IDEA – CDR thoughts

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

Outline

- Main physics/technical drivers
- Detector layout
- Work in progress
- Future test beam
- Conclusions

Physics drivers recap

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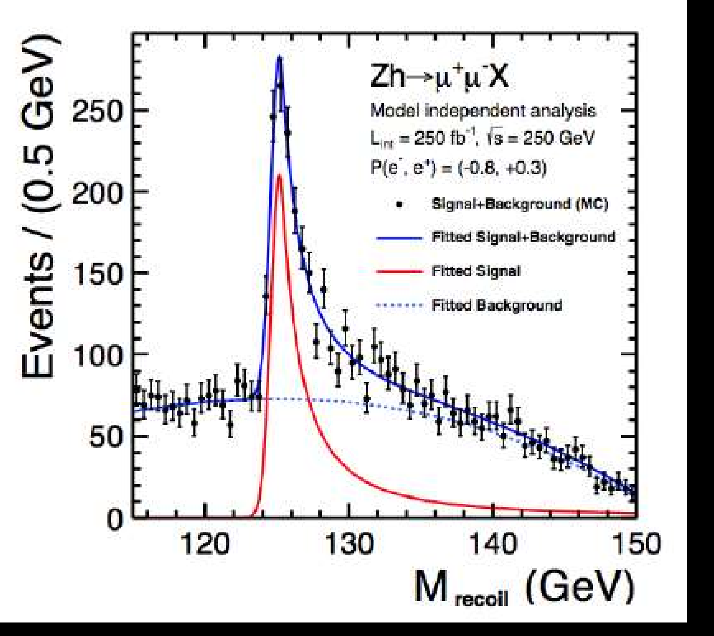
  - Higgs:
    - Tracking (recoil mass), vertex (b/c separation), calorimetry (hadronic W/Z, γγ), pre-shower (τ decays with π^0's)
  - Z pole:
    - Mostly covered by above
    - Excellent acceptance determination



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)

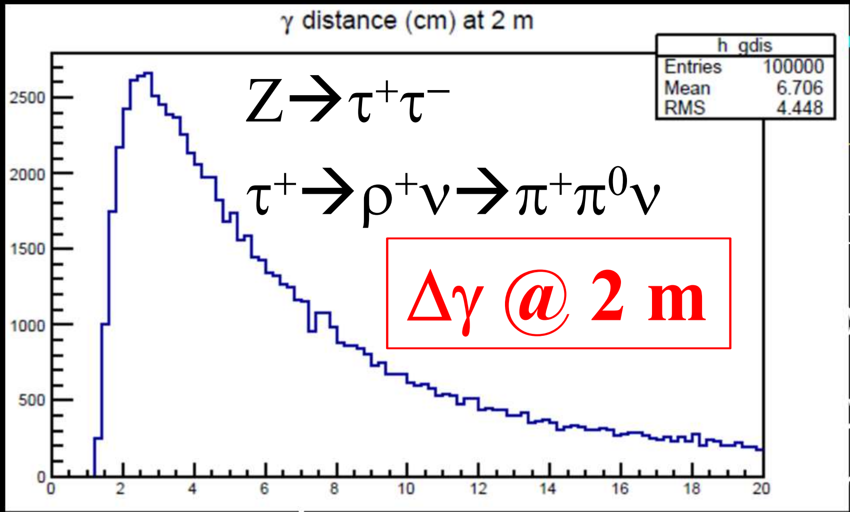
Differences with ILC

- 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
  - Non-negligible machine backgrounds
    - Cooling issues for PF calorimeter and vertex detector
    - 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% $\tau \rightarrow 1\,(e, \mu)\,\nu\nu$ + 20% $\tau \rightarrow (1,3)\pi^{\pm}\,l\nu$
  - 1 π^0: 28% $\tau \rightarrow (1,3)\pi^{\pm}\pi^0 l\nu$
  - 2 –3π^0: 10% $\tau \rightarrow \pi^{\pm}(2,3)\,\pi^0 l\nu$

Other drivers



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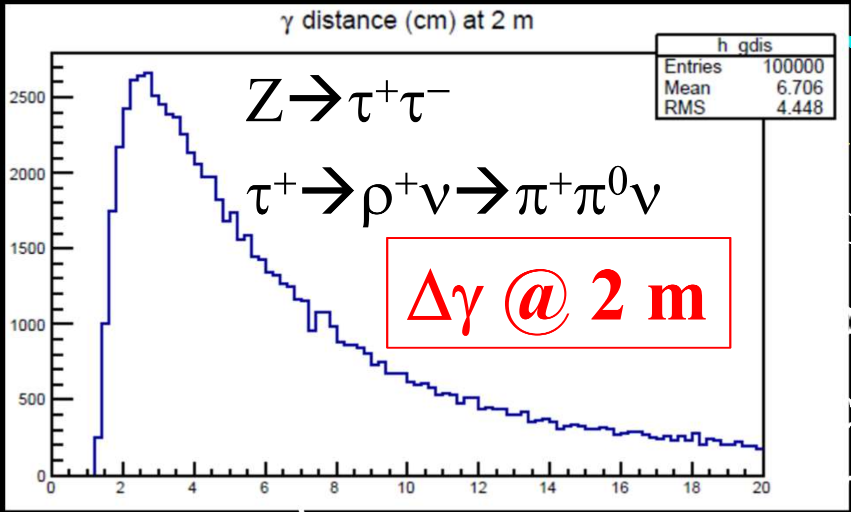
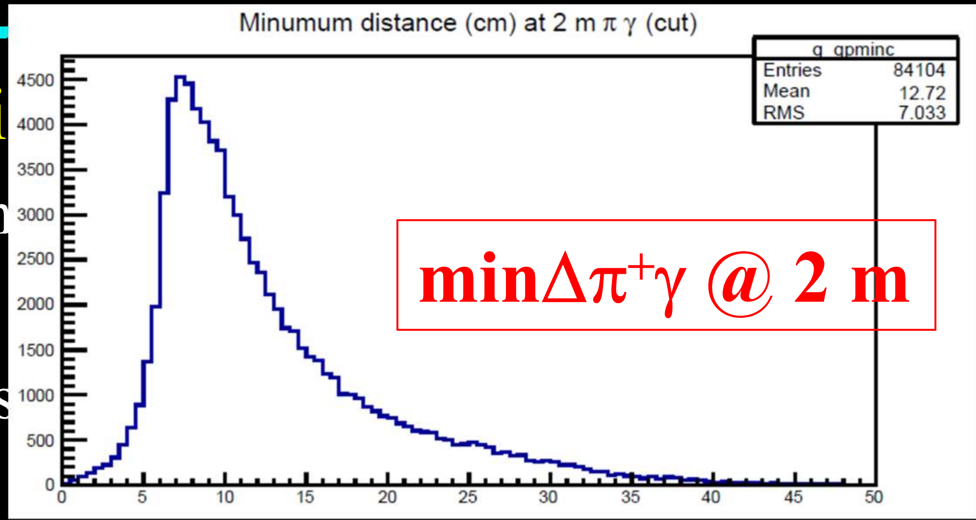
  - 2 –3π^0: $10\%\ \tau \rightarrow \pi^{\pm}\,(2,3)\ \pi^0 l\nu$
  - Pre-shower improves π^0 identification

