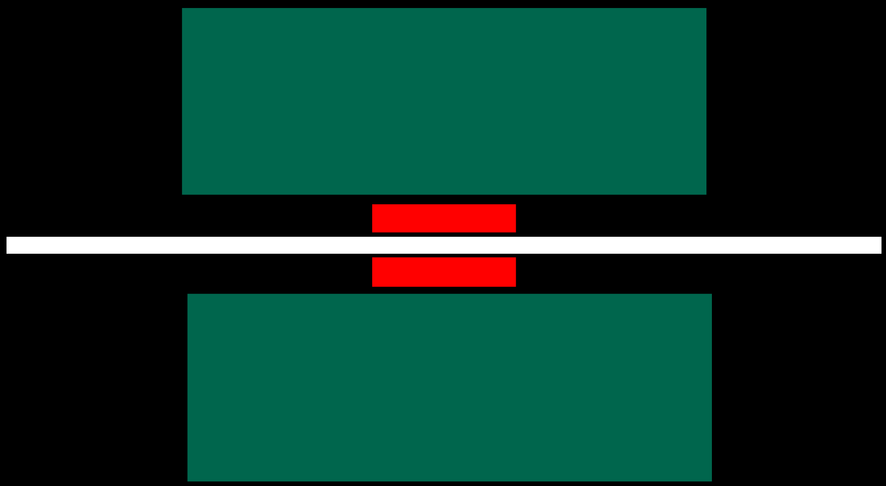

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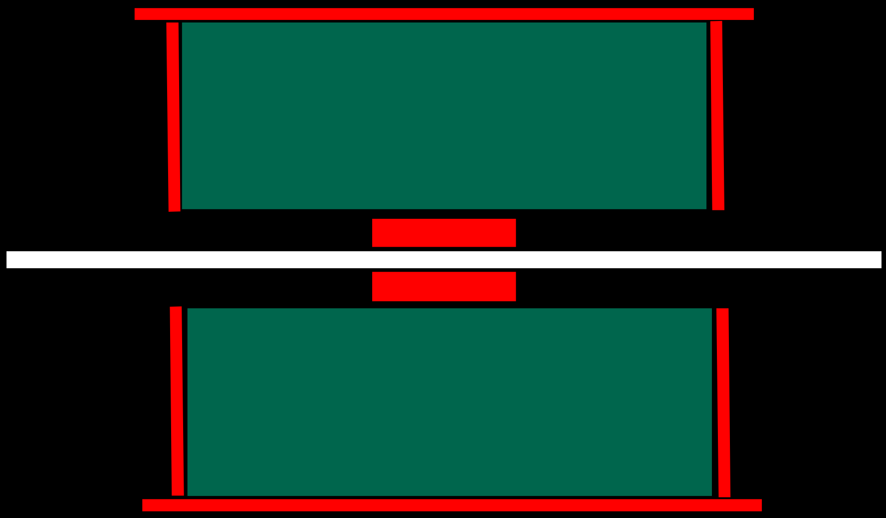

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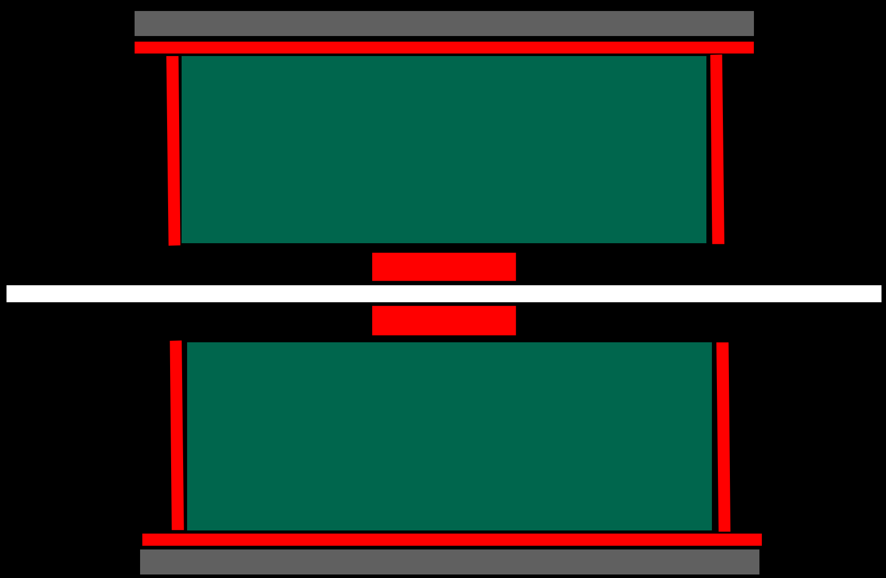

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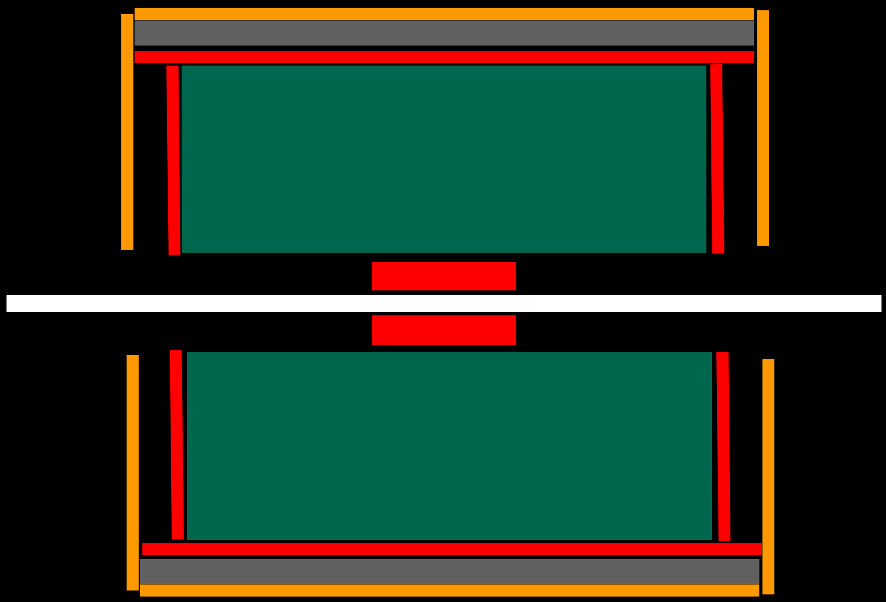

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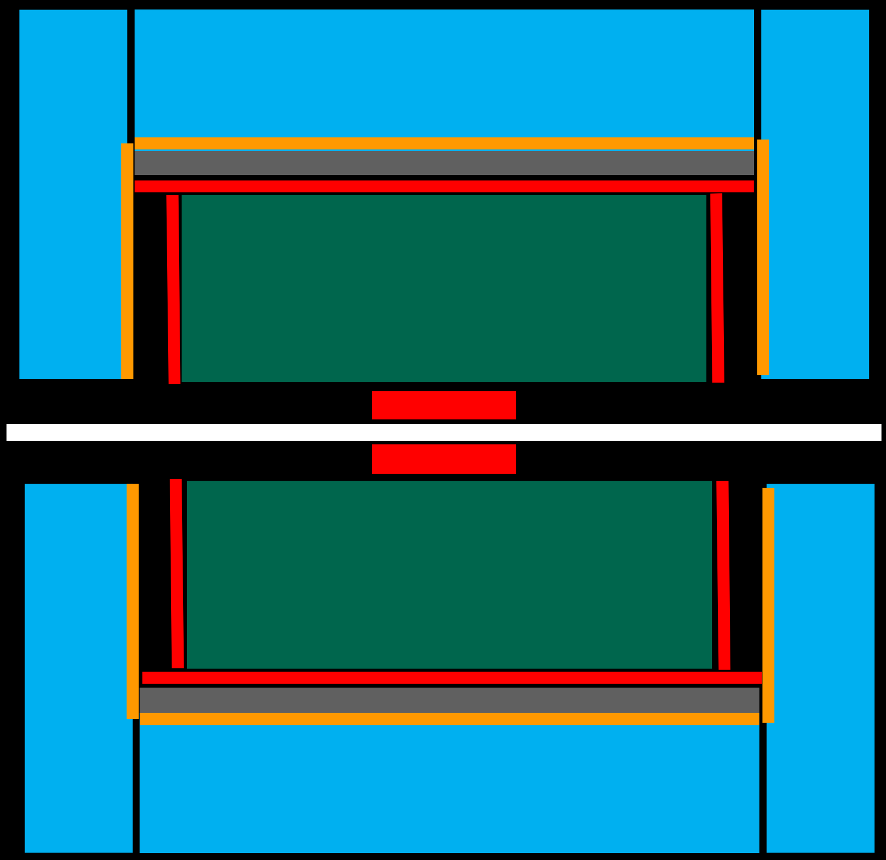

