# IDEA: a detector concept for FCC


## Outline

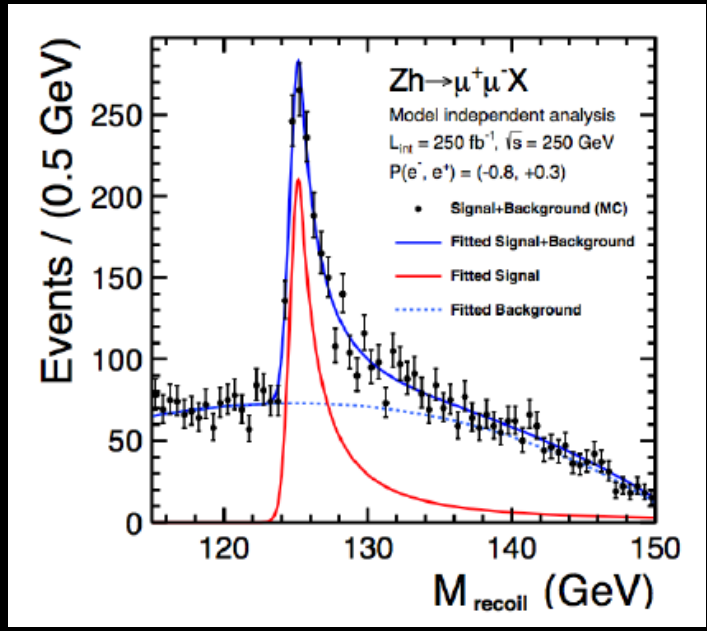
- Main physics/technical drivers
- Detector layout
- Open issues/Future work
- Conclusions

F. Bedeschi, INFN-Pisa
FCC week,
Amsterdam, April 2018

# Physics drivers recap

- Physics drivers
  - Higgs:
    - Tracking (recoil mass), vertex (b/c separation), calorimetry (hadronic W/Z, $\gamma\gamma$), pre-shower ($\tau$ decays with $\pi^0$'s)

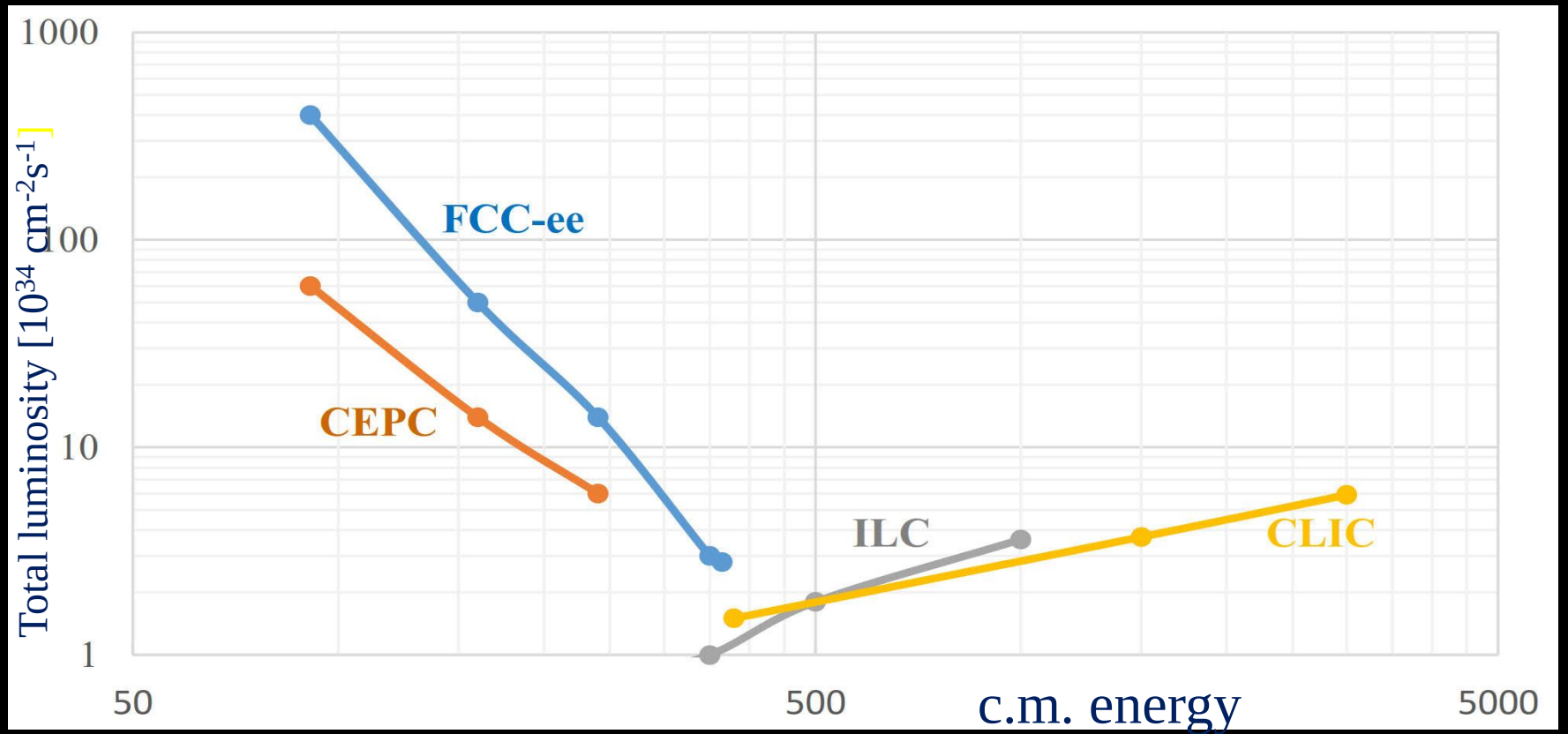
| Physics Process | Measured Quantity | Critical Detector | Required Performance |
|---|---|---|---|
| $ZH \to \ell^+\ell^- X$ | Higgs mass, cross section | Tracker | $\Delta(1/p_{\mathrm{T}}) \sim 2 \times 10^{-5}$ |
| $H \to \mu^+\mu^-$ | BR($H \to \mu^+\mu^-$) | | $\oplus 1 \times 10^{-3}/(p_{\mathrm{T}}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




  - Z pole:
    - Mostly covered by above
    - Excellent acceptance determination
  - WW, t t-bar mostly covered by previous

# Differences with ILC

- Luminosity is much higher!
  - Non-negligible machine backgrounds
    - Fast detector integrates less background in each readout



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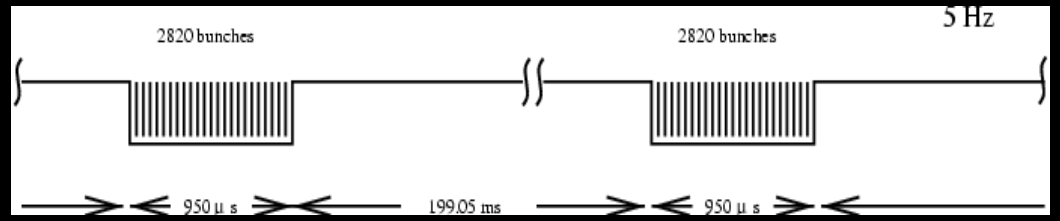
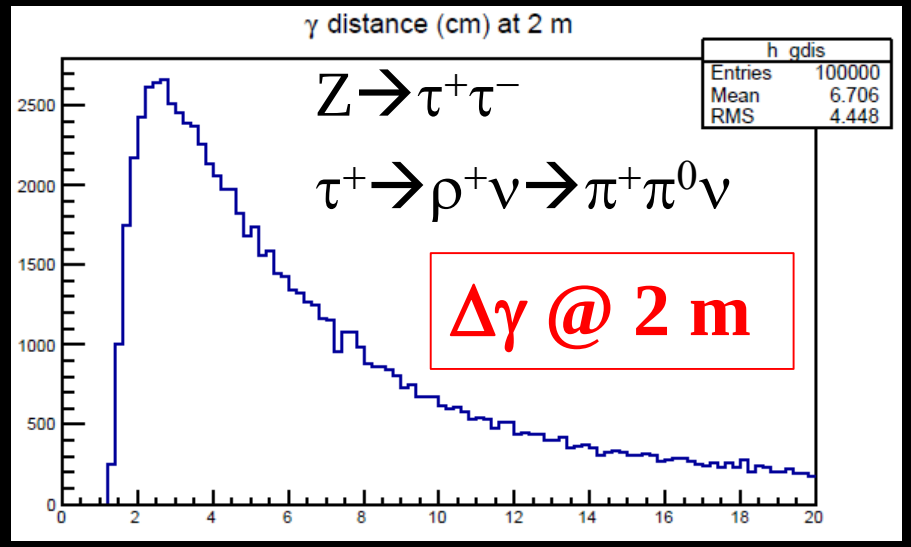
- Beam time structure:
  - Short bunch spacing (~ 20-30 ns Z, ~ 1 μs H)
  - No large time gap
    - Cooling issues for PF calorimeter and vertex detector
    - TPC ion backflow

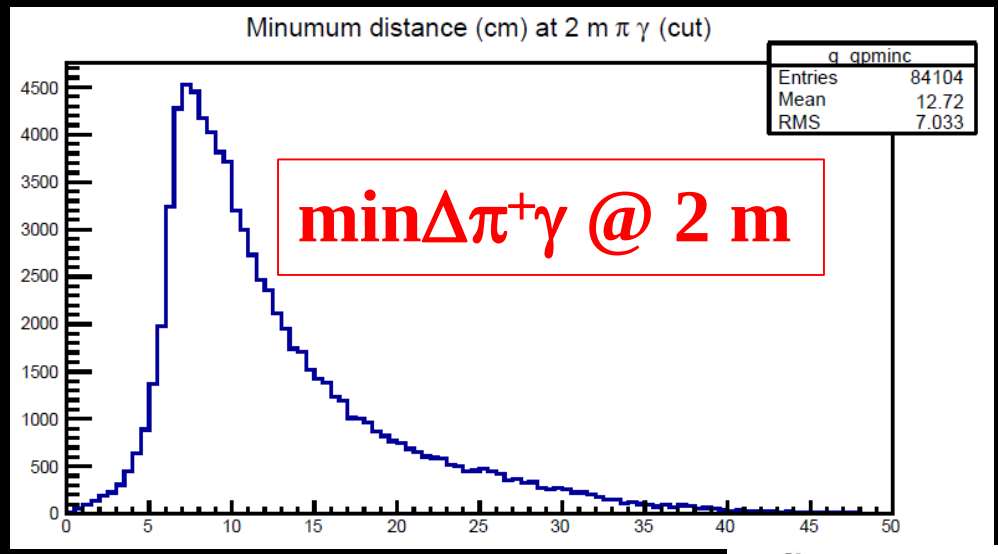


# Other drivers

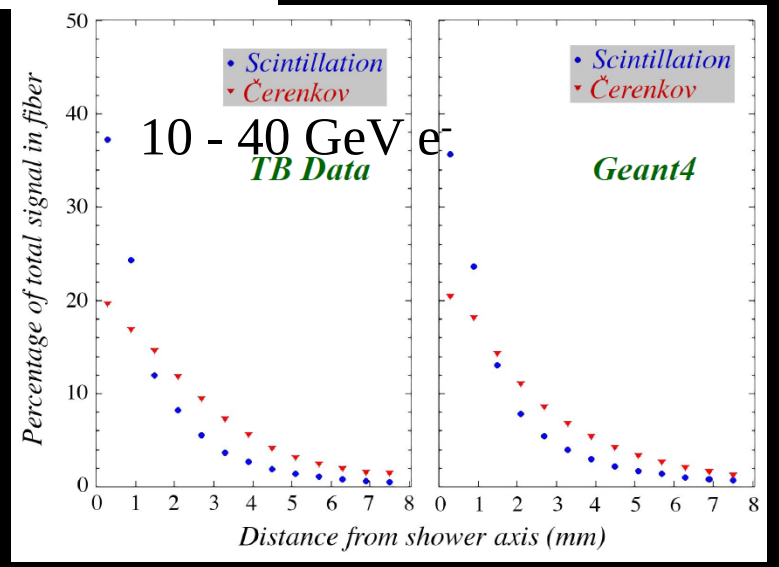
- Extreme statistical resolution on Z pole
  - Acceptance systematics control is critical
    - **Silicon layer** after DCH for acceptance and charged resolution
    - **Pre-shower** with high precision and stability allows μm level acceptance definition for $\gamma$