Other drivers





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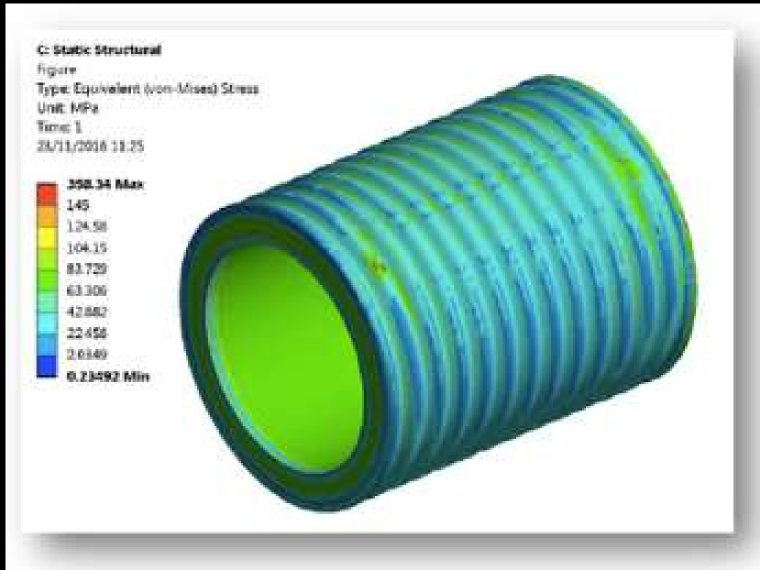
- Pre-shower improves π^0 identification
- Overlap with π^+ may require longitudinal segmentation

Detector solenoid

- 2T field solenoid – Rin = 2 m
  - Can be made very thin ~30 cm total = 0.74 X_0 (0.16 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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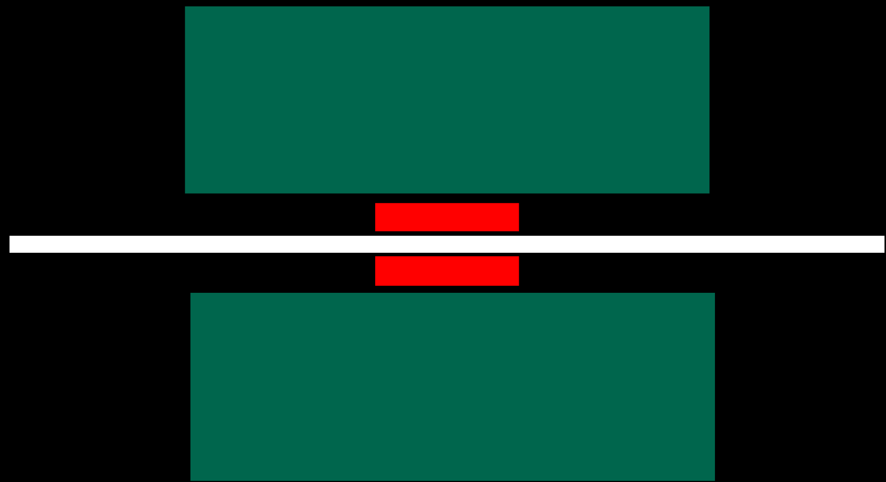

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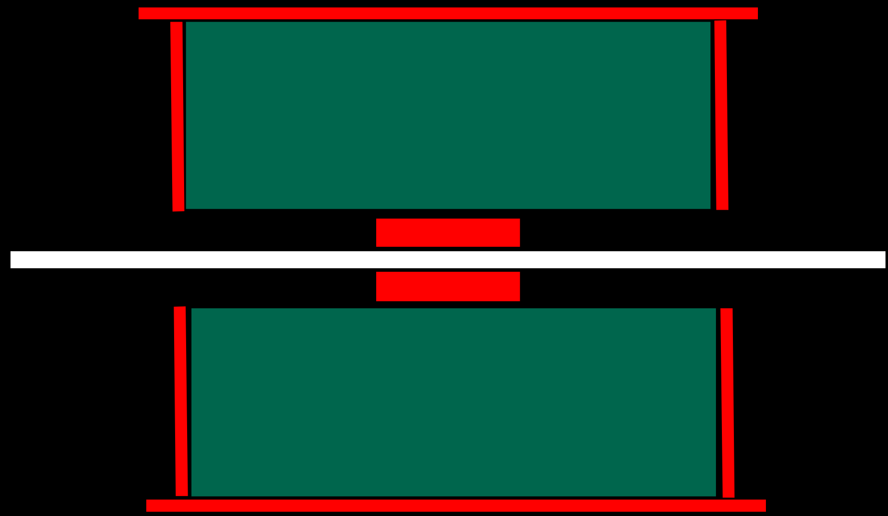