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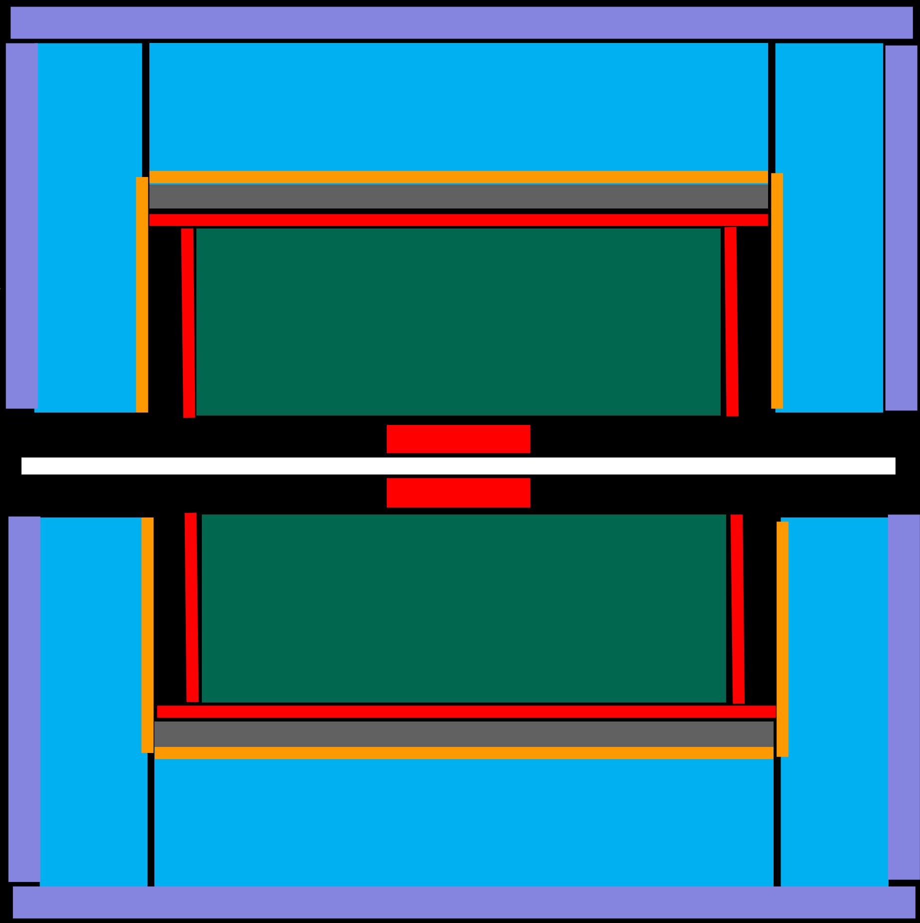
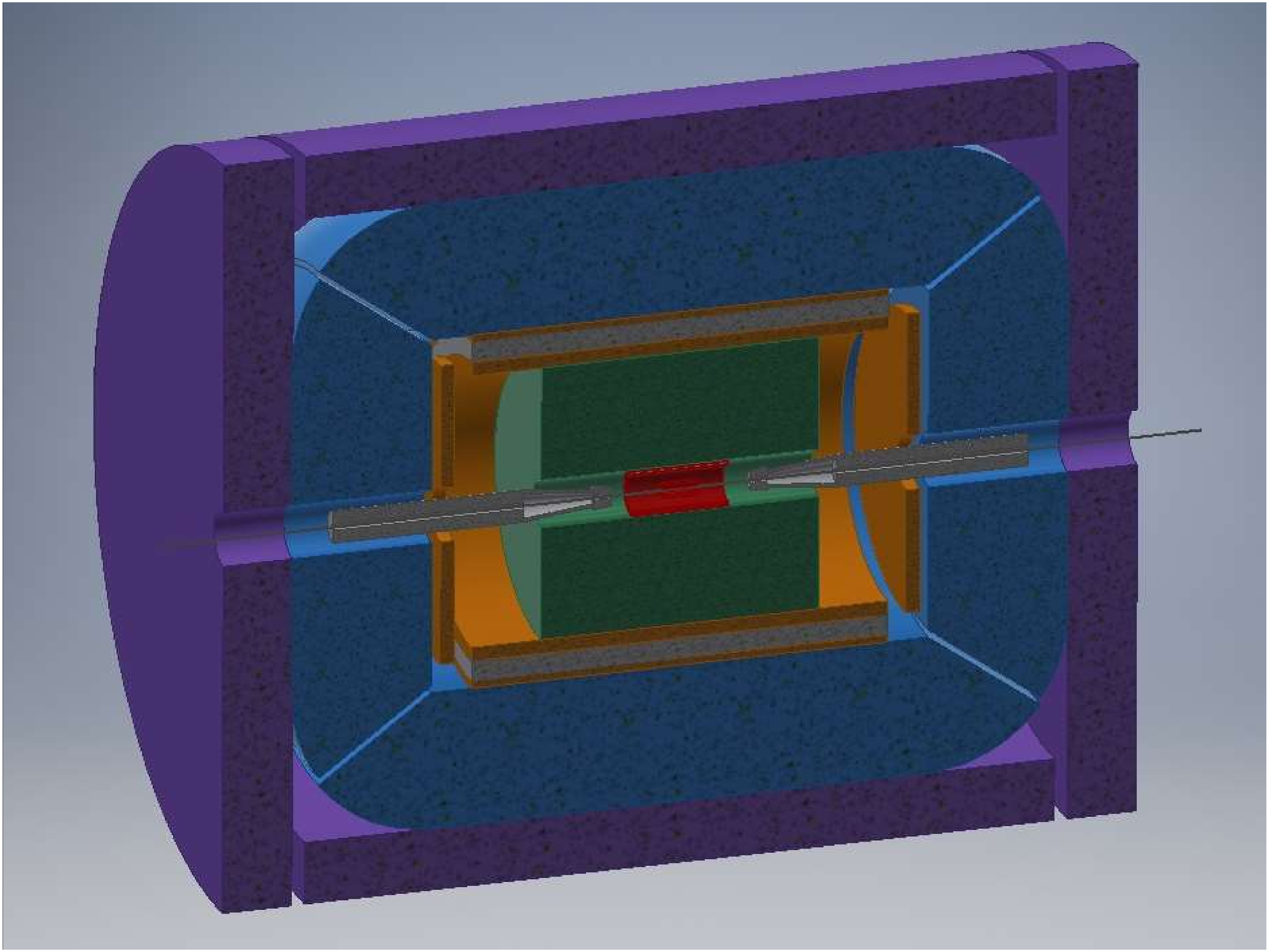
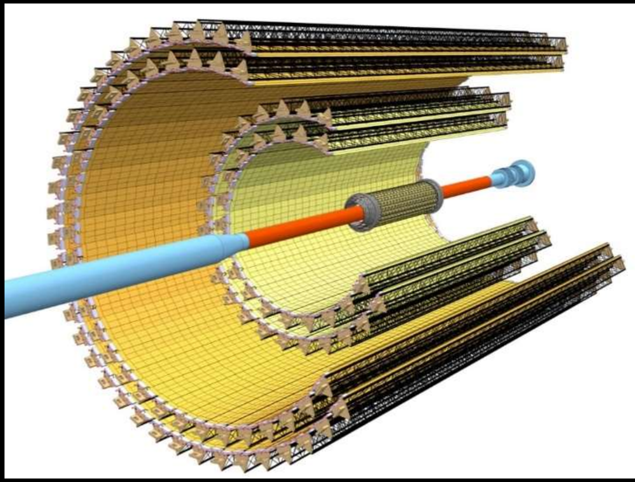
- Yoke + muon chamber

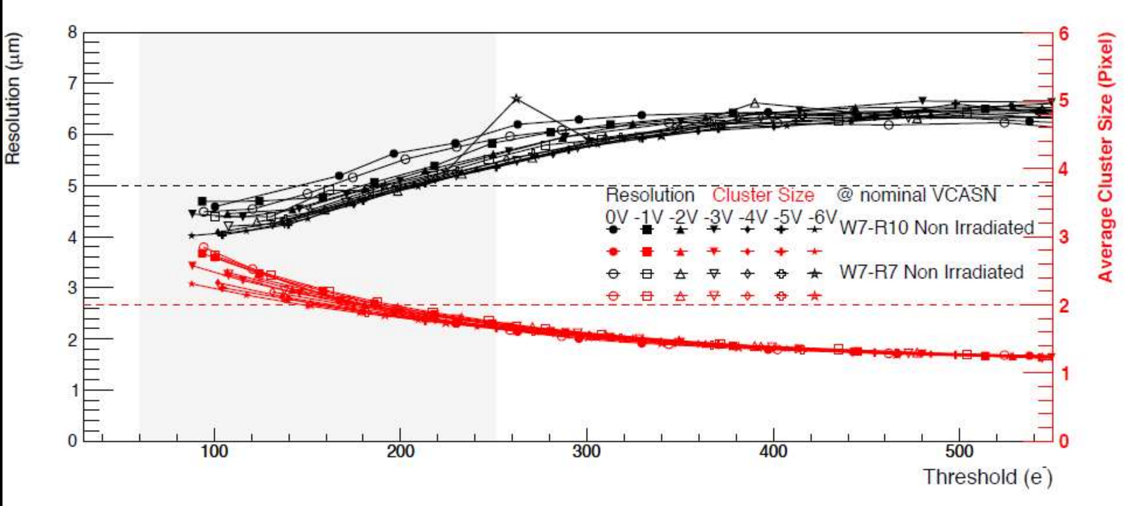




Vertex detector

- Build on ALICE ITS technology
  - 30x30 µm MAPS
  - 5 µm spatial resolution
    - Also after irradiation
  - %X0
    - 0.3-1.0% (in-out)
  - Power:
    - 41-27 mW/cm2 (in-out)
  - Radiation hard
  - >100 kHz readout