# Other drivers




- $\pi^0$ important in tau and HF physics
  - No $\pi^0$: 35% $\tau \rightarrow l\,(e, \mu)\,\nu\nu$ + 20% $\tau \rightarrow (1,3)\pi^{\pm}\,l\nu$
  - 1 $\pi^0$: 28% $\tau \rightarrow (1,3)\pi^{\pm}\pi^0 l\nu$
  - 2 –3$\pi^0$: 10% $\tau \rightarrow \pi^{\pm}\,(2,3)\,\pi^0 l\nu$
- High granularity/Pre-shower → $\pi^0$ identification
- Overlap with $\pi^+$ may require longitudinal segmentation

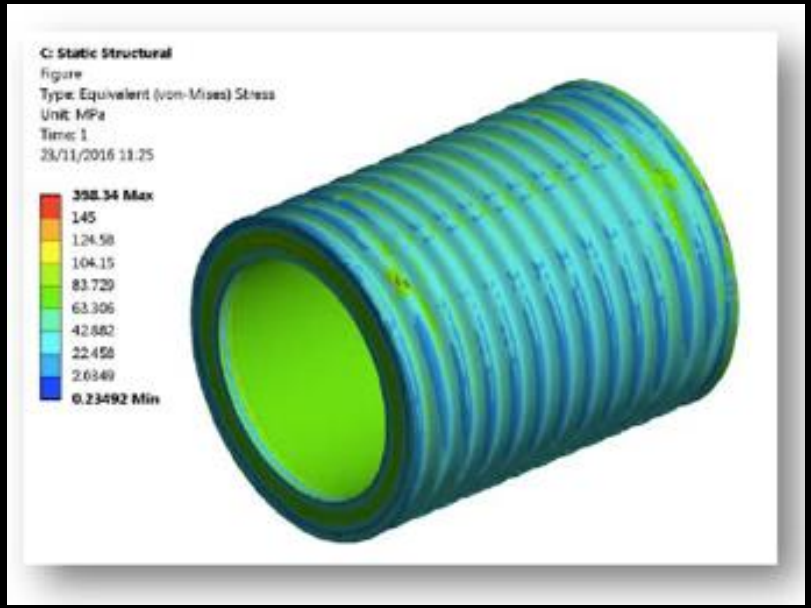


# Detector solenoid

- 2T field solenoid – Rin ~ 2 m
  - Can be made very thin ~30 cm total = 0.74 $X_0$ (0.16 $\lambda$) at $\theta = 90^o$
    - Calorimeter can be located outside coil
  - Small yoke thickness 50-100 cm Fe
    - Scales with B $R^2$ → cost reduction over large coil

**See next talk of H. ten Kate**

| 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 |



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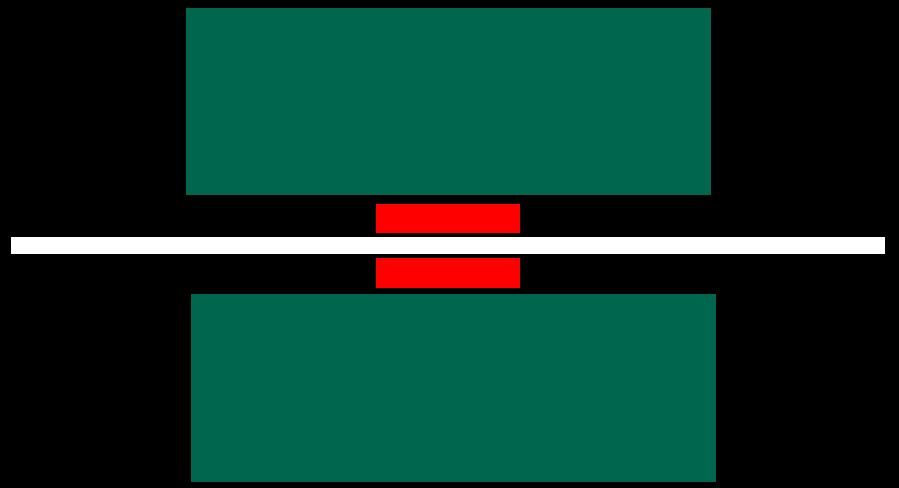

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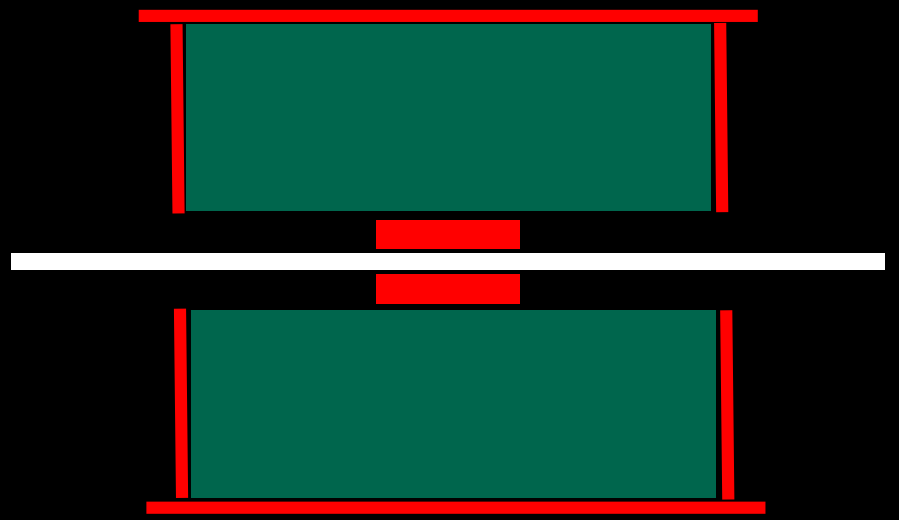

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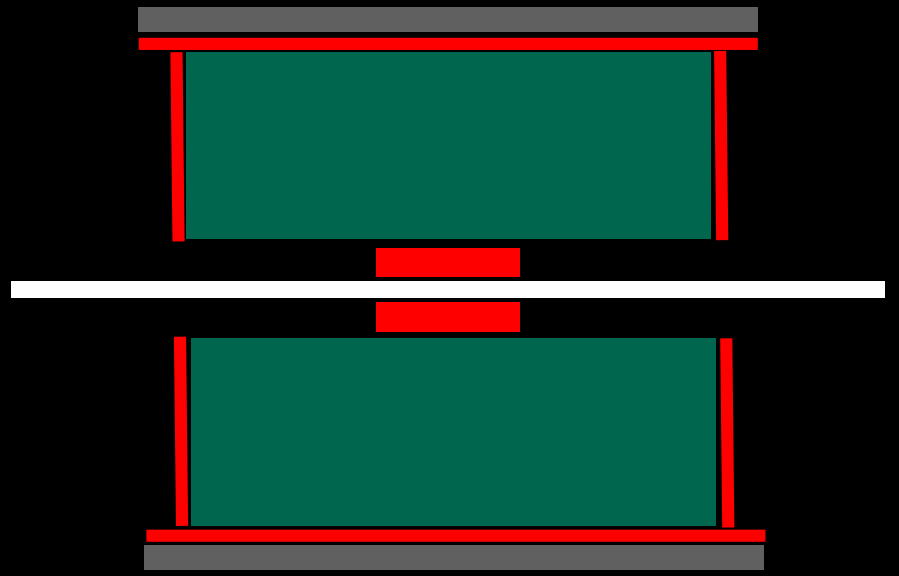

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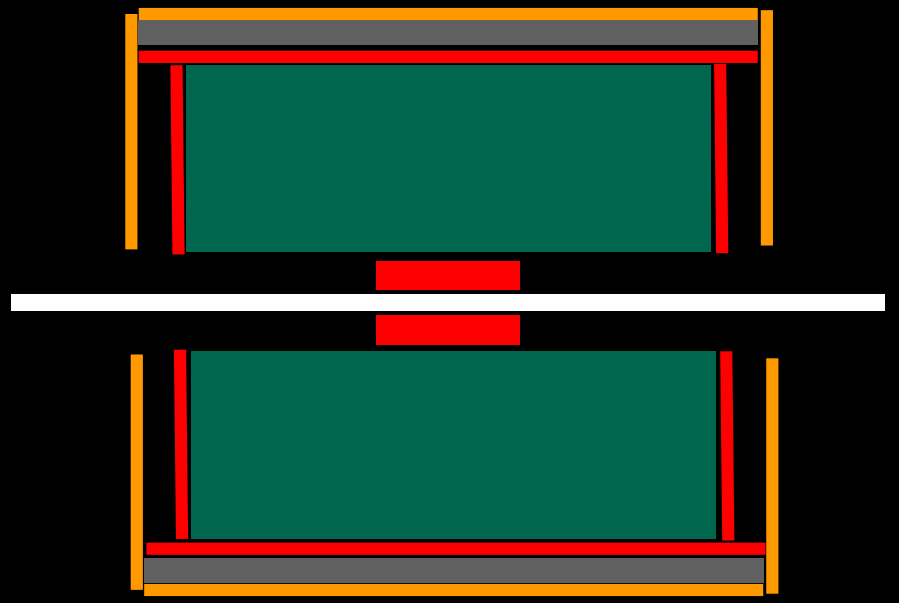

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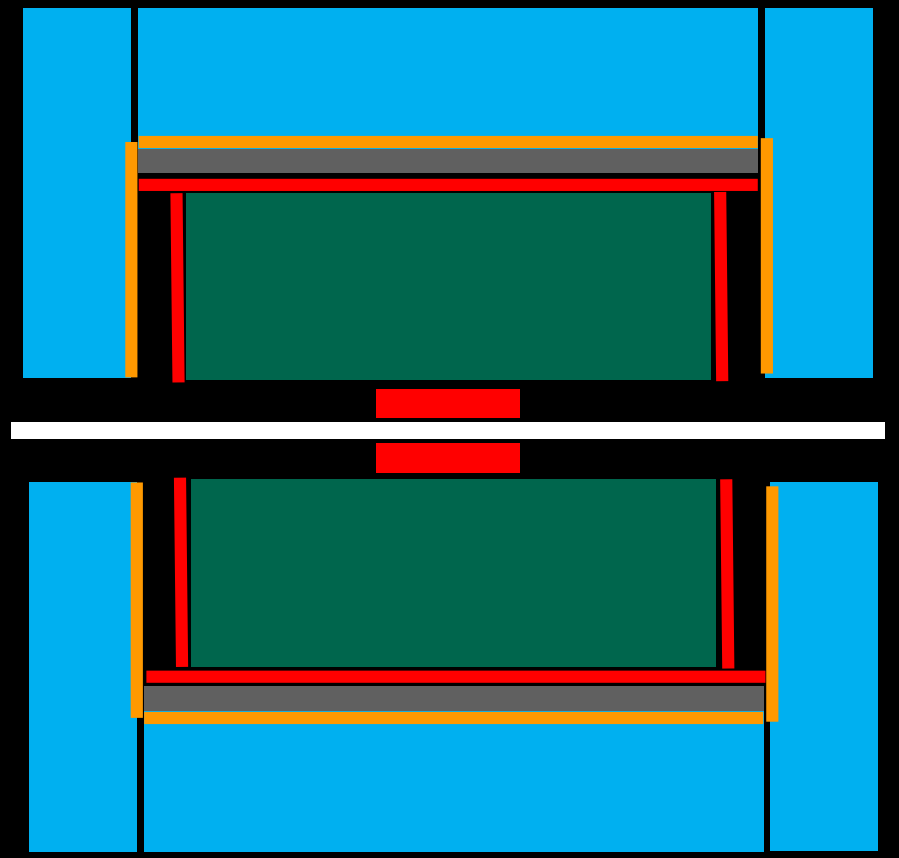