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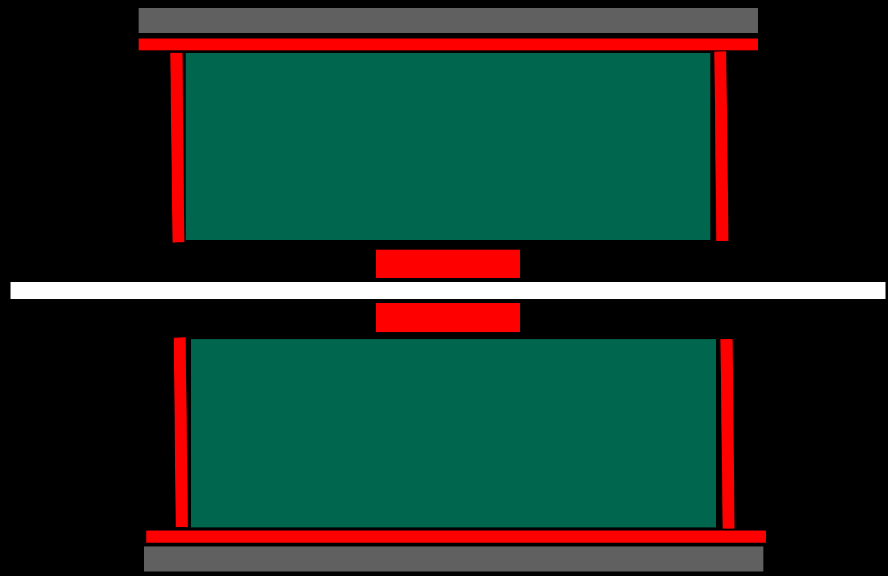

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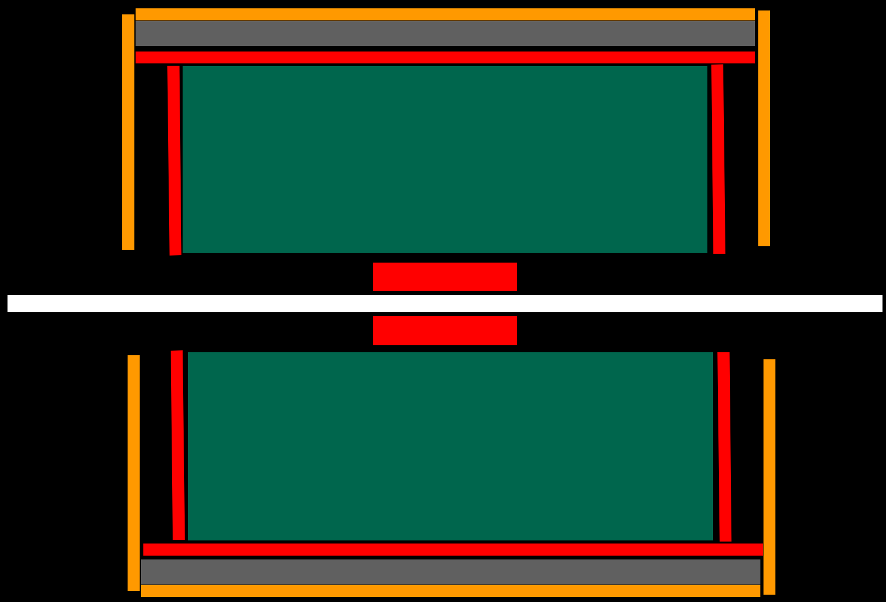

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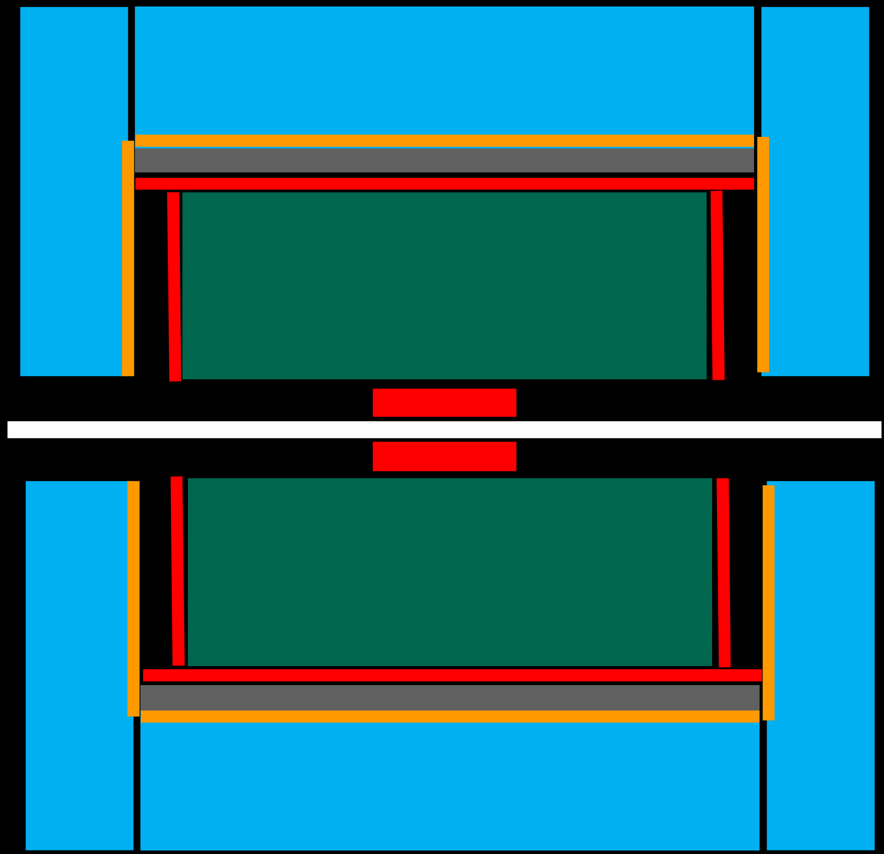