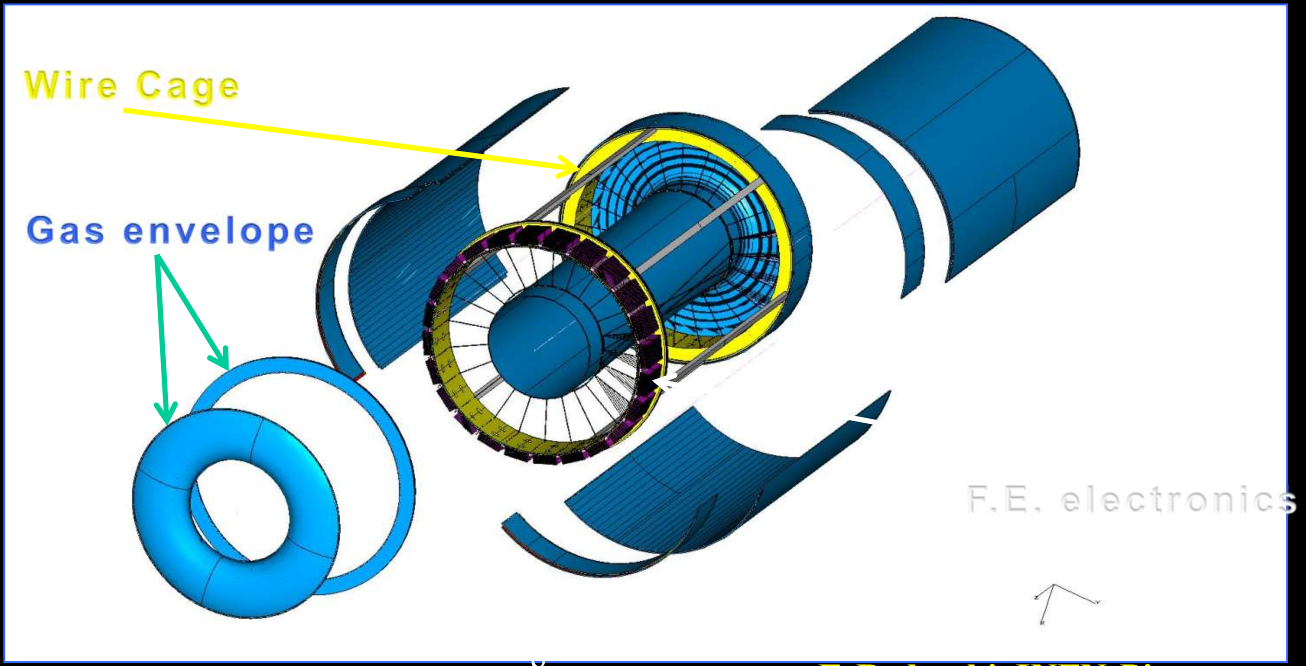




Courtesy of ALICE J.W. van Hoorne

Tracker

- Drift Chamber: fast, good resolution/dE/dx w/ cluster count
  - Ultralight chamber (<1% X_0) – gas: He 90% - iC_4H_{10} 10%
  - 4 m long, drift length ~1 cm, drift time ~400ns, σ_{xy} < 100 μm
  - DCH only $\frac{\Delta p_\perp}{p_\perp} = \frac{8\sqrt{5}\sigma}{.3BL^2\sqrt{n}} p_\perp = 7.1\times10^{-5} p_\perp [GeV/c]$



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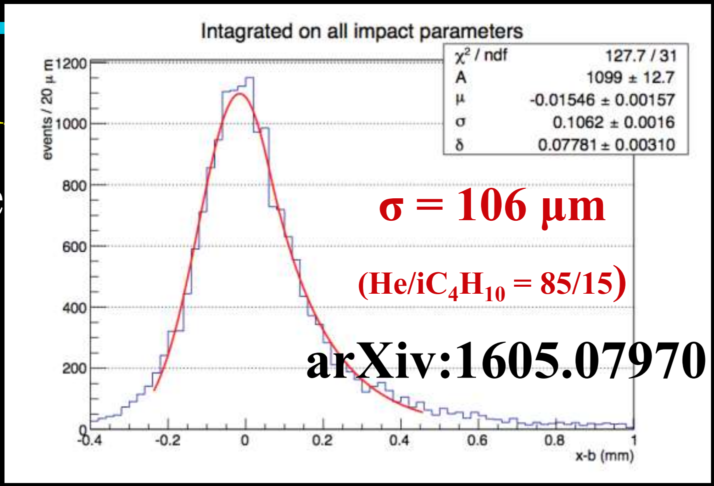
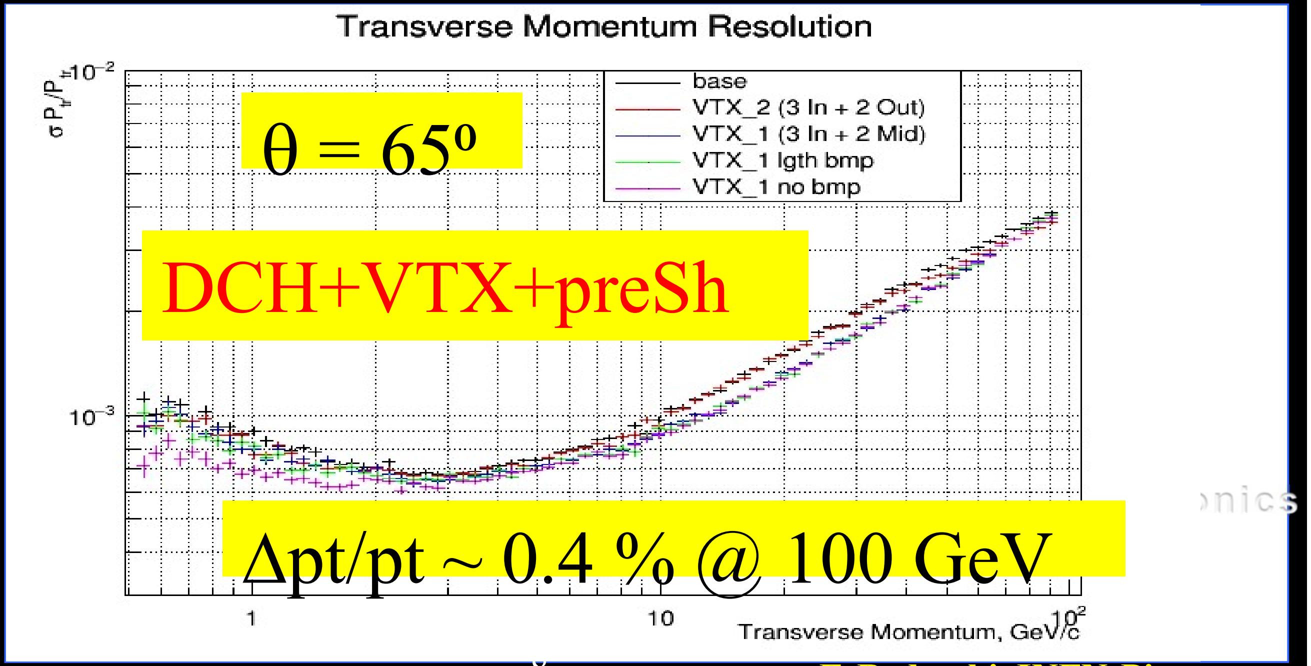