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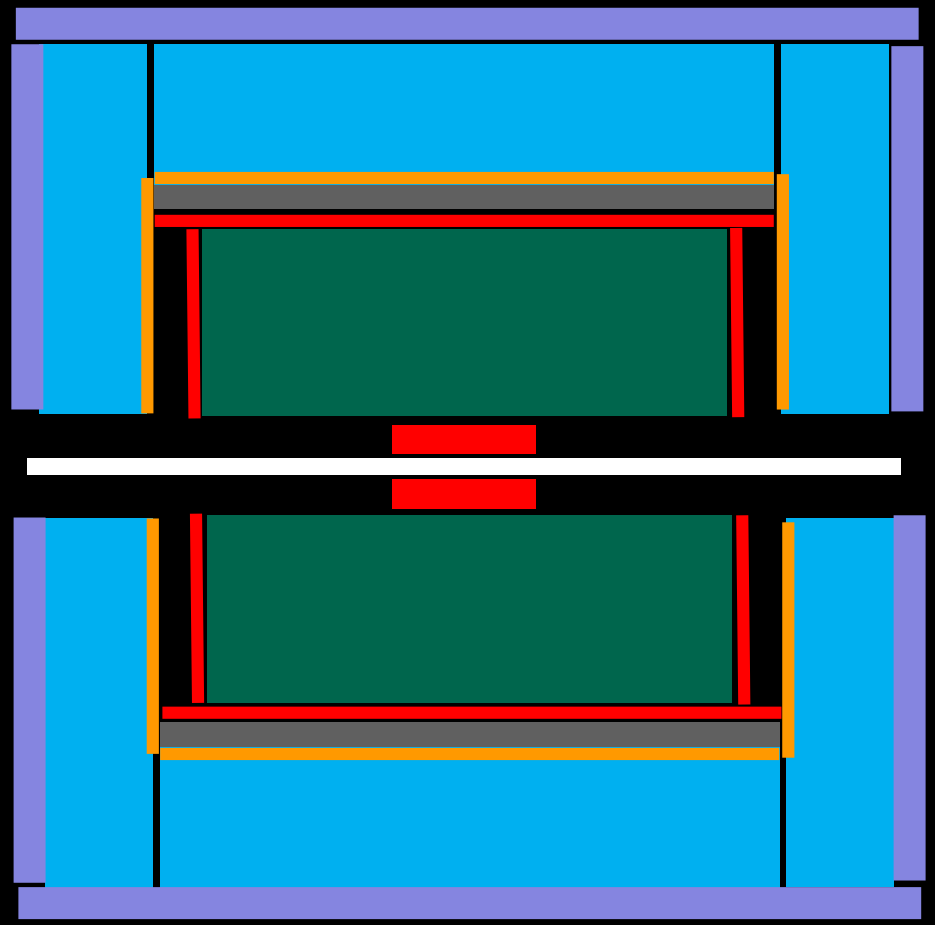

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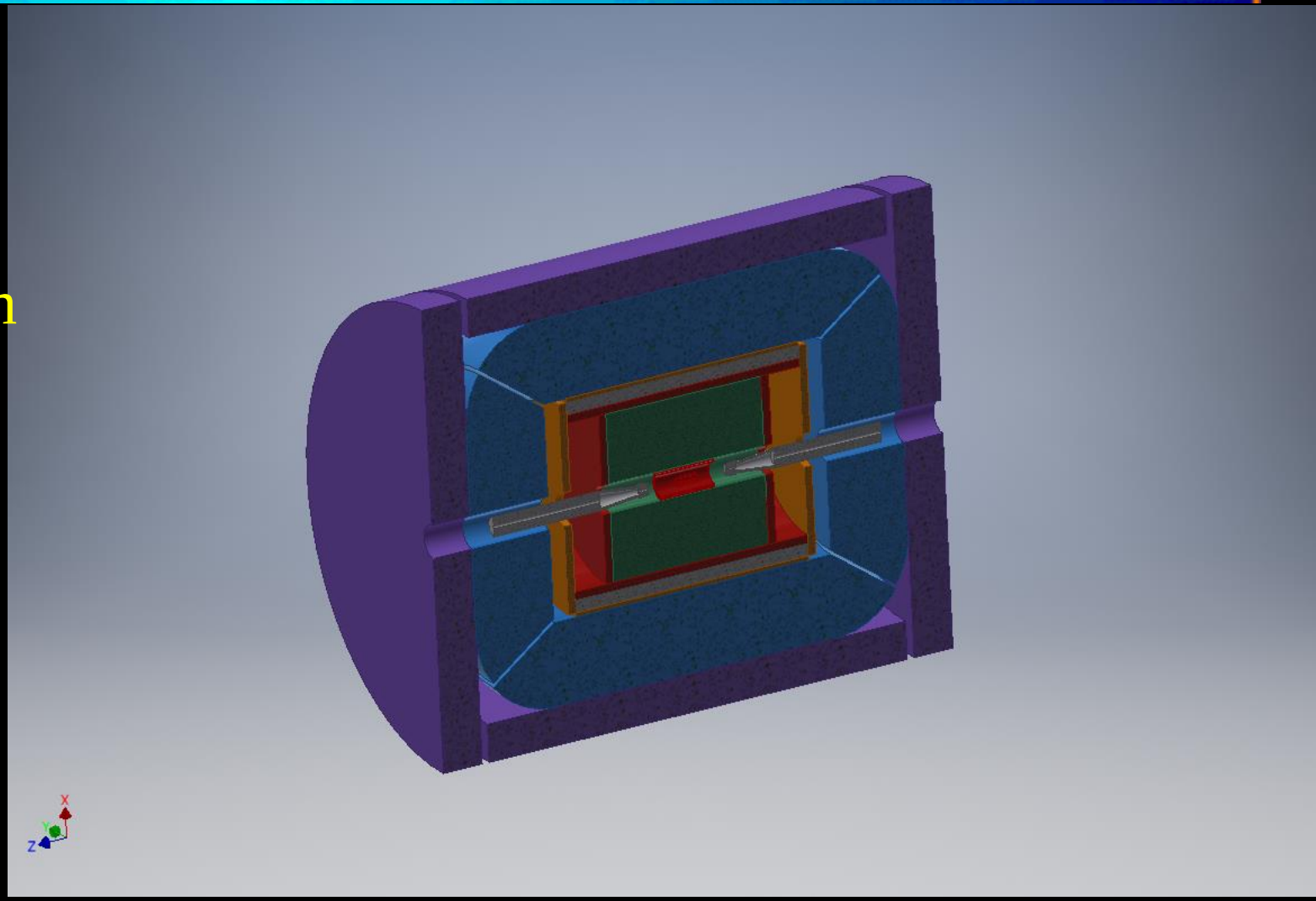
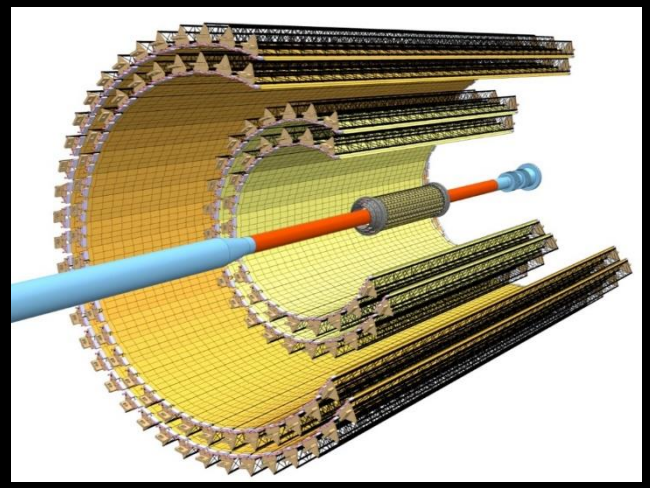
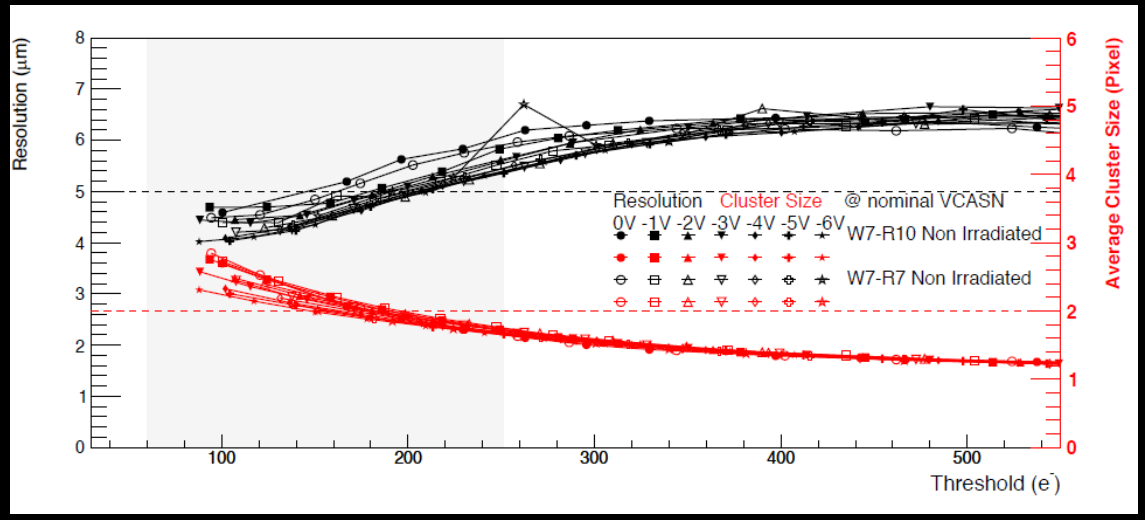