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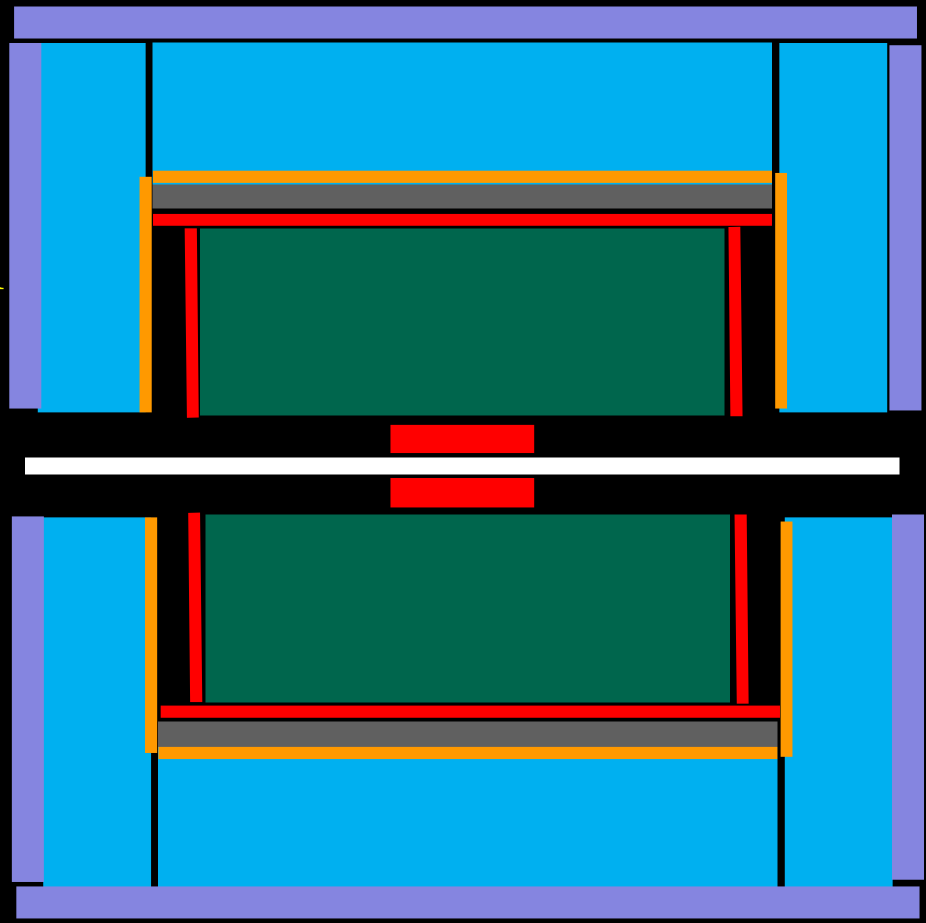
- Yoke + muon chamber



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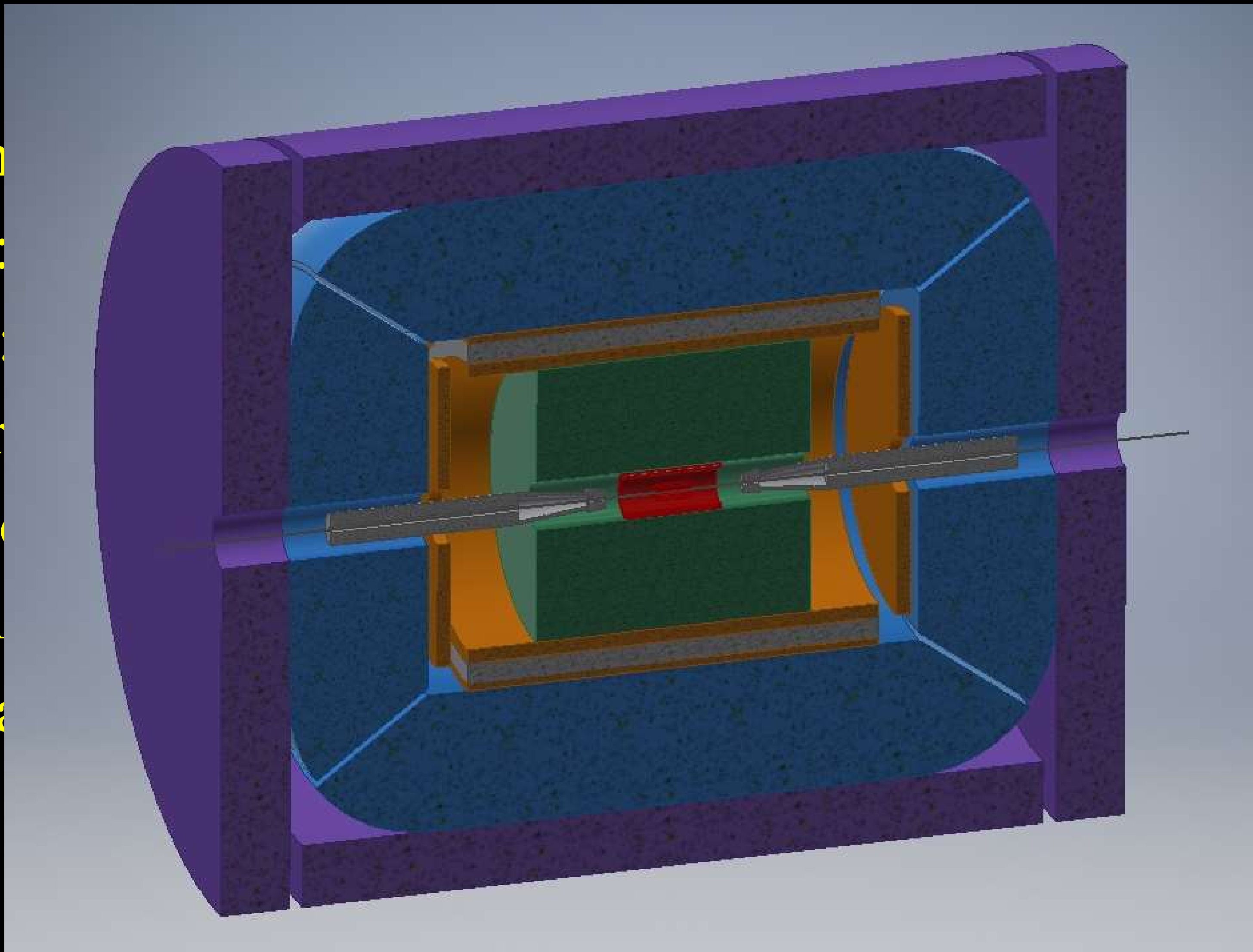
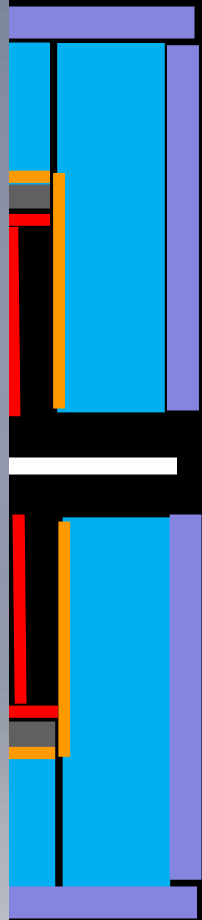