- B = 2 T
- L = 2 m
- N = 112



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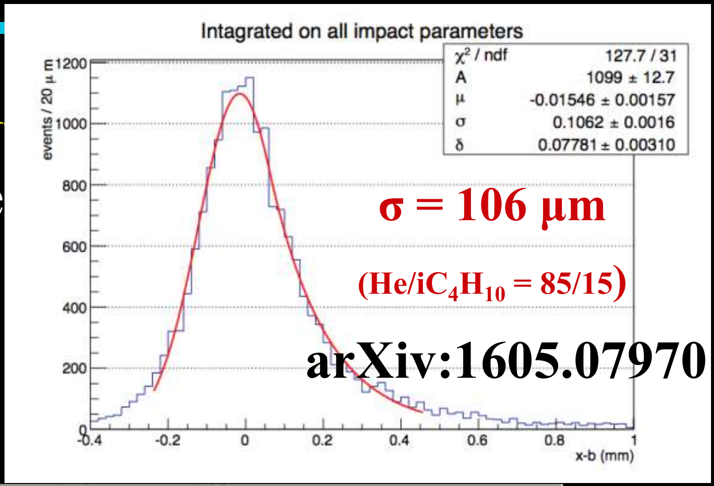
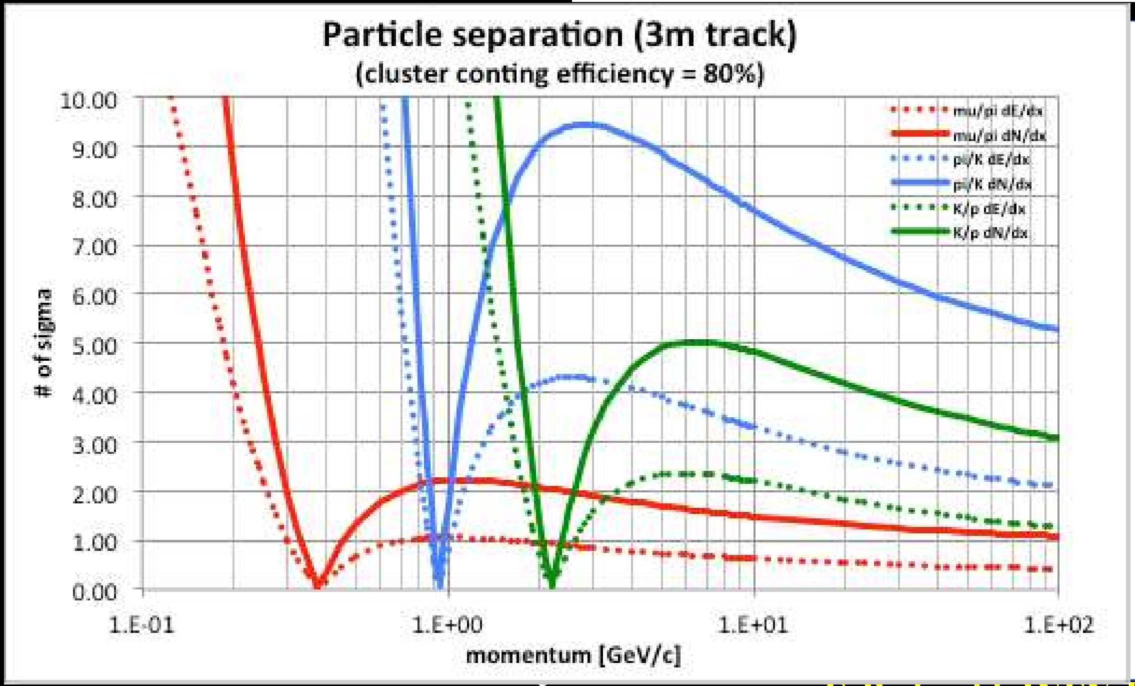
    - B = 2 T
    - L = 2 m
    - N = 112
  - dE/dx ~ 4%
  - dN/dx ~ 2%

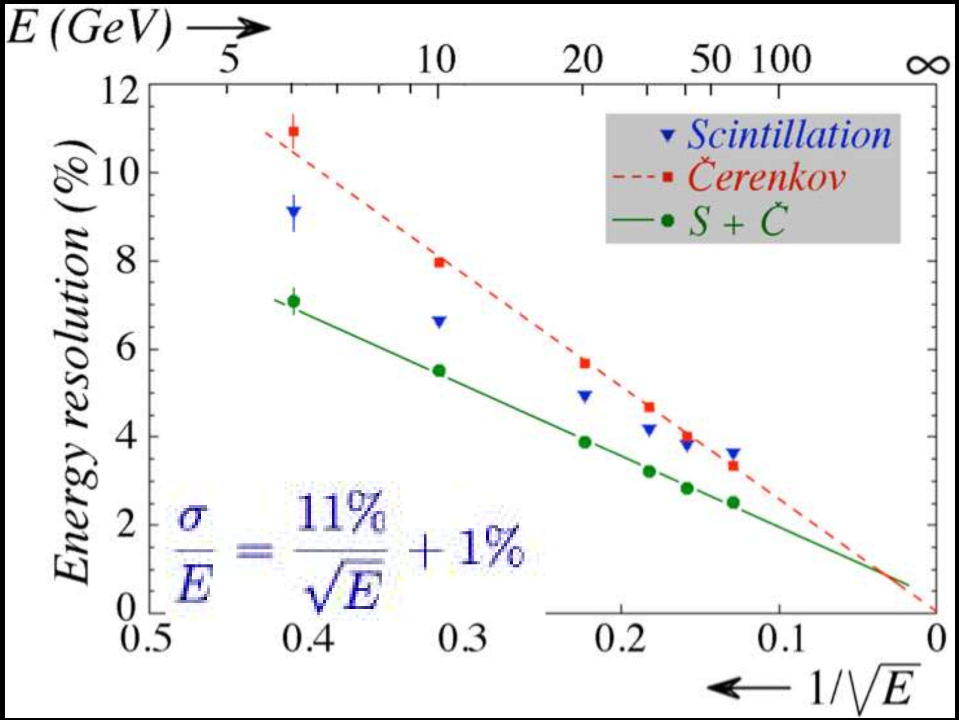


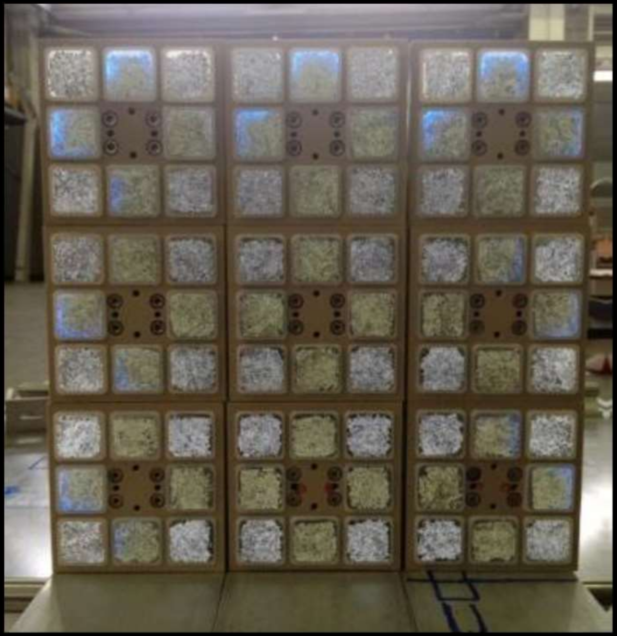


Calorimeter

- Dual readout calorimeter
  - Build on DREAM/RD52 experience
  - Demonstrated EM resolution

Courtesy of DREAM/RD52





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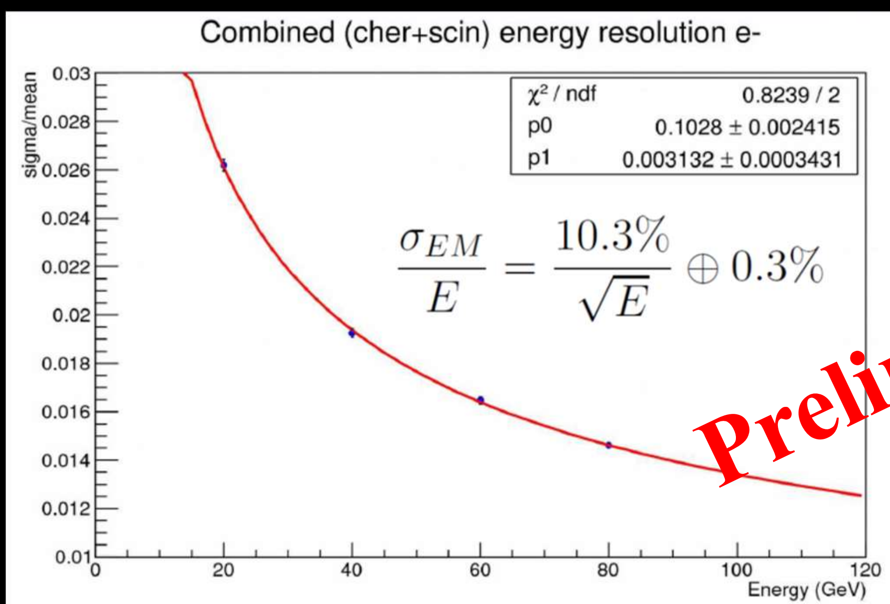
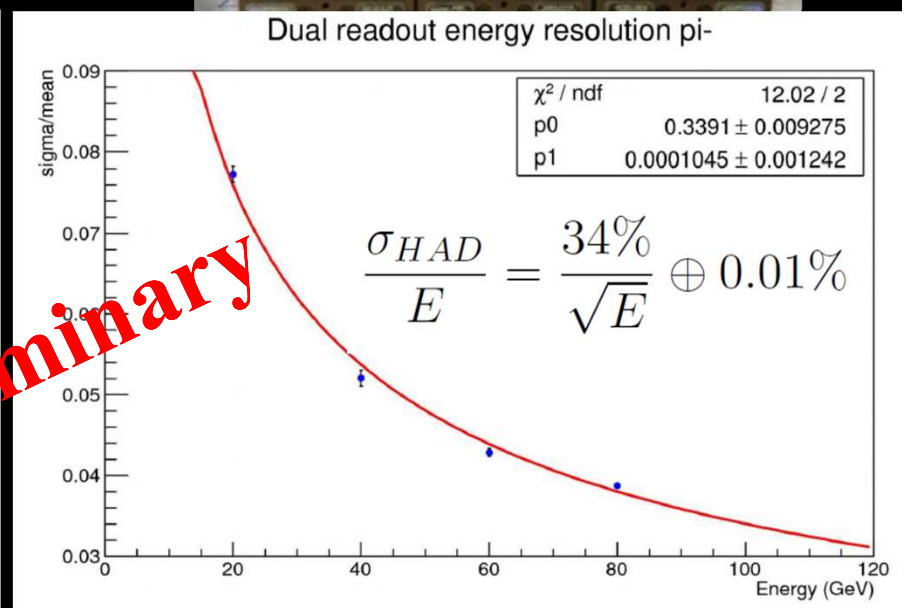
  - Resolution extrapolated with GEANT4 to full acceptance