# Vertex detector

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

Courtesy of ALICE J.W. van Hoorne

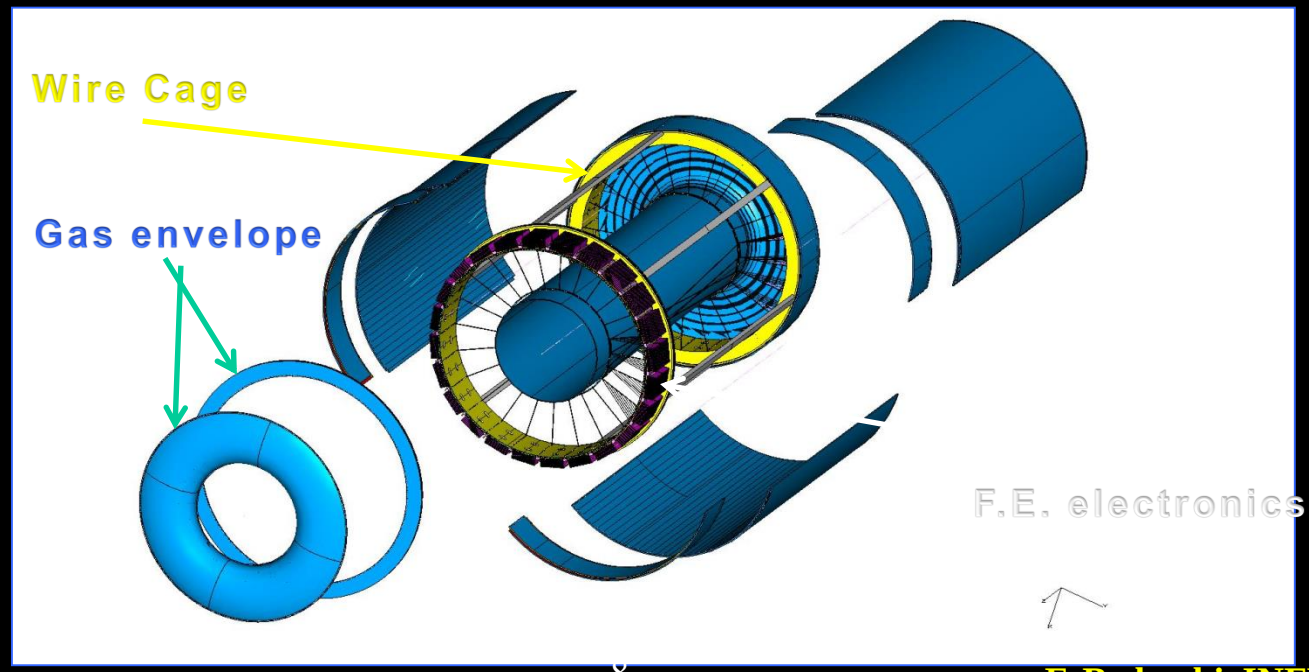




# Tracker

- 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, $\sigma_{xy}$ < 100 μm

More details in next talk from G. Tassielli



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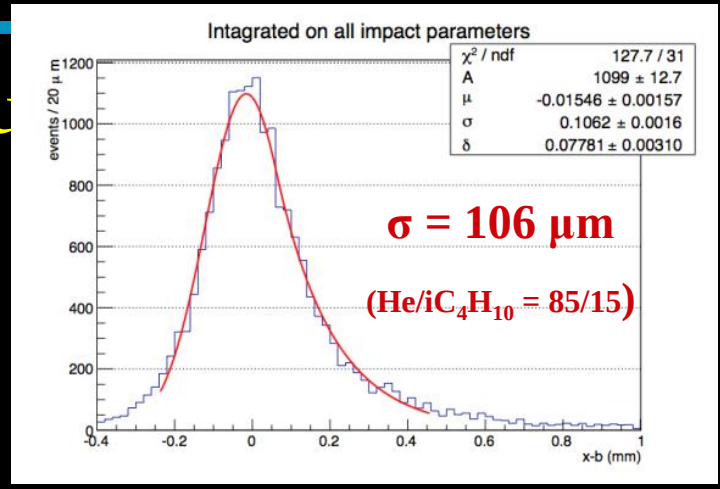
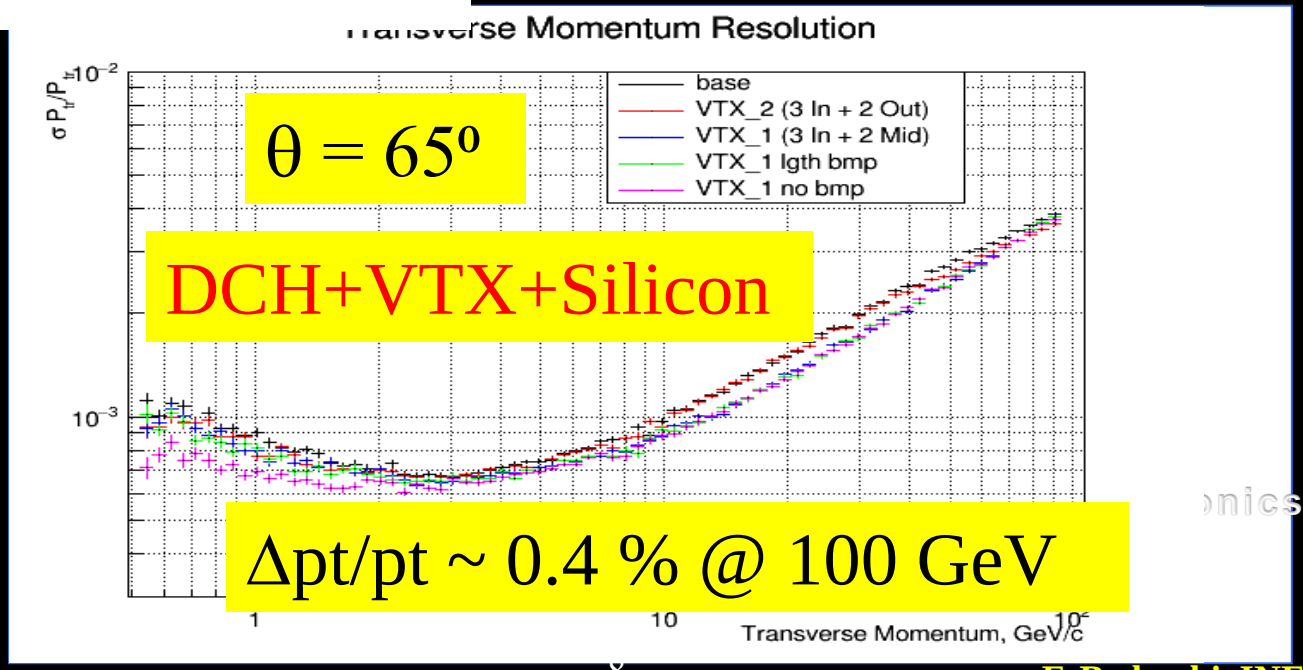
  - DCH only $\frac{\Delta p_\perp}{p_\perp} = \frac{8\sqrt{5}\sigma}{.3BL^2\sqrt{n}} p_\perp = 7.1\times10^{-5} p_\perp [GeV/c]$
    - B = 2.0 T
    - L = 1.7 m
    - N = 112



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    - B = 2.0 T
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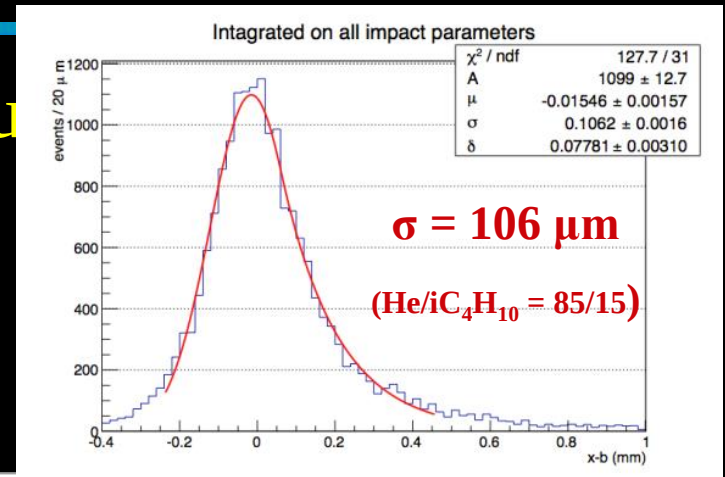
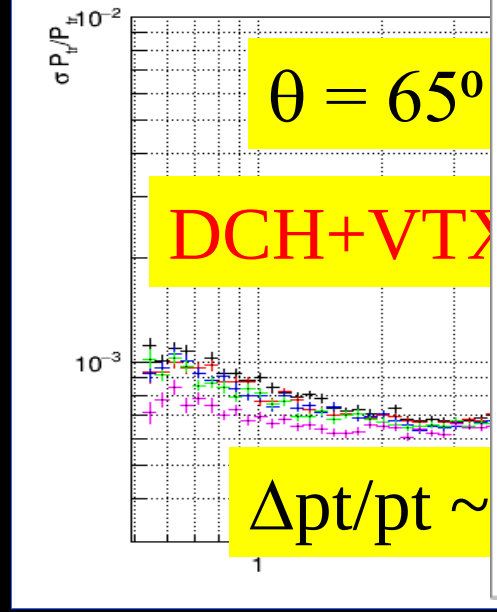
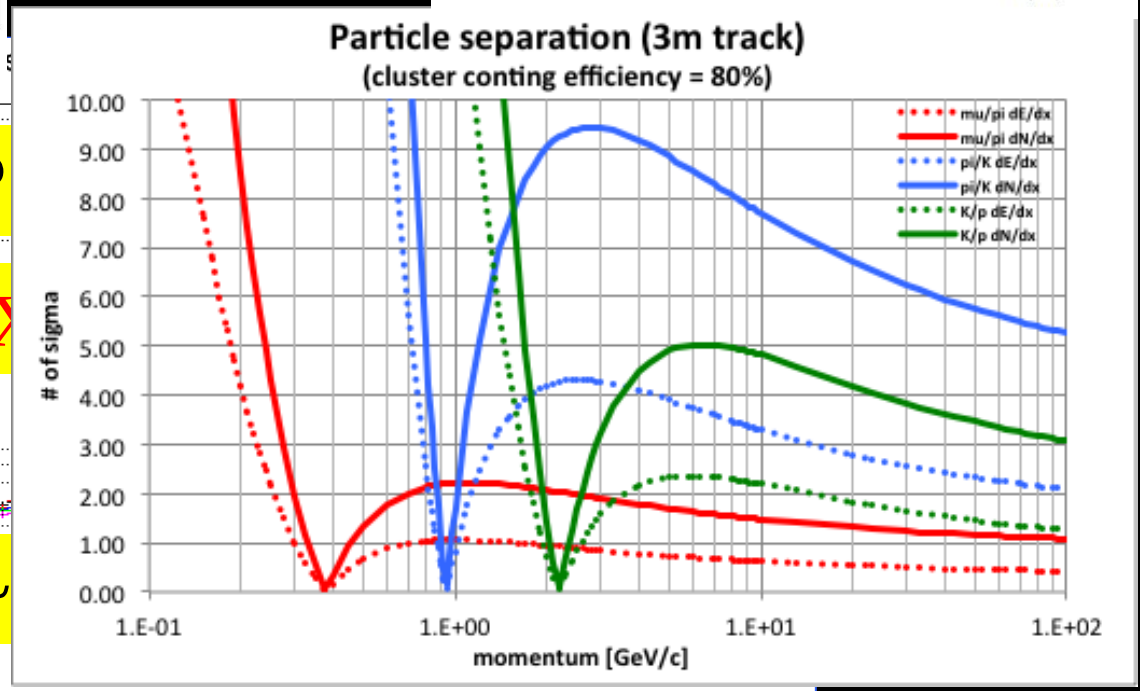
  - dE/dx ~ 4%
  - dN/dx ~ 2%
    - To be tested



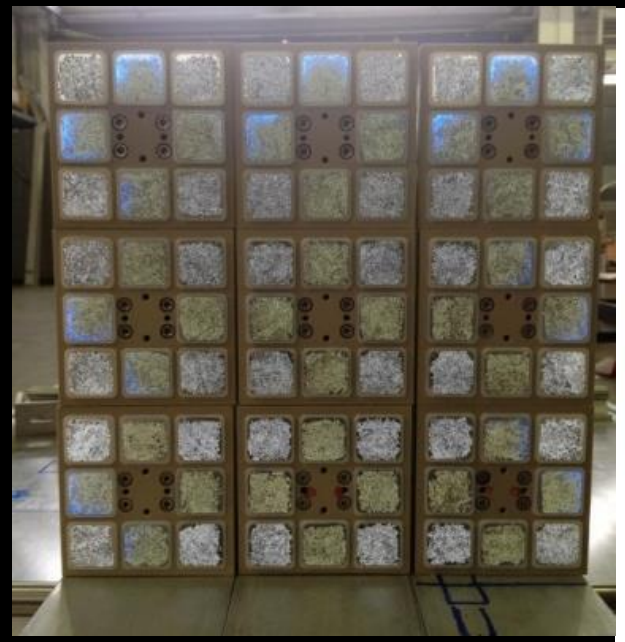



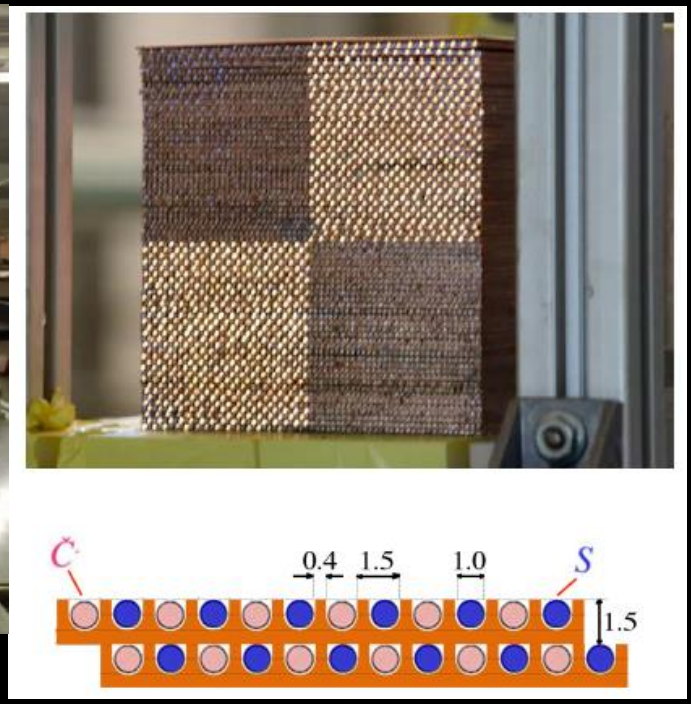



# Calorimeter

- Dual readout calorimeter
  - Build on DREAM/RD52 experience
    - Transverse granularity ~ 2 mm
    - Event-by-event $f_{em}$ fluctuations correction

Courtesy of DREAM/RD52






Details in next talk by M. Antonello

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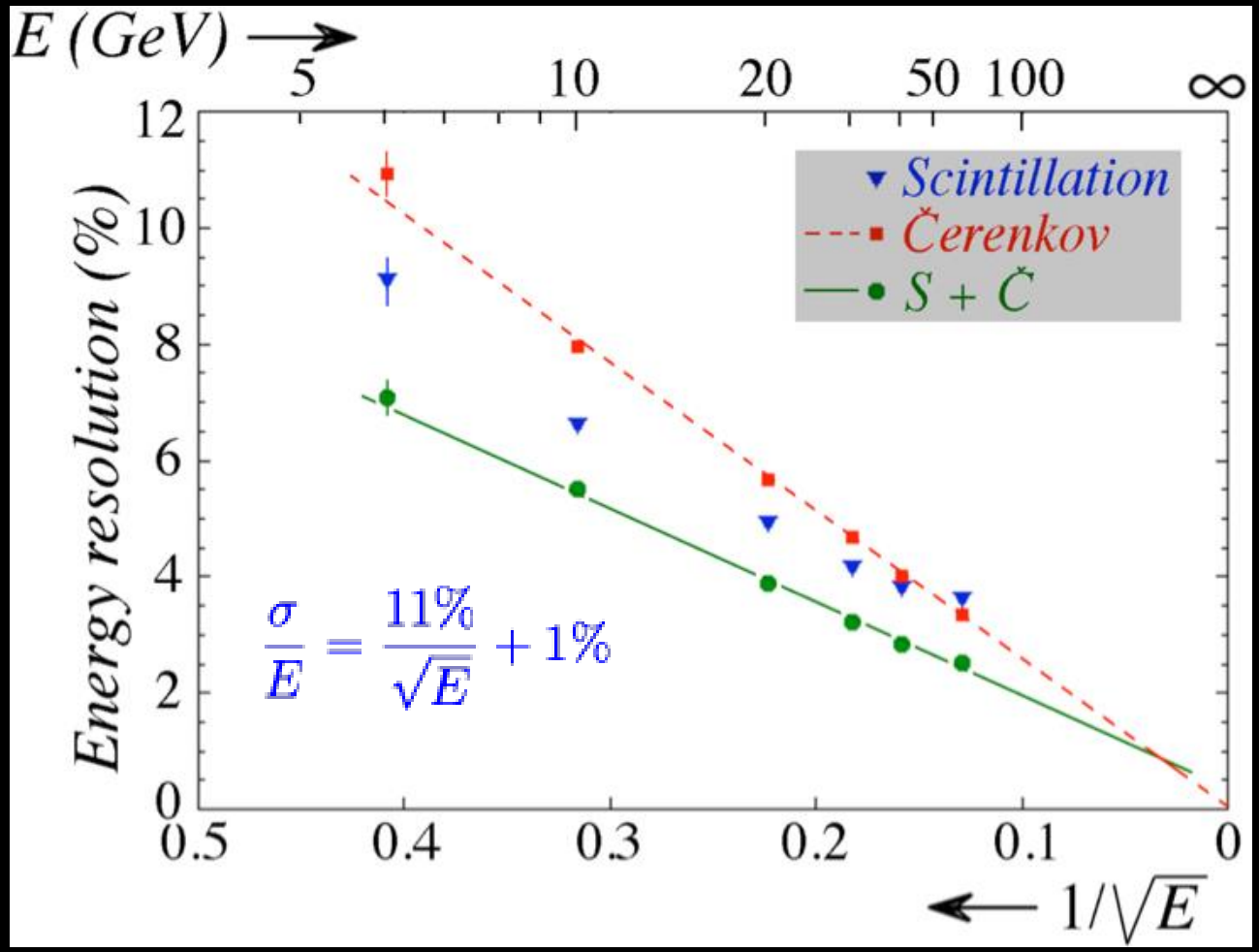