- Beam
- VTX:
- DCH:
- Outer
- SC C
- Presh
- DR c
- Yoke

In progress/wish list

- Tracking performance (done by FCC week)
  - Expected noise from beam background
  - Optimize VTX detector configuration
  - Comparison with TPC and all Si option
  - Higgs recoil mass from $Z \rightarrow \mu\mu$
- Pre-shower thickness and # layer optimization (possible for FCC)
- Calorimeter longitudinal segmentation (longer study)
  - Is it really needed?
  - How to best implement it?
- Full simulation on benchmark processes (longer study)

September 2018 Test Beam

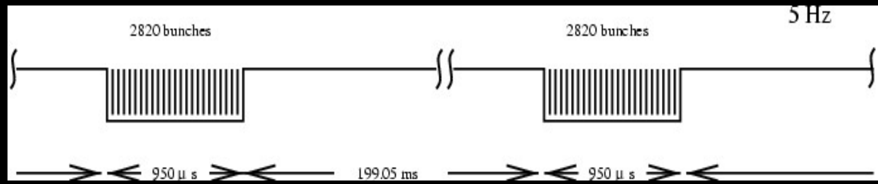
- FCC-ee has an approved test beam at CERN
  - 1 week in early September
- Great opportunity for a vertical slice test of IDEA
  - More studies on SiPM calorimeter readout
  - Calorimeter performance with pre-shower of different thickness
  - Segmented calorimeter
  - PID with cluster counting
  - μRwell muon chambers
- Huge effort to be successful in just one week
  - Help welcome from everyone
  - Should start planning soon

Backup slides

Backup slides

Tracking issues

- Timing
  - ILC: 1 ms pulse trains @ 5 Hz
  - CepC: 1 BX 5-20ns (Z) , ~1μs (H)
  - No large time gap:
    - Ion backflow issues → TPC
    - No power pulsing → VTX
    - Fast tracker, calorimeter, muon system → trigger/DAQ, Bck



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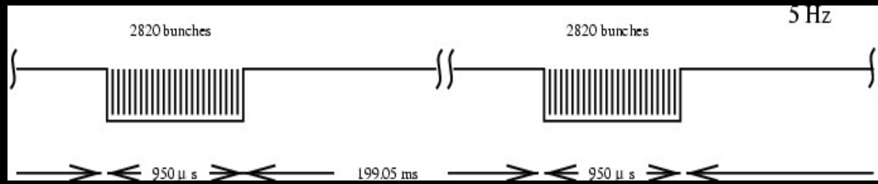
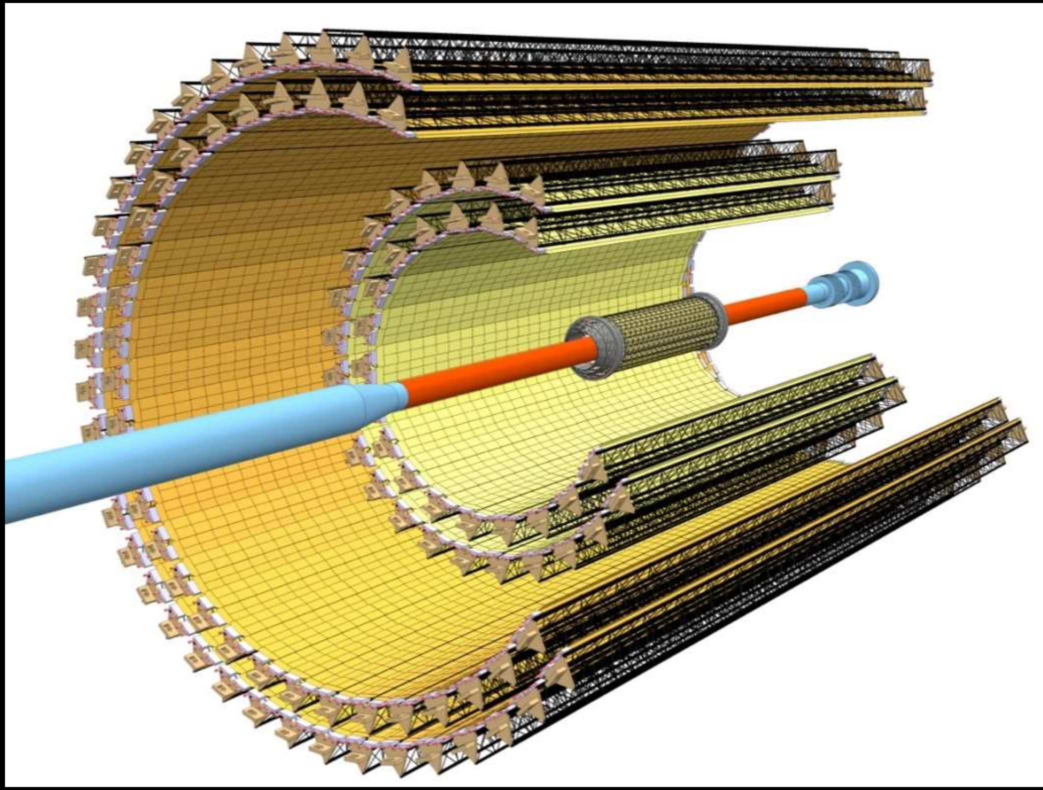