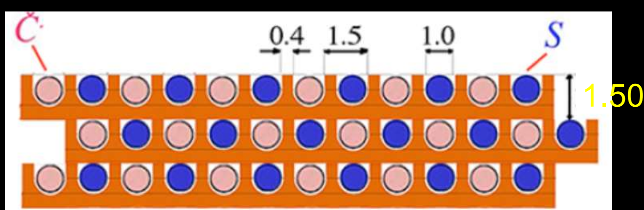


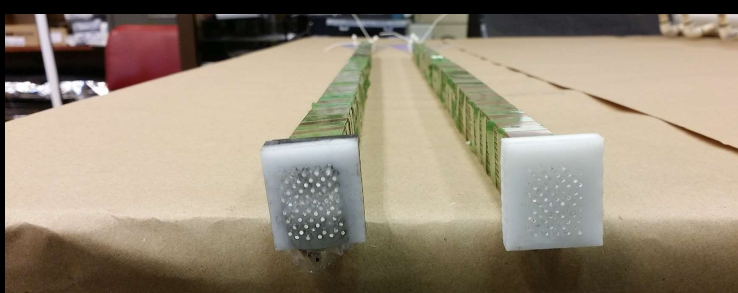


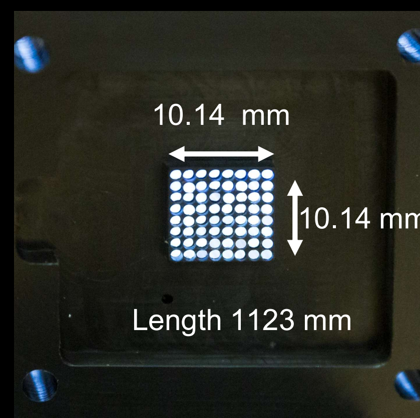
Preliminary

Calorimeter R&D

- SiPM readout studies in progress
  - Test beam@CERN in June 2016







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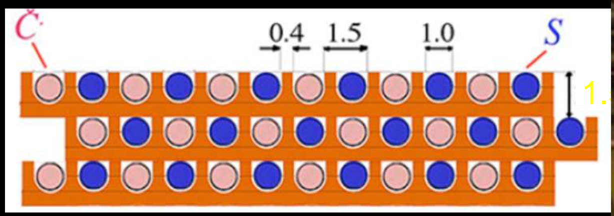
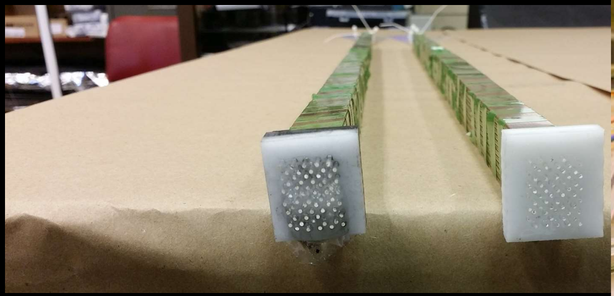
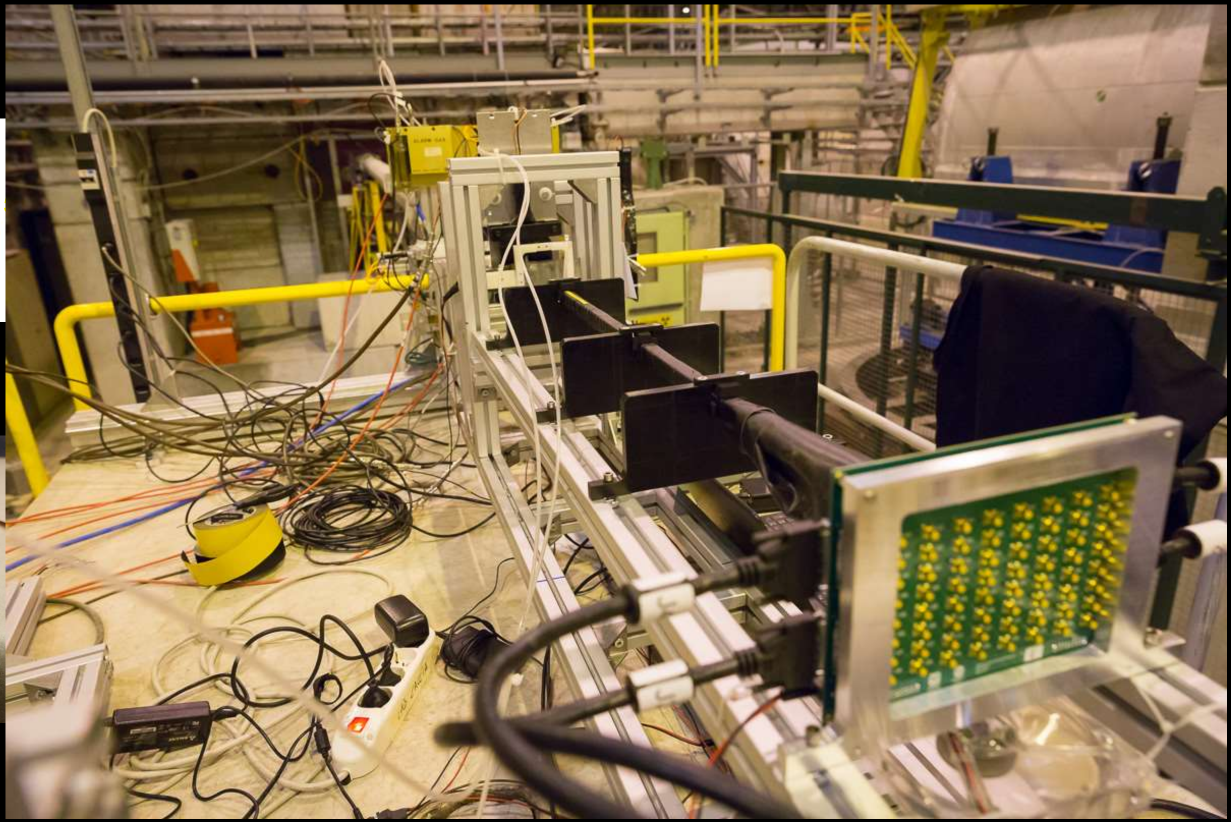
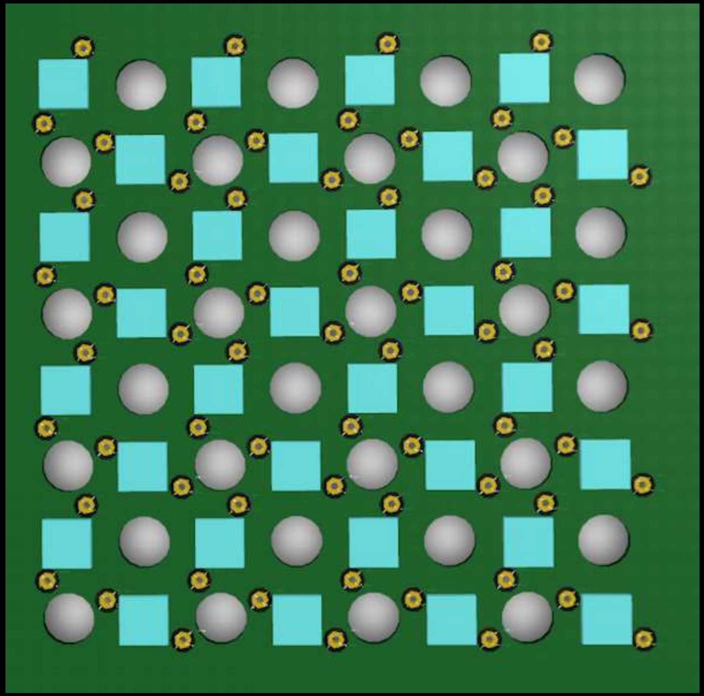


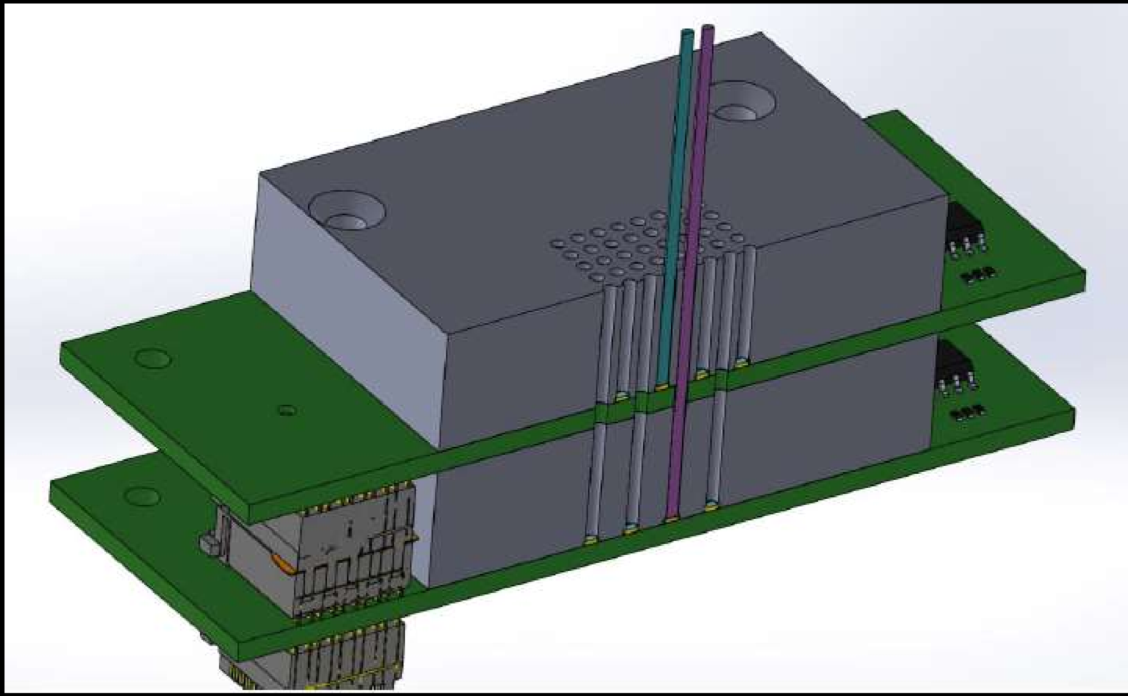




Calorimeter R&D

- SiPM readout studies in progress
  - Test beam@CERN in June 2016
  - Test beam@CERN in September 2017 with upgraded SiPM matrix