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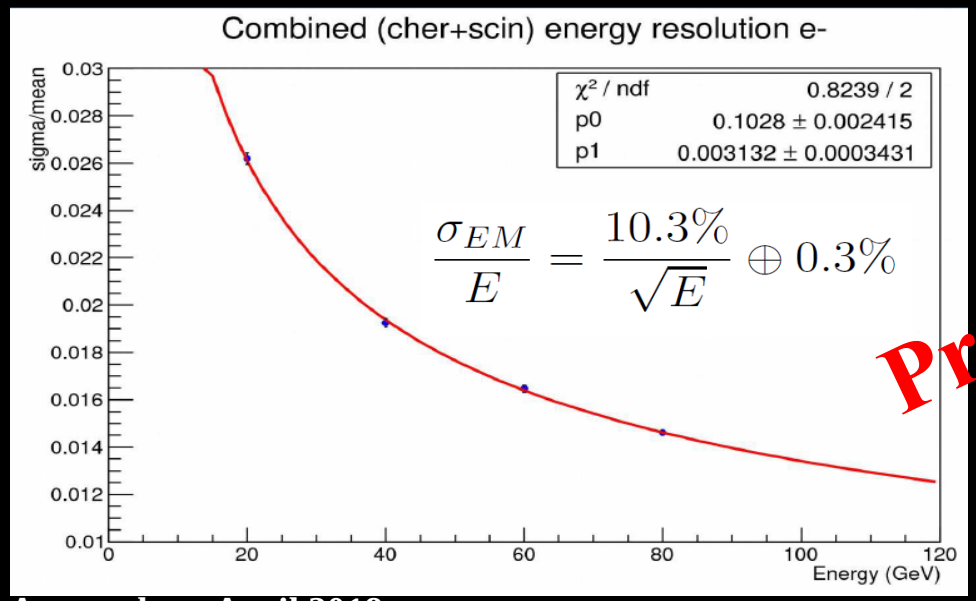


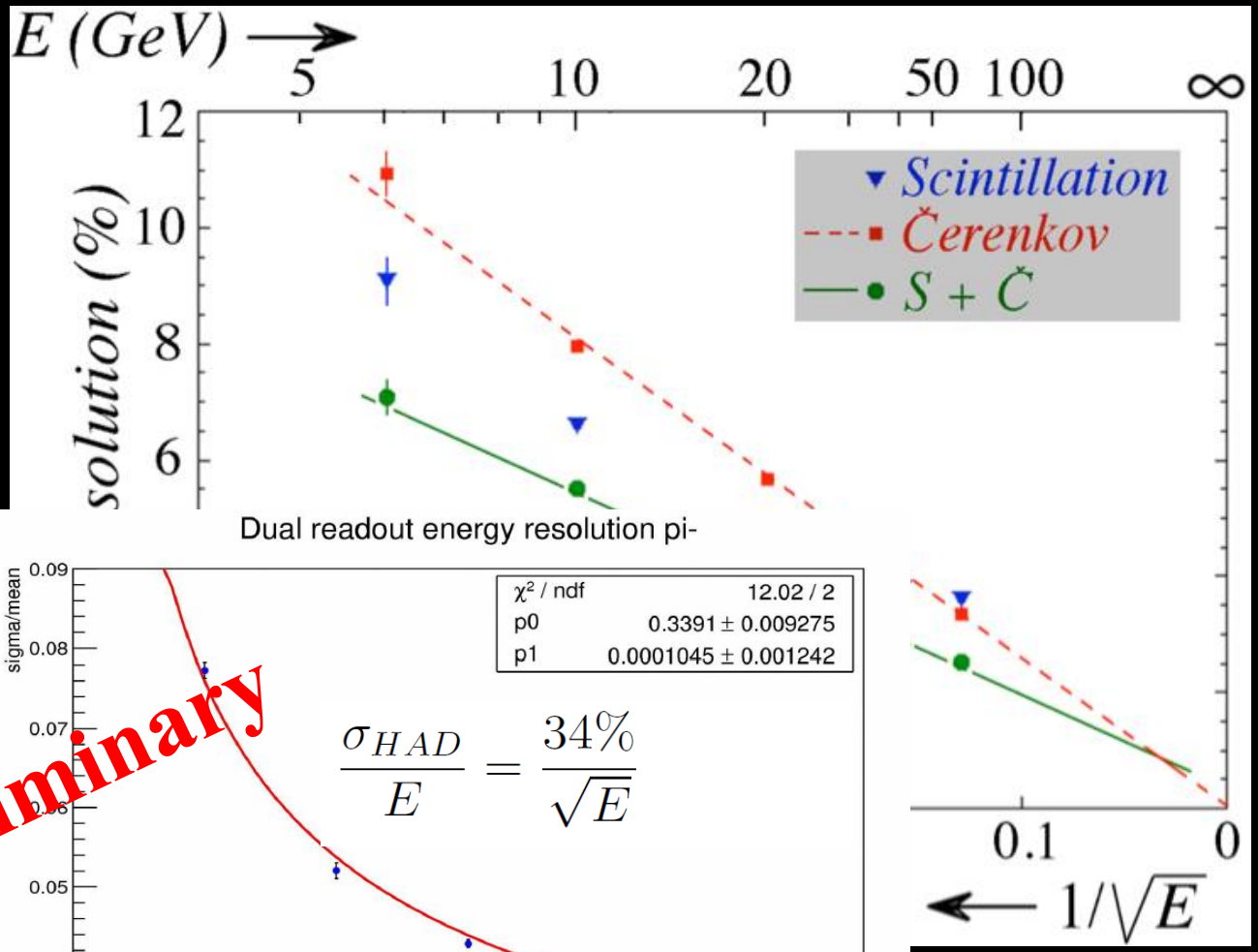

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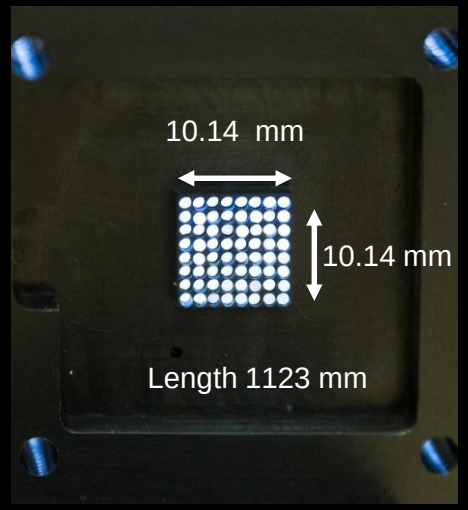


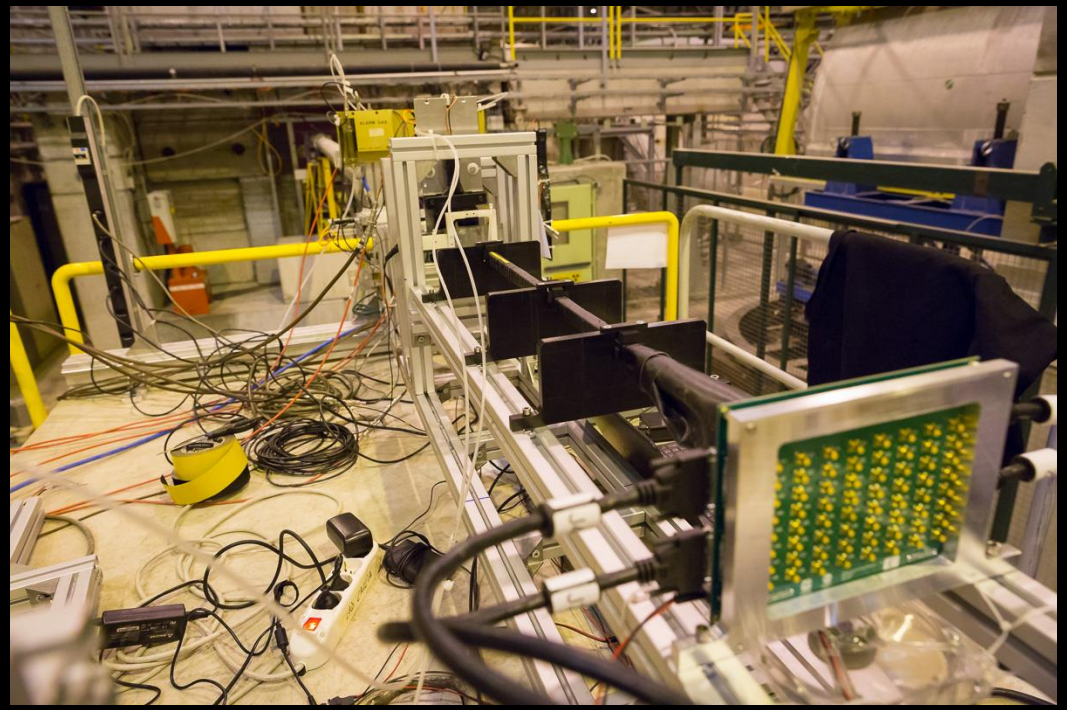

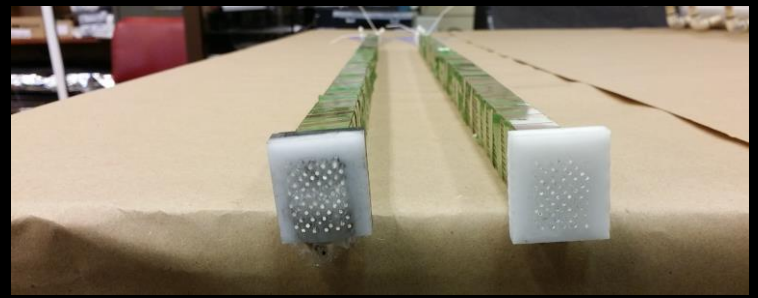

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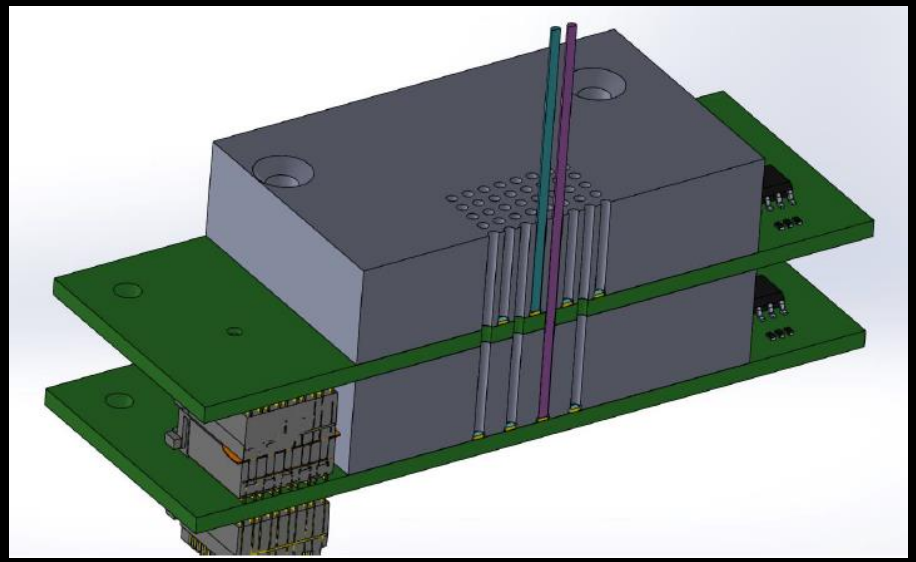