- Limited max radius & B field
  - Many measurements at high resolution
    - Gas is lighter (and cheaper) than rocks (ie. Si)

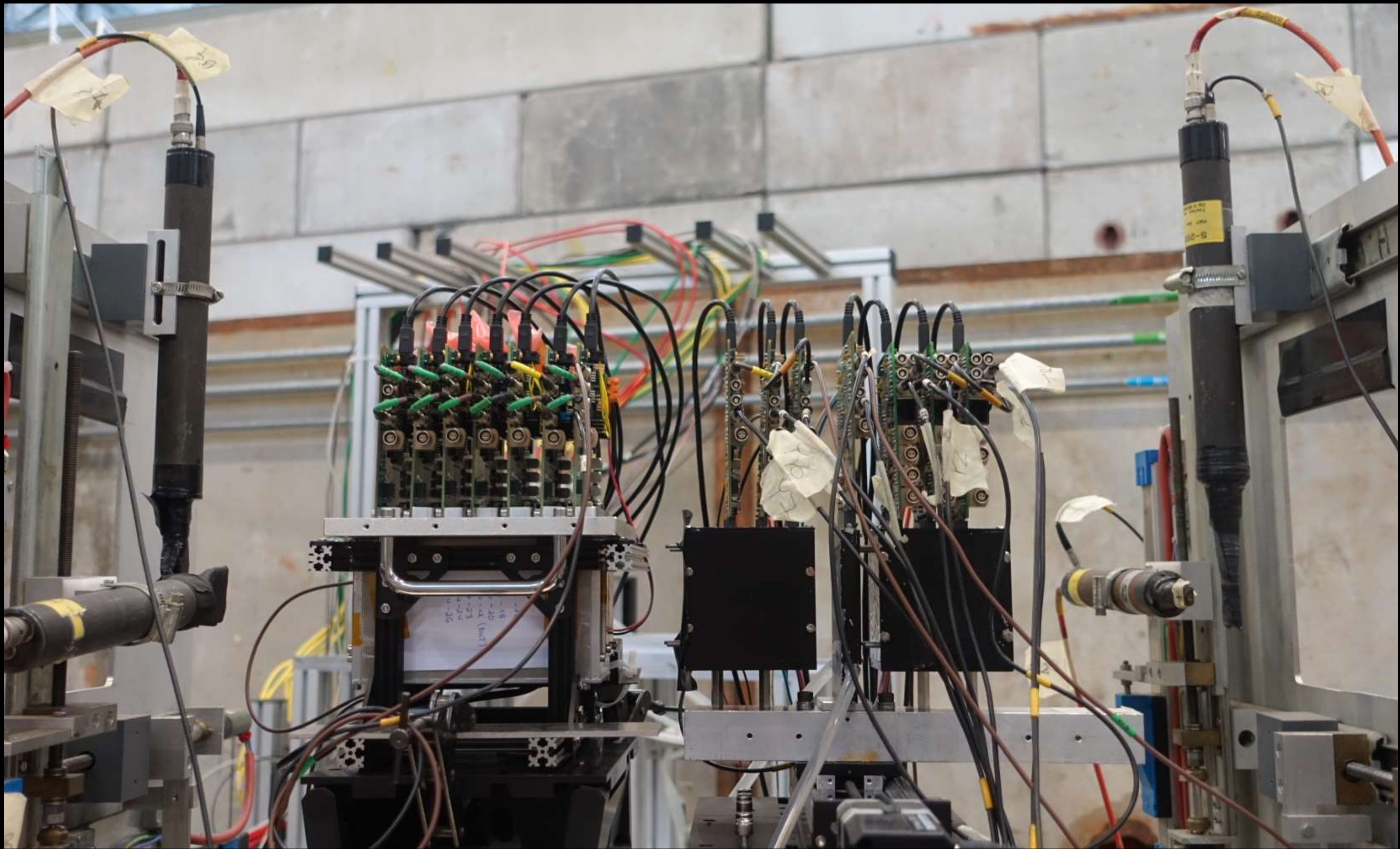
Vertex detector

- 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



Vertex detector

- Impressive recent test beam results