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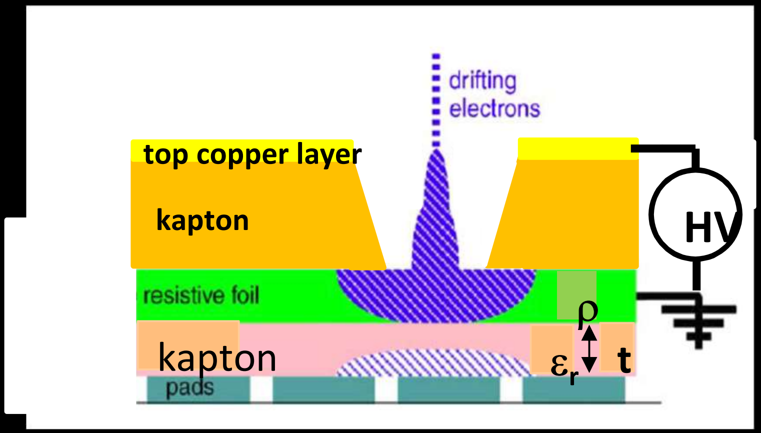
  - with additional chambers
    - μ-RWELL low-cost technology already proven for low rate applications (CMS/SHiP)



Comments & work in progress

- Tracking performance
  - Noise from beam background drives inner radius → see later
  - Optimizing VTX detector configuration → little sensitivity
  - Comparison with CLD all Si option
    - Same pt resolution @100 GeV
    - Impact parameter resolution depends on pixels size
- IDEA vertical slice test beam next September
  - Measure improvement on PID with cluster counting
  - Effect of pre-shower in front of RD52 prototype
  - Test ideas for calorimeter longitudinal segmentation
  - More studies of calorimeter SiPM readout
  - Test muons chamber efficiency and resolution

Conclusions

- IDEA detector is a detector concept optimized for FCC
- Basic detector components based on proven techniques
- Current detector described in FCC-ee CDR
- More work in progress to optimize design
  - Detector R&D/test beam
  - Benchmark with simulation
  - Mechanical engineering
- If encouraged by EU strategy could setup a significant effort for the TDR

Backup slides

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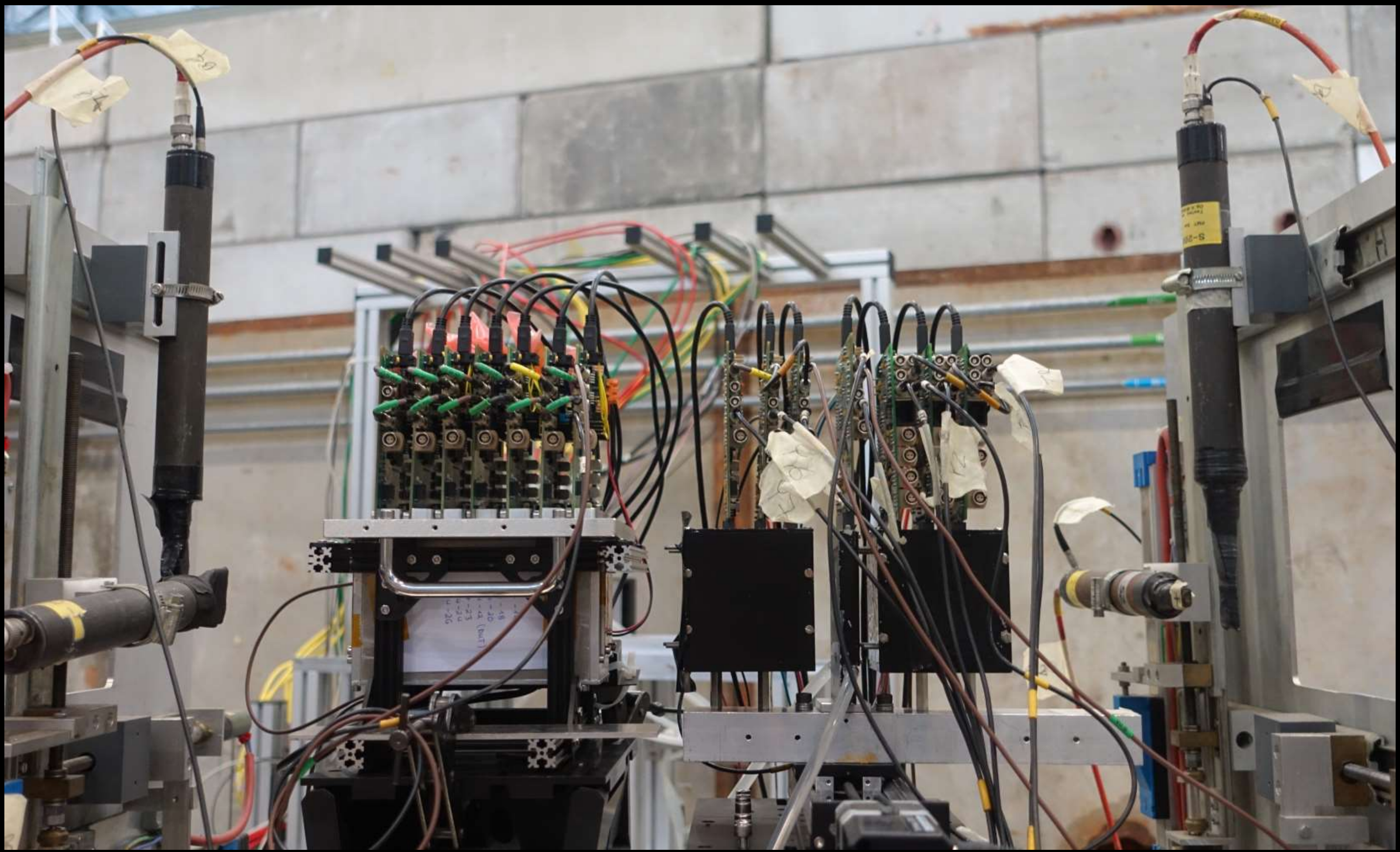
Vertex detector

- Impressive recent test beam results



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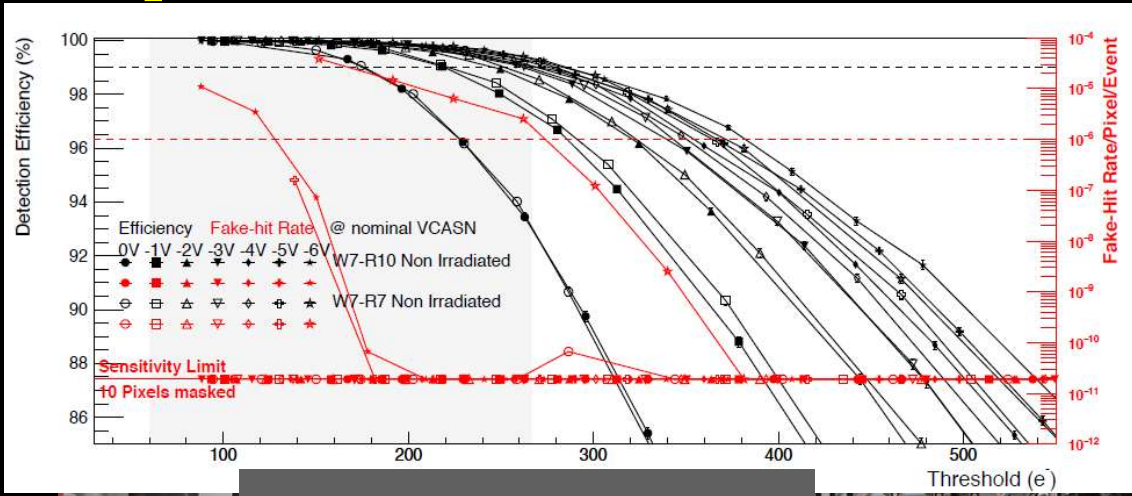
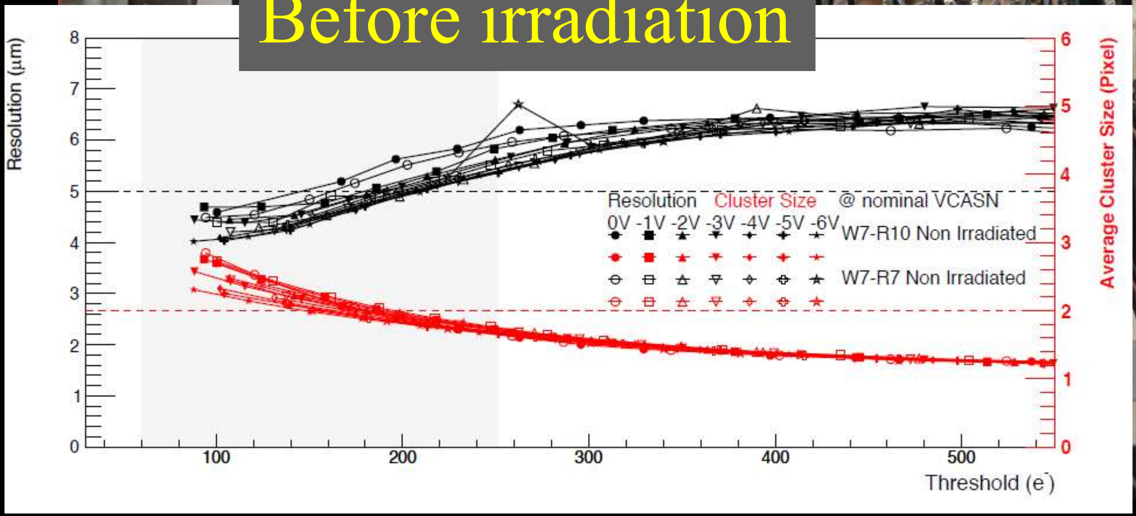