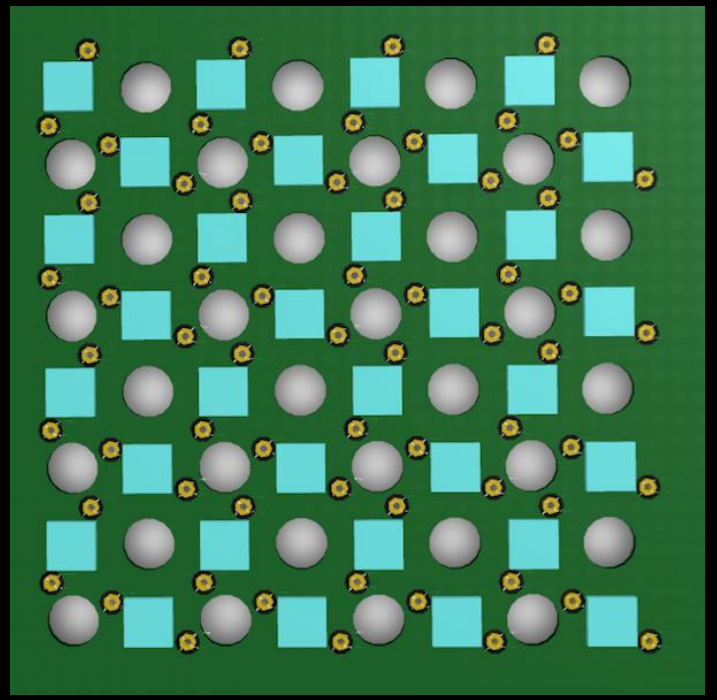

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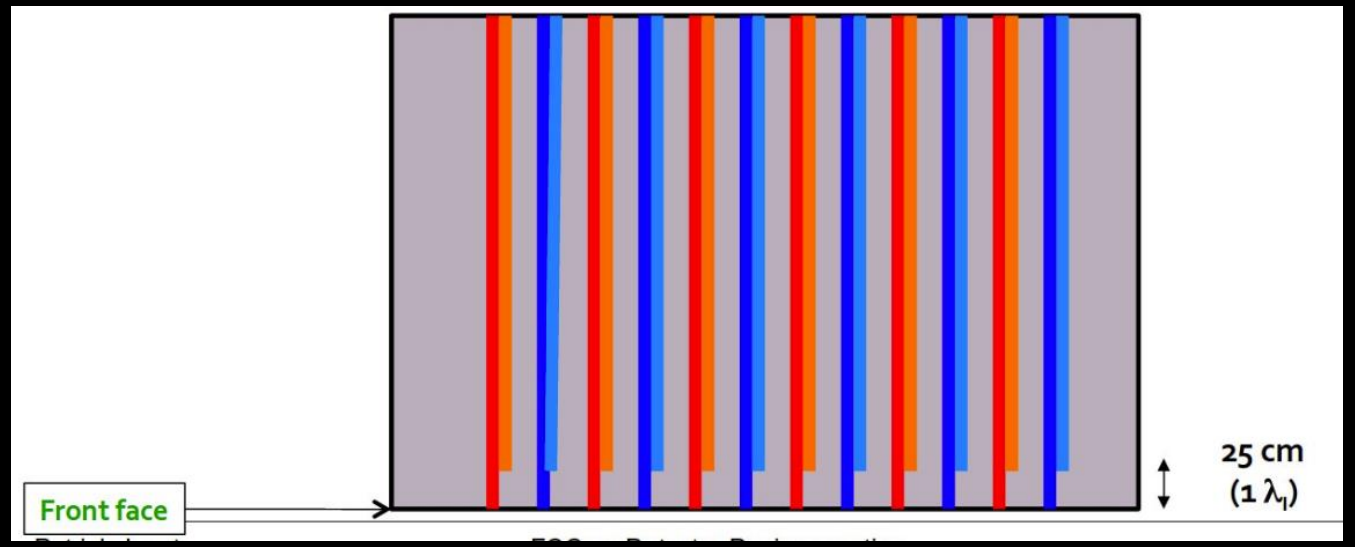

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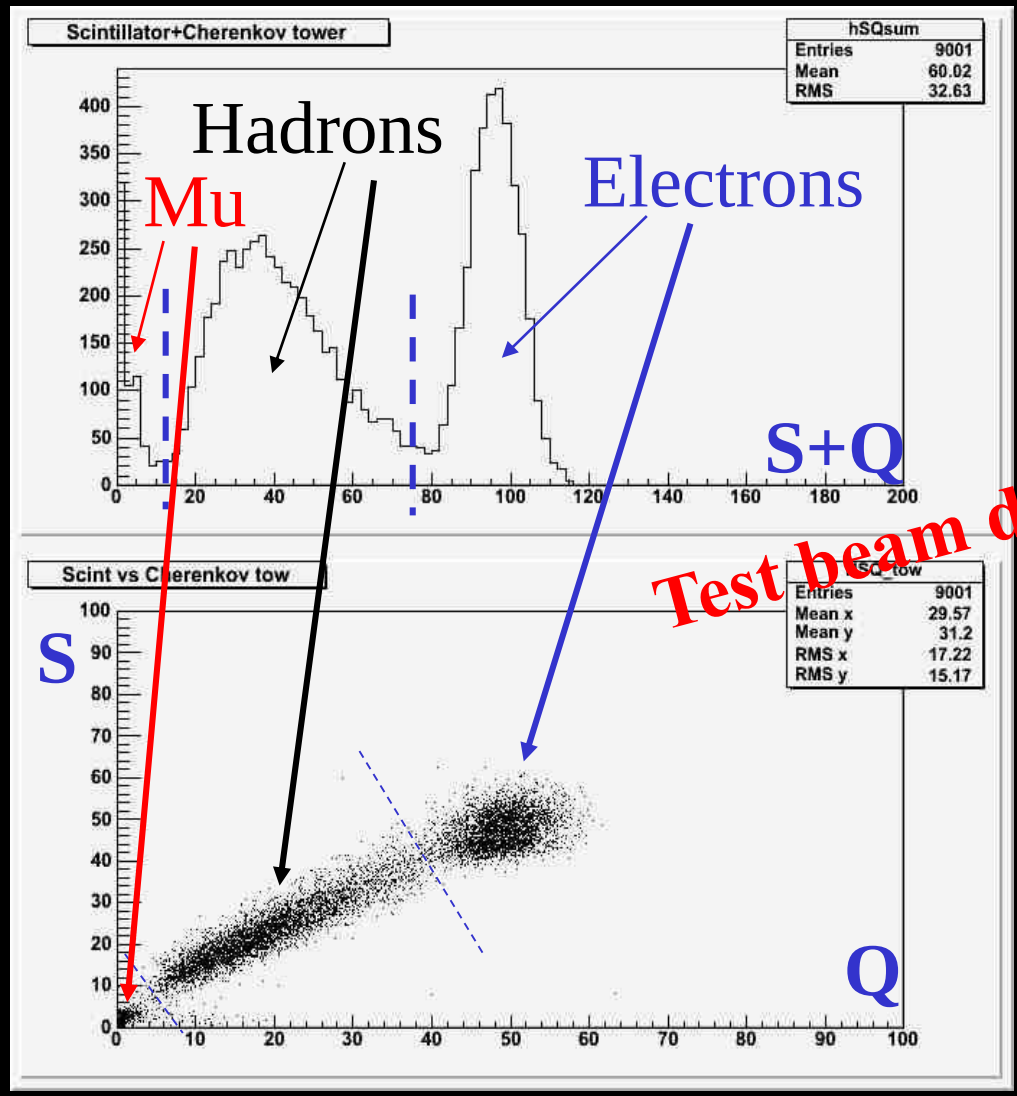

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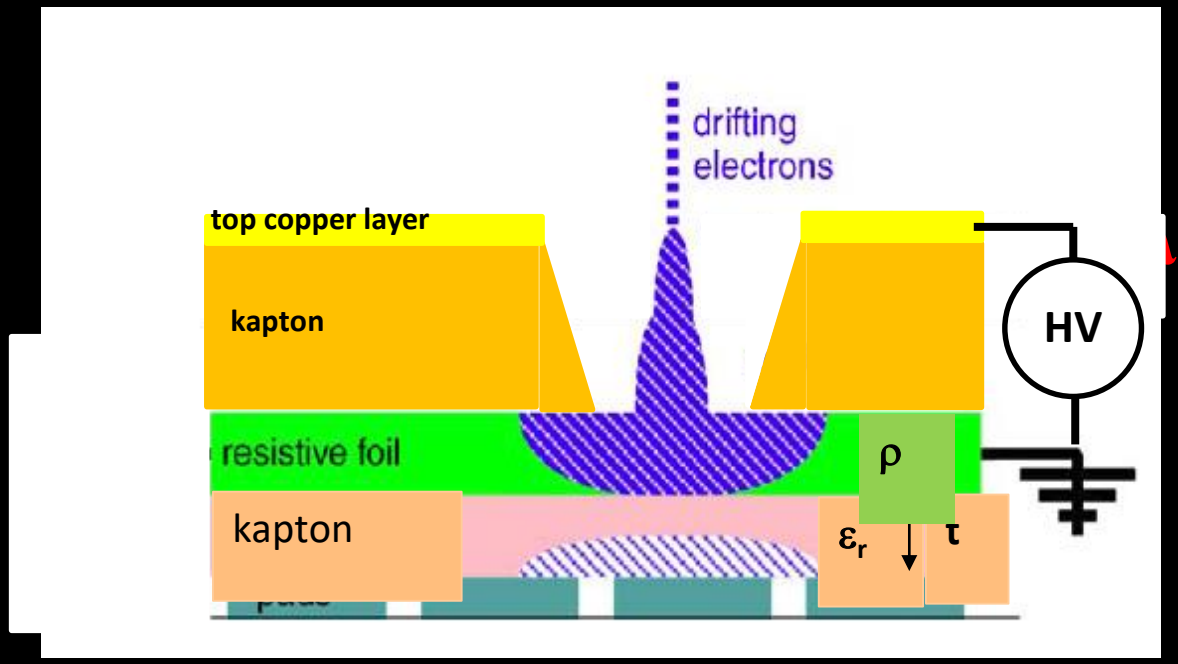
- Better muon ID in jets:
  - More filter behind calorimeter
    - Iron yoke (>50 cm Fe)
  - with additional chambers
    - μ-RWELL low-cost technology already proven for low rate applications (CMS/SHiP)
    - See:
      - Talk by P. Giacomelli in Common Det. Tech.
      - Poster by G. Bencivenni



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- IDEA vertical slice test beam September 2018
  - 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 muon chamber efficiency and resolution

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- Pre-shower optimization
  - Thickness, resolution & coverage

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- More work in progress to optimize design
  - Detector R&D/test beam
  - Benchmark with simulation
  - Mechanical engineering