Courtesy of ALICE J.W. van Hoorne

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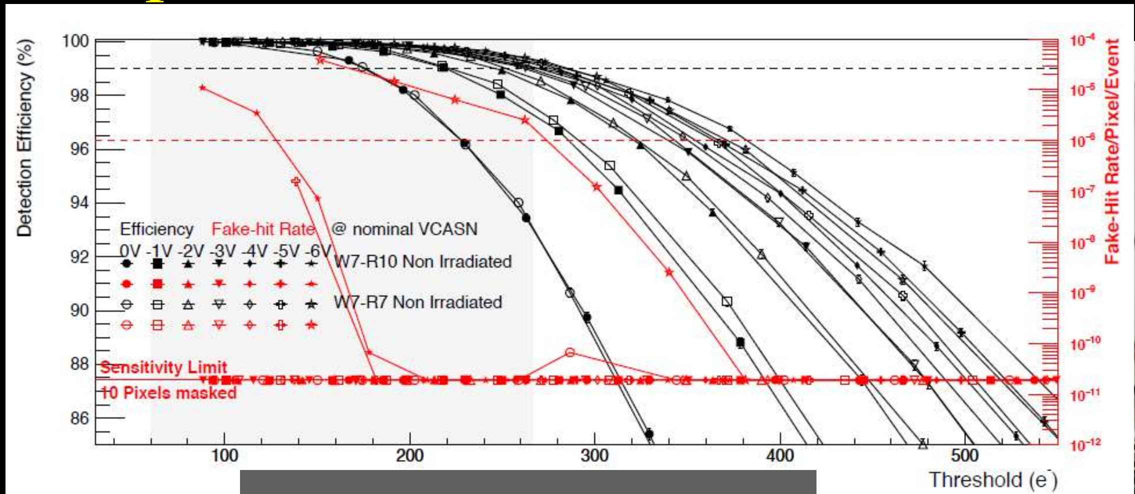
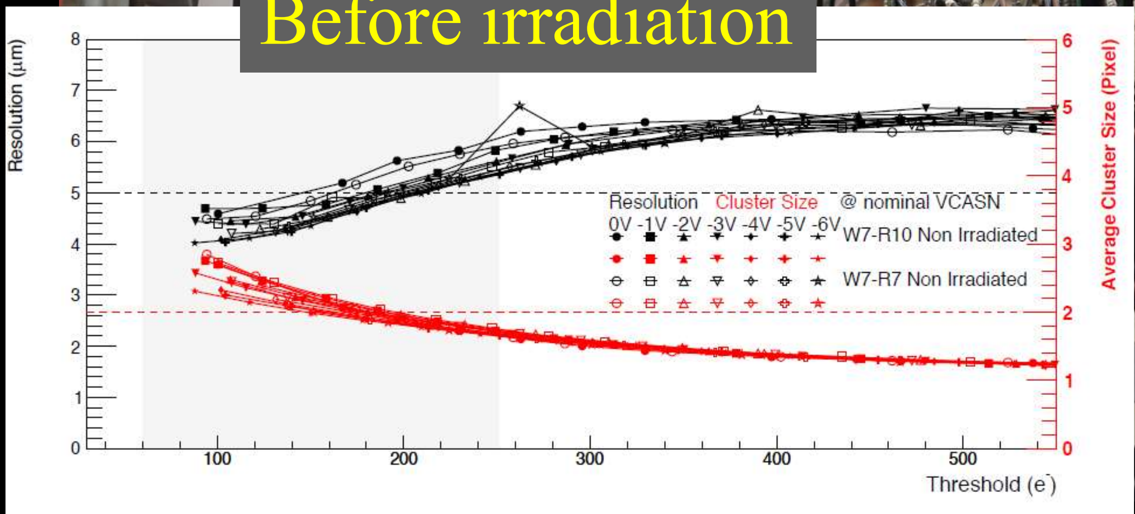


Before irradiation



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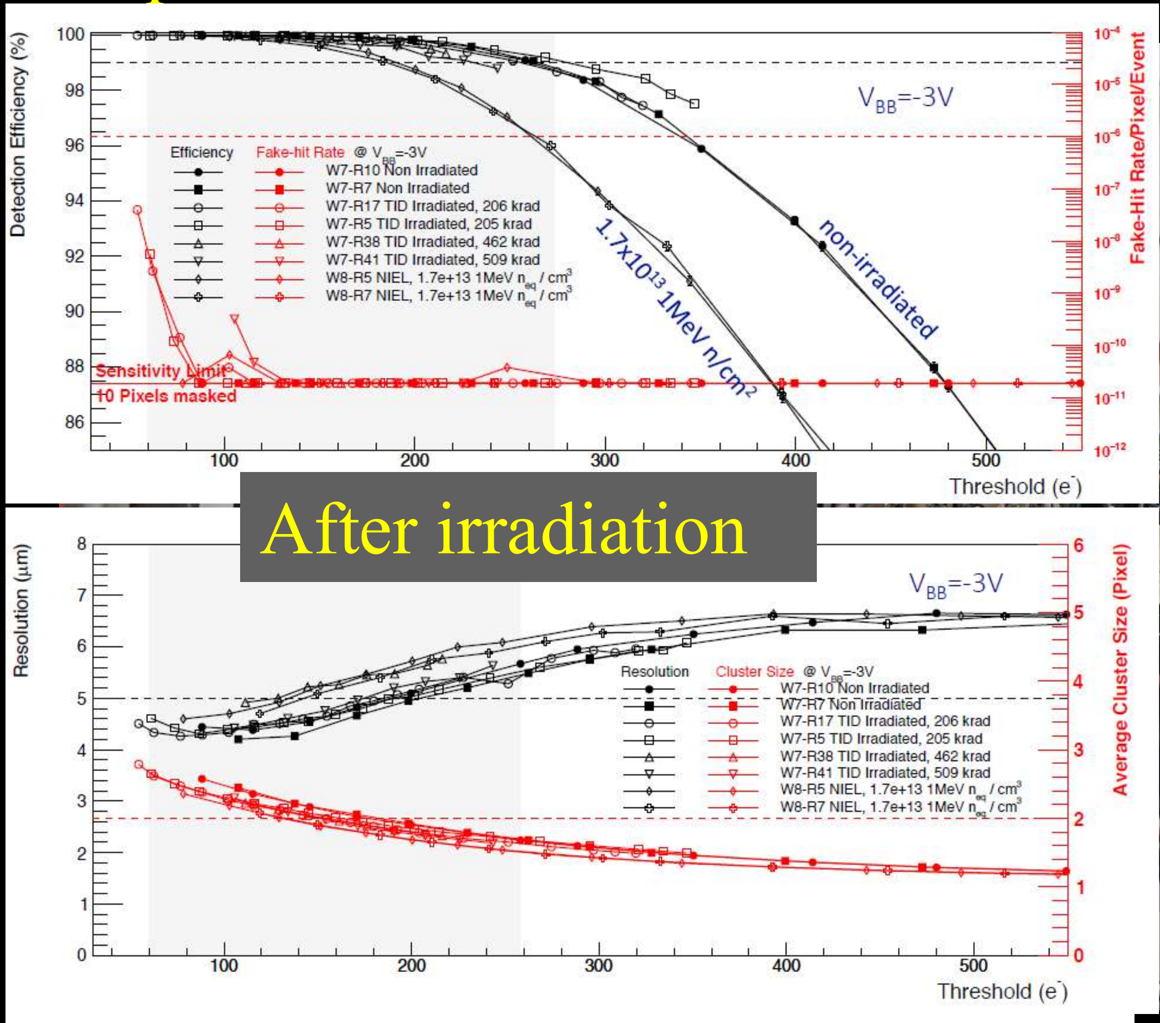