Before irradiation



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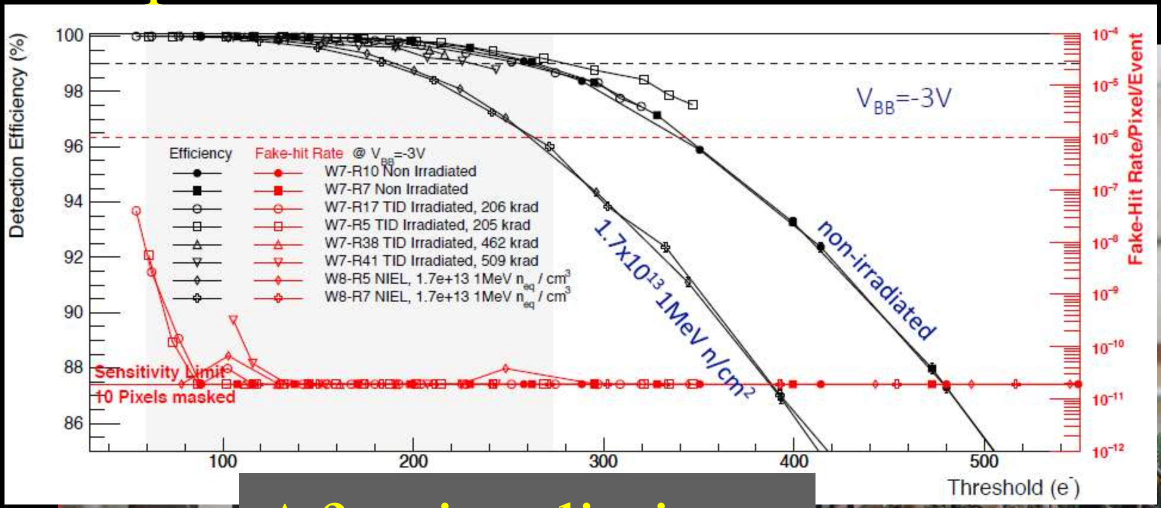

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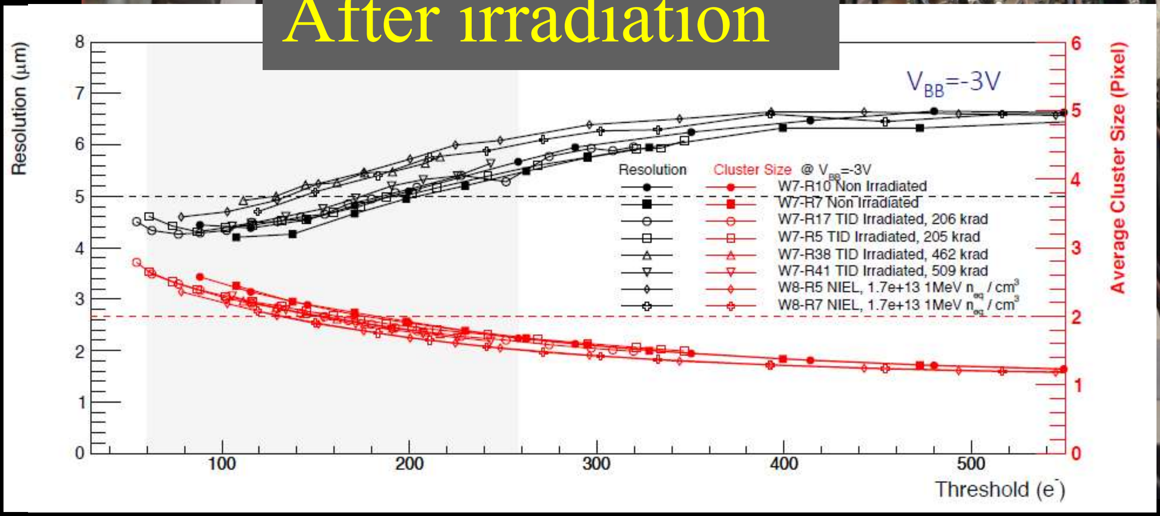

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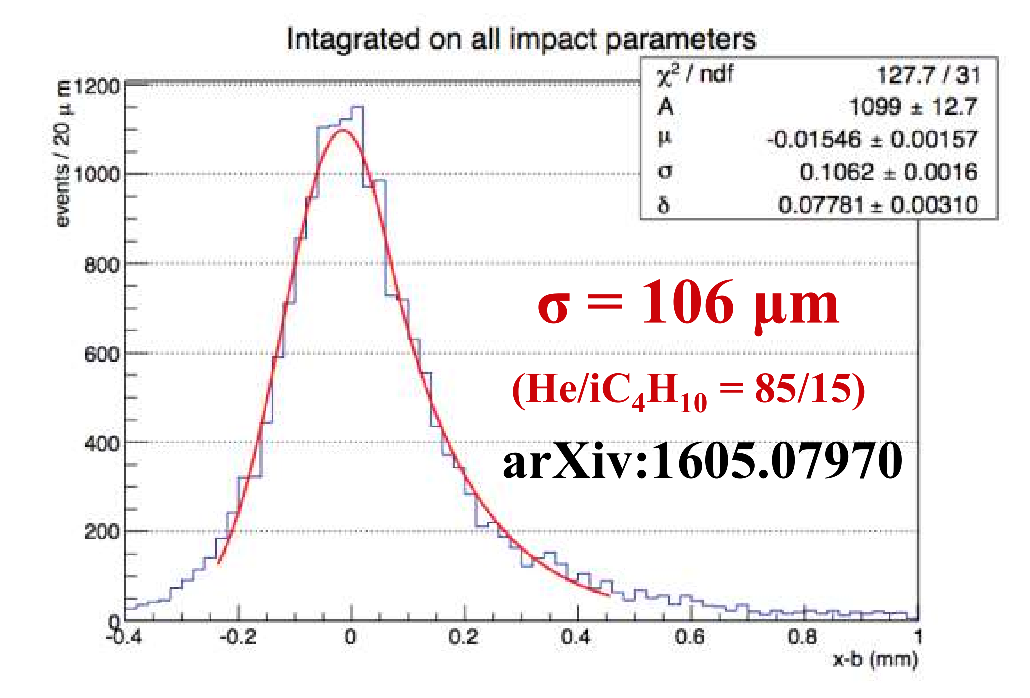

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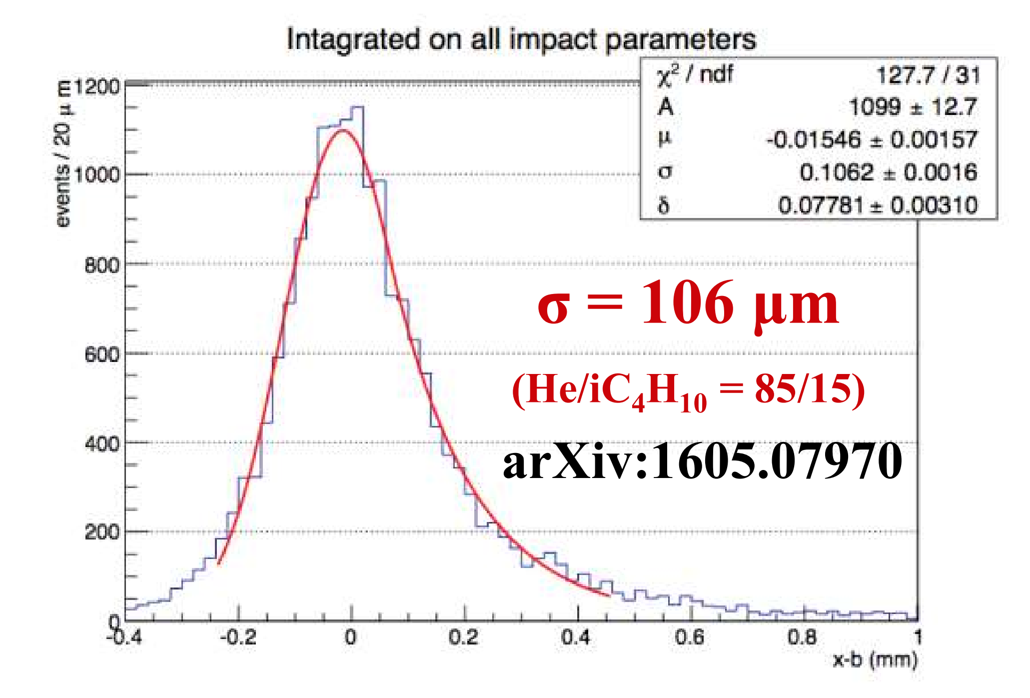