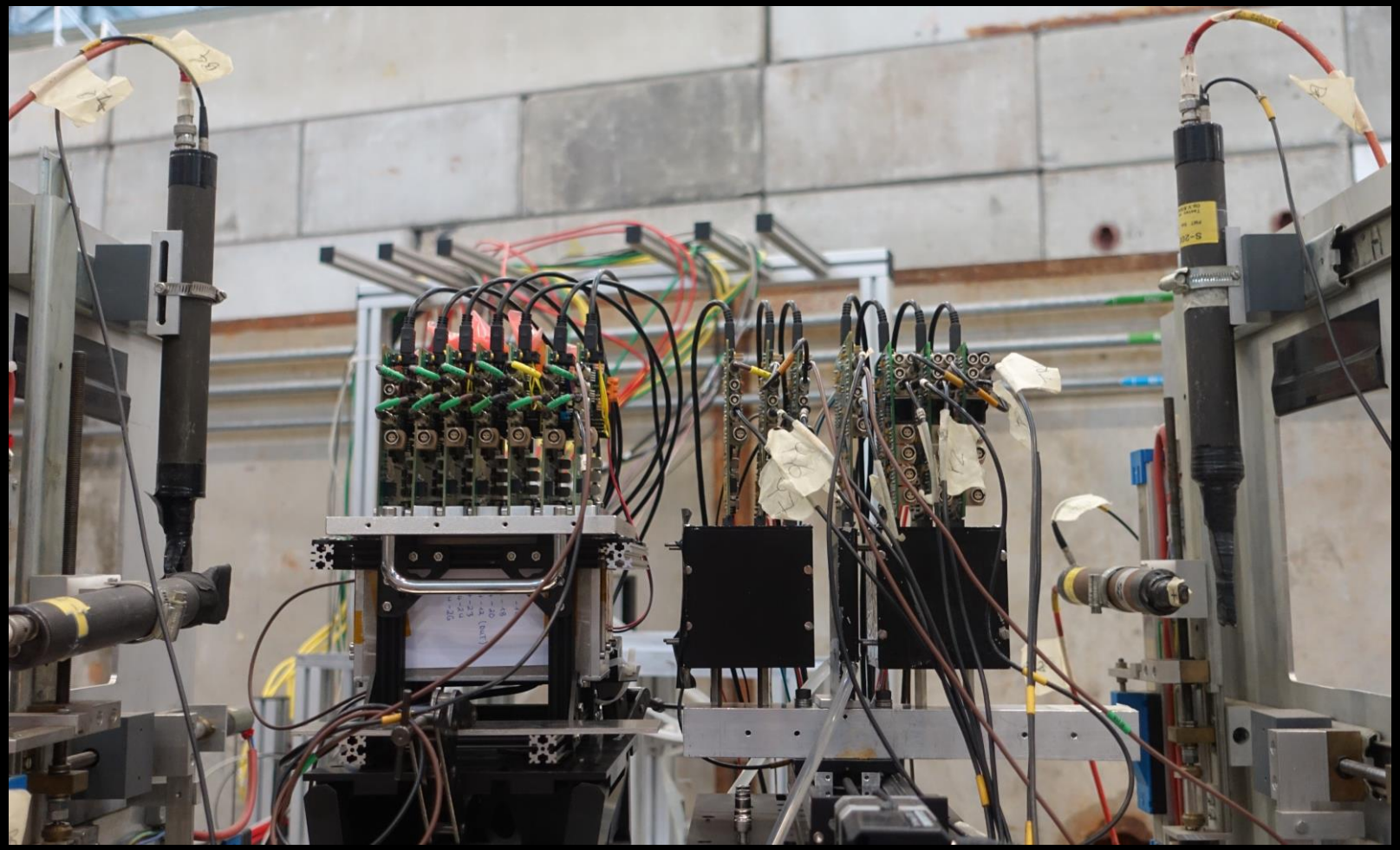
# Conclusions

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

# Backup slides

# Vertex detector

- Impressive recent test beam results



Courtesy of ALICE J.W. van Hoorne

# Vertex detector

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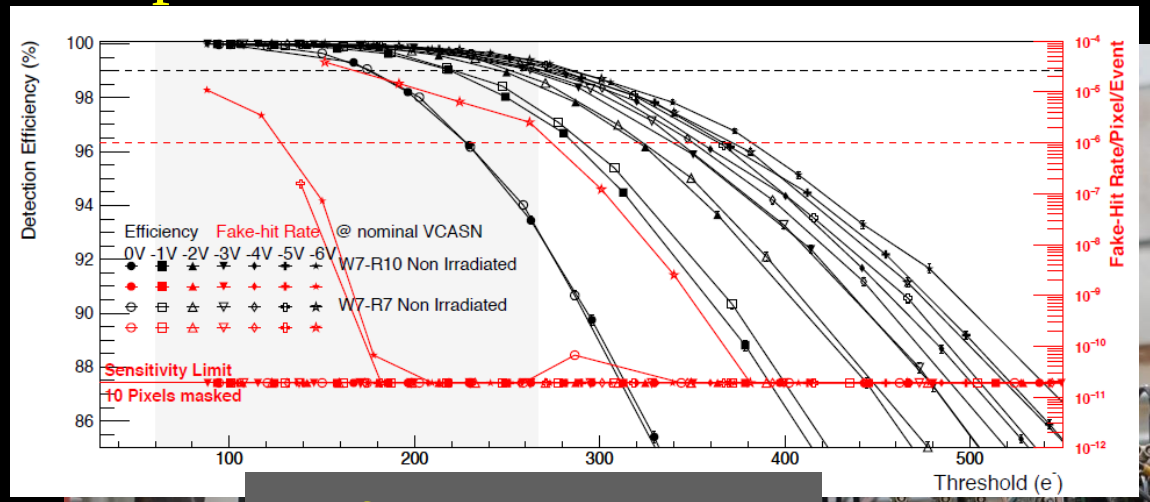
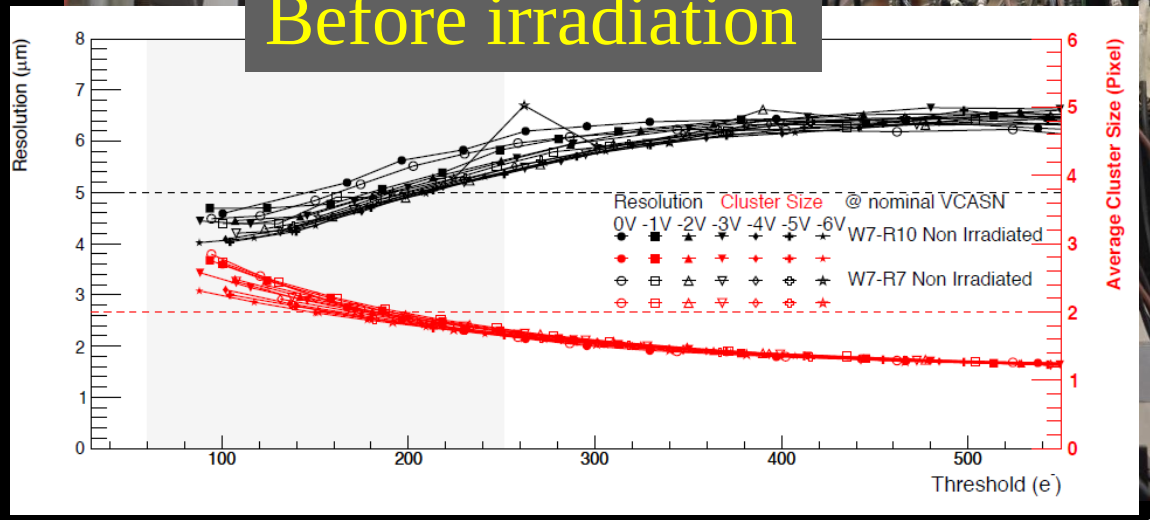



Before irradiation

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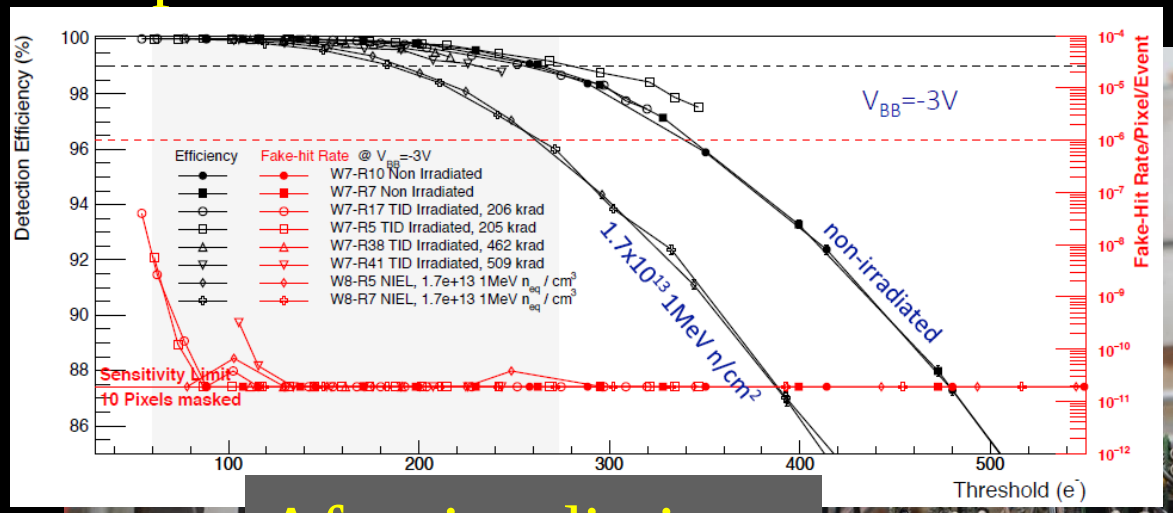
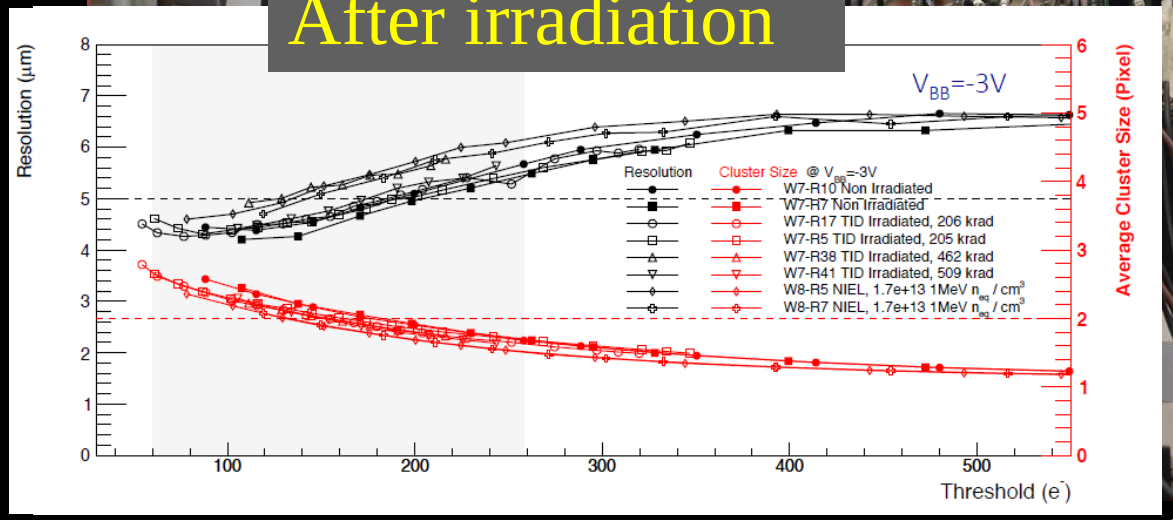
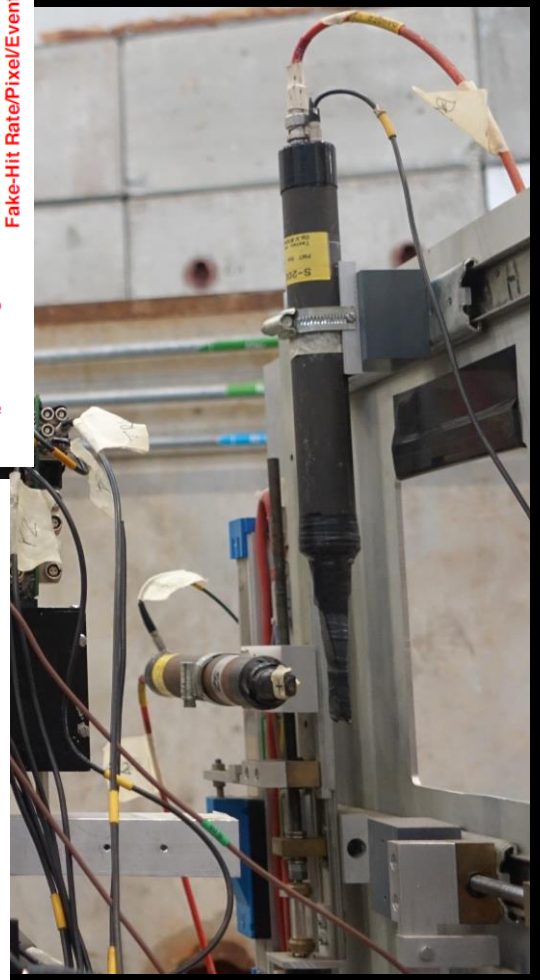



After irradiation

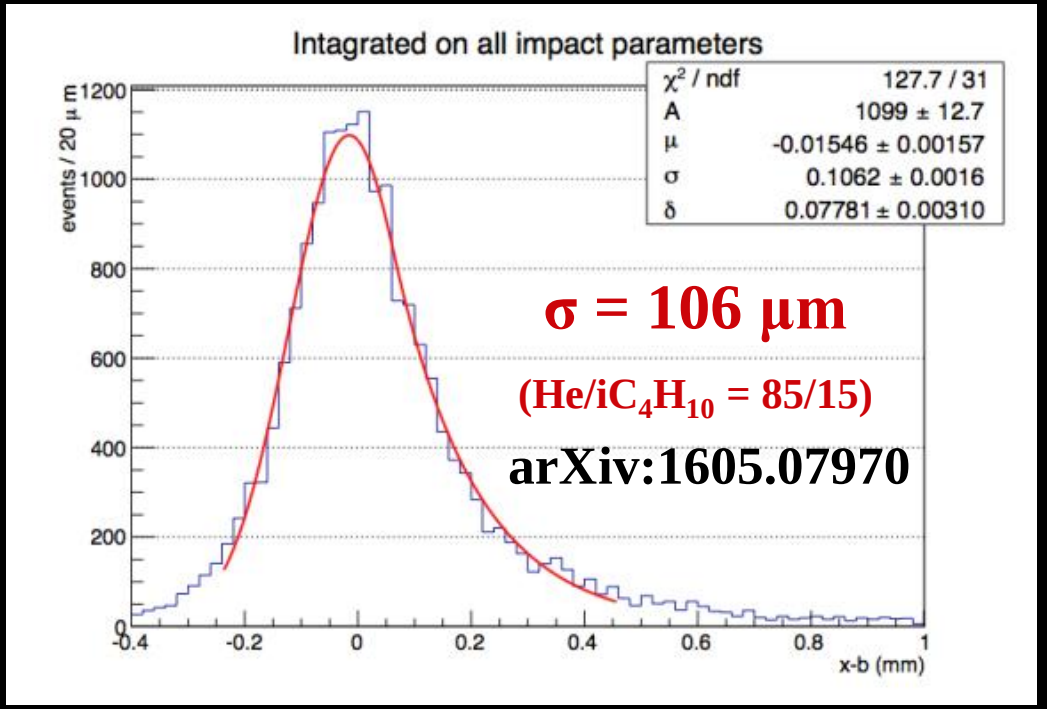


Courtesy of ALICE J.W. van Hoorne

# Tracker

- Minimal performance established (MEG-II prototype)



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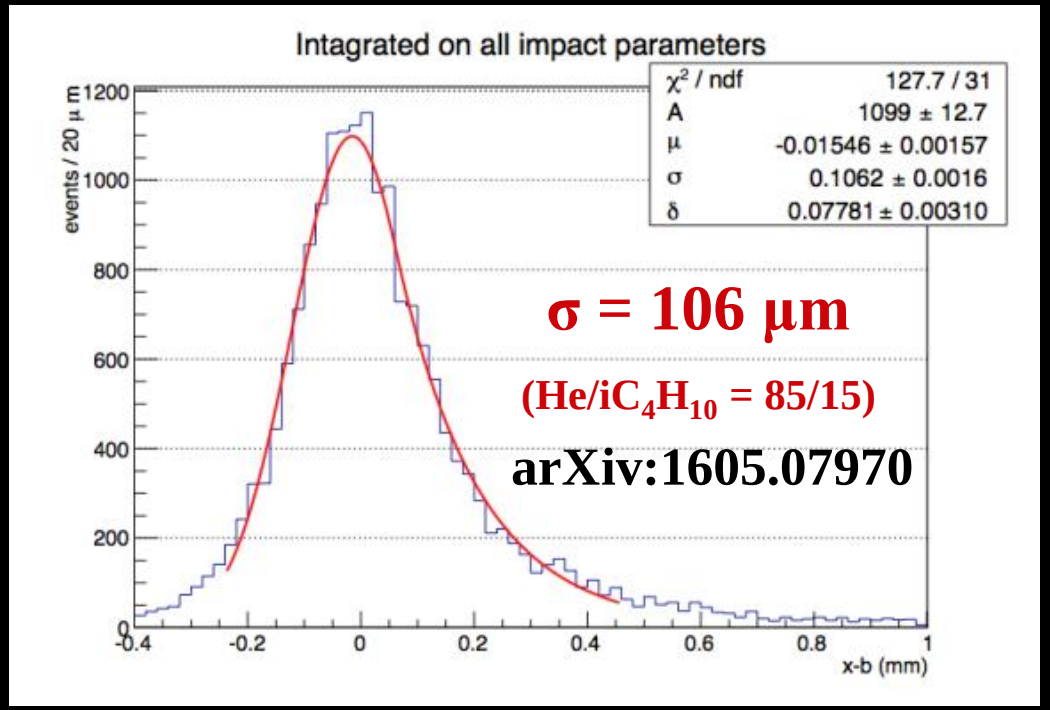

# Tracker

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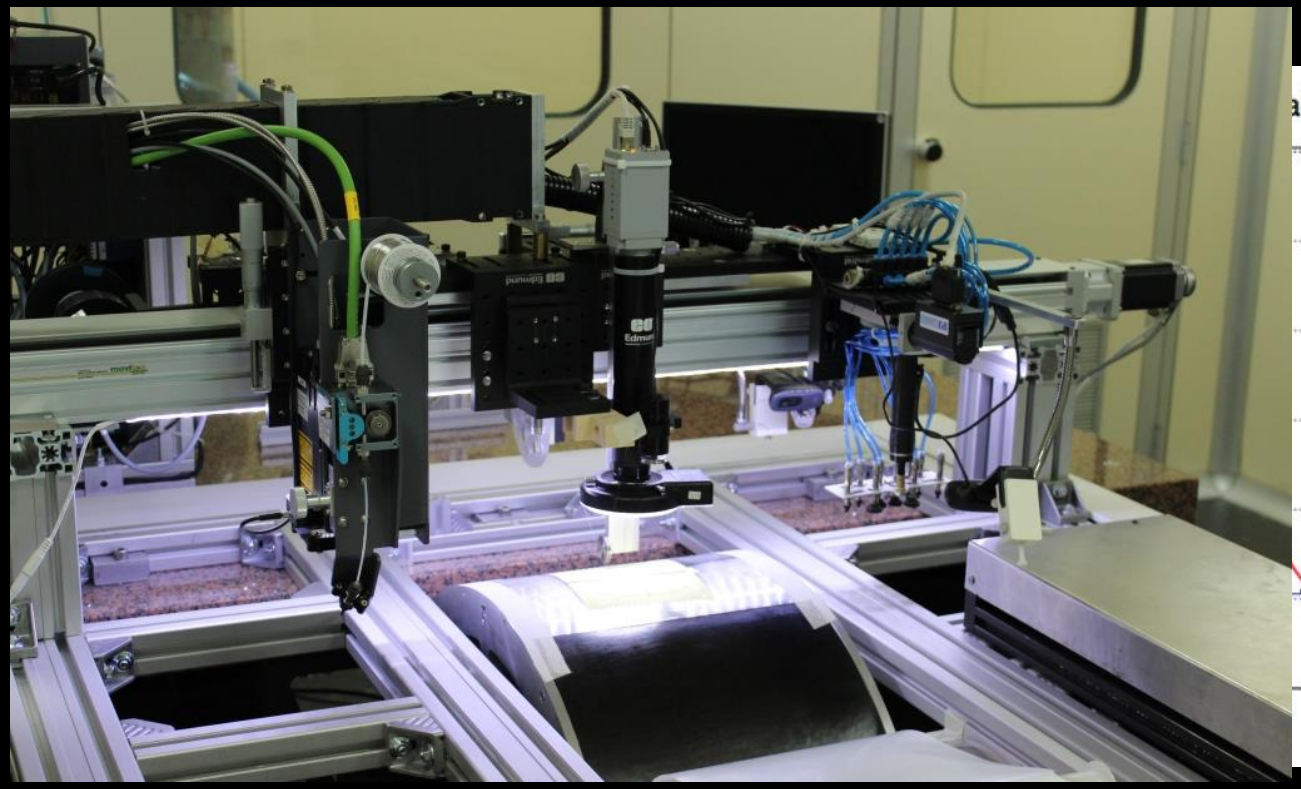
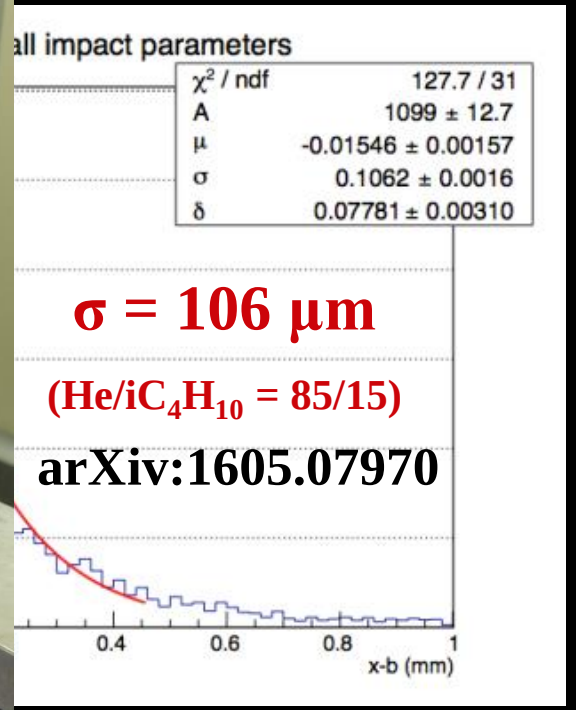
- Technical solutions engineered (MEG-II)
  - E.g. Wire stringing and soldering machine





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- Potential resolution in jets
  - ~ $40\%/\sqrt{E}$
    - (see 4° detector concept LOI)

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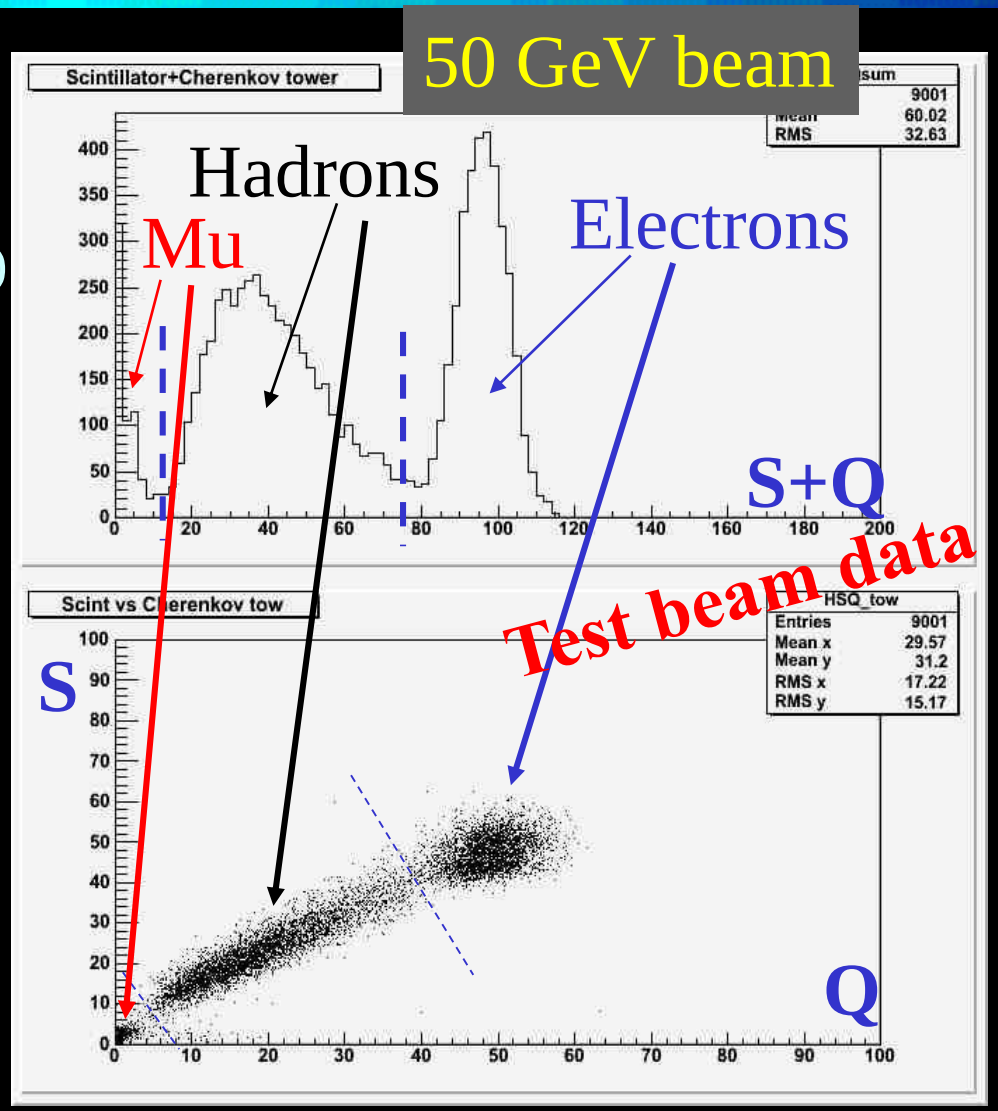

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    - $\varepsilon_{el}$ > 99%, <0.2% $\pi$ mis-ID
- Preshower
  - Acceptance determination
  - e/$\gamma$ /$\pi^0$ separation near hadrons
    - Synergy with part. flow