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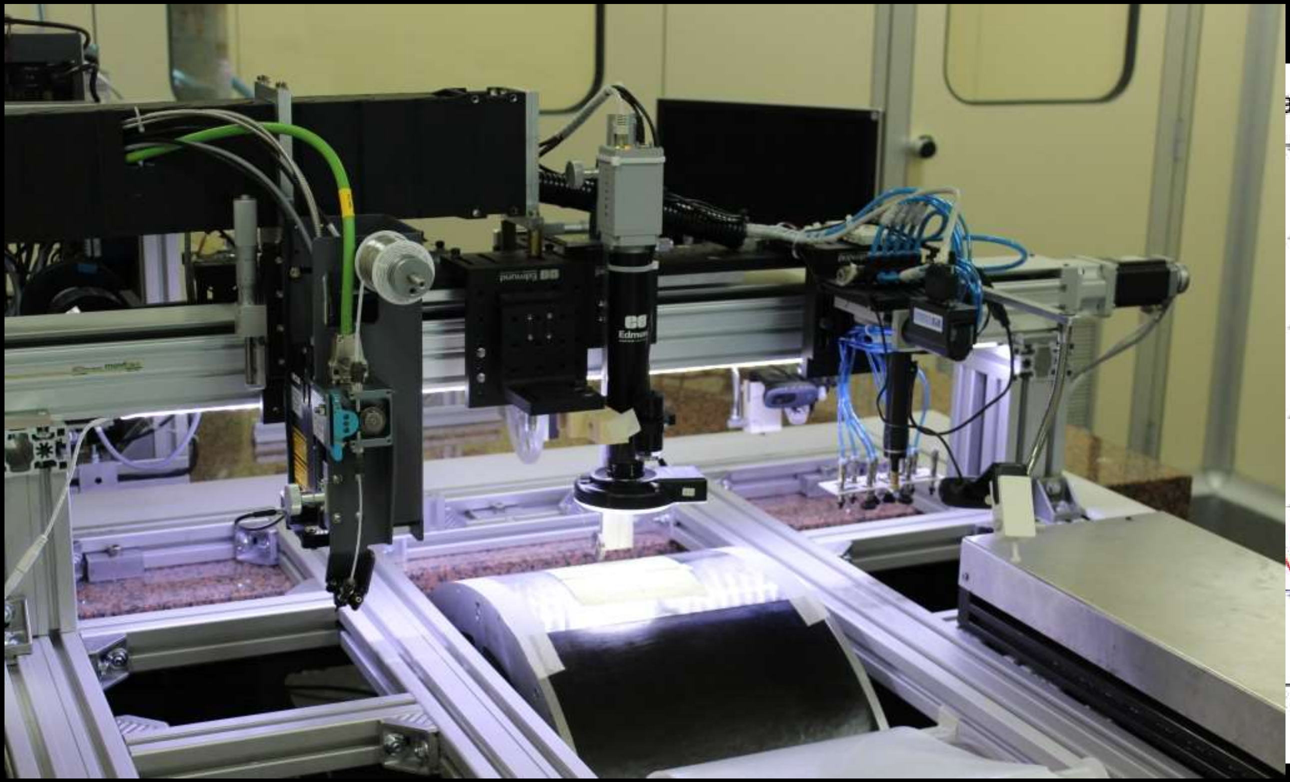

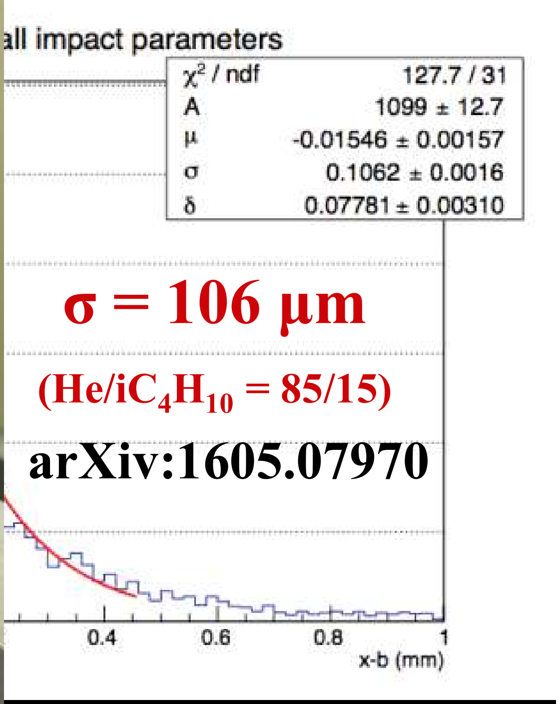

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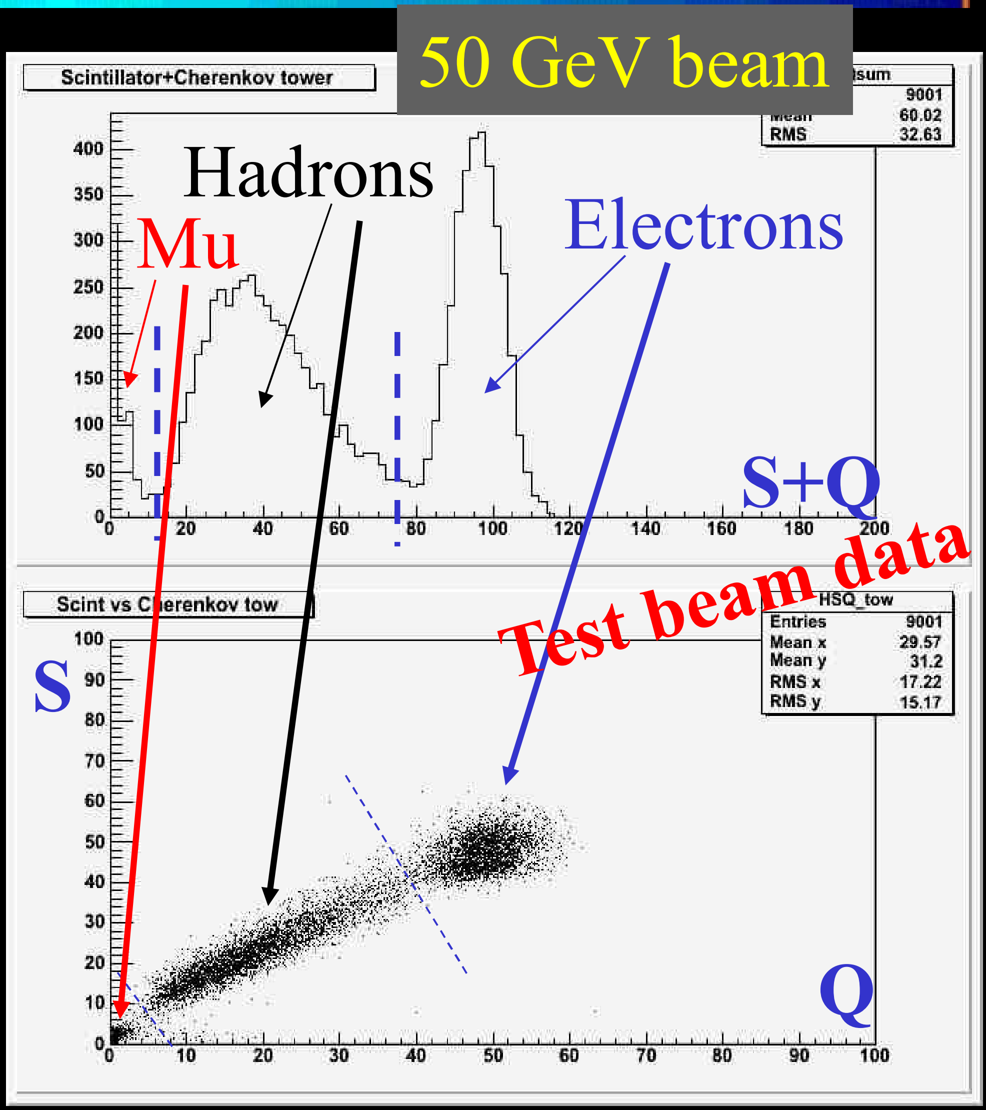

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  - Can improve with timing and lateral shape cuts
    - $\varepsilon_{el} > 99\%$, <0.2% π mis-ID
- Preshower (~2 X_0)
  - Acceptance determination
  - $e/\gamma\ /\pi^0$ separation near hadrons
    - Synergy with part. flow