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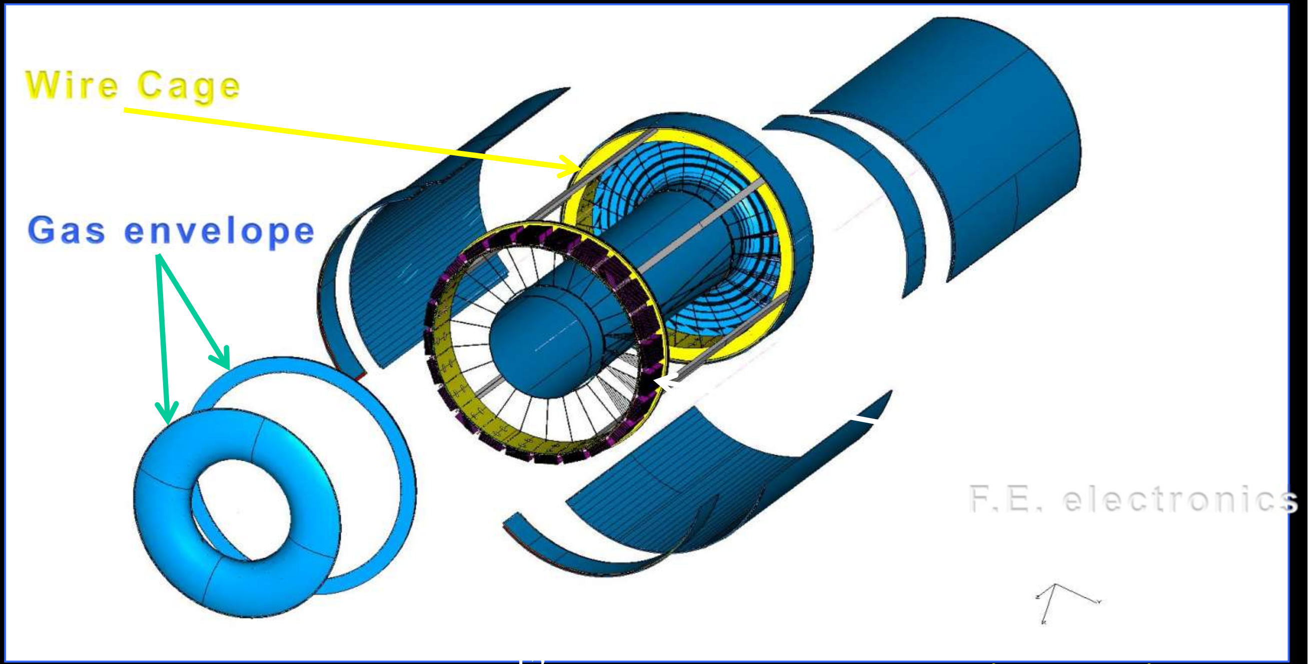
Tracker

- 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



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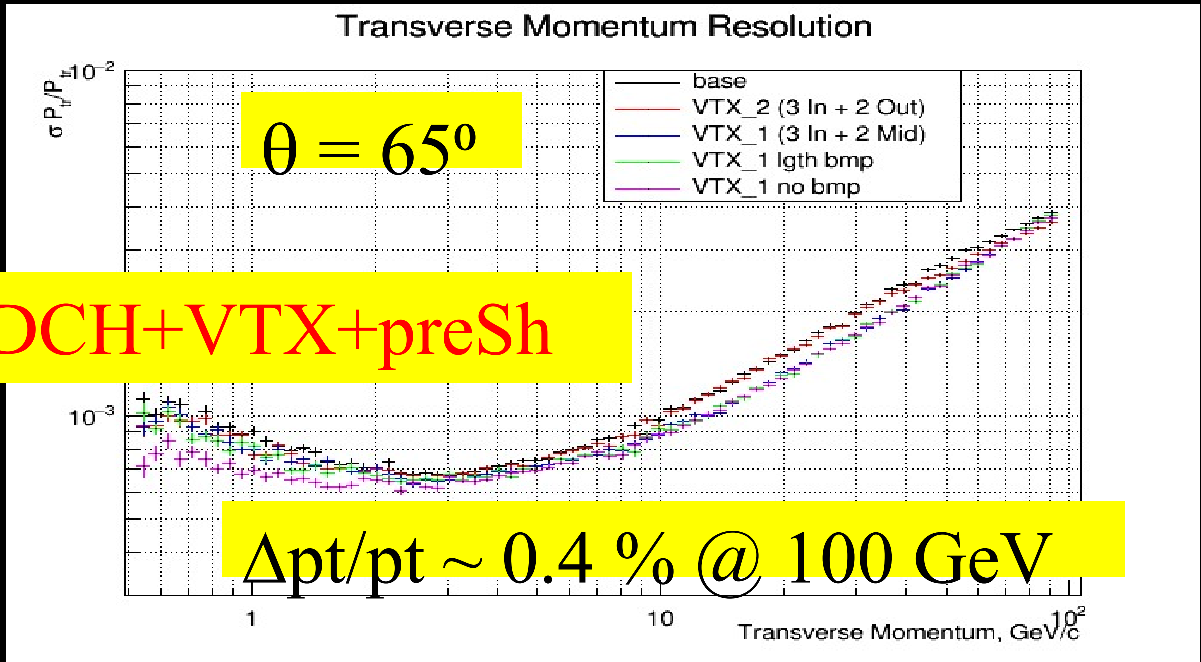
- B = 2 T
- L = 2 m
- N = 112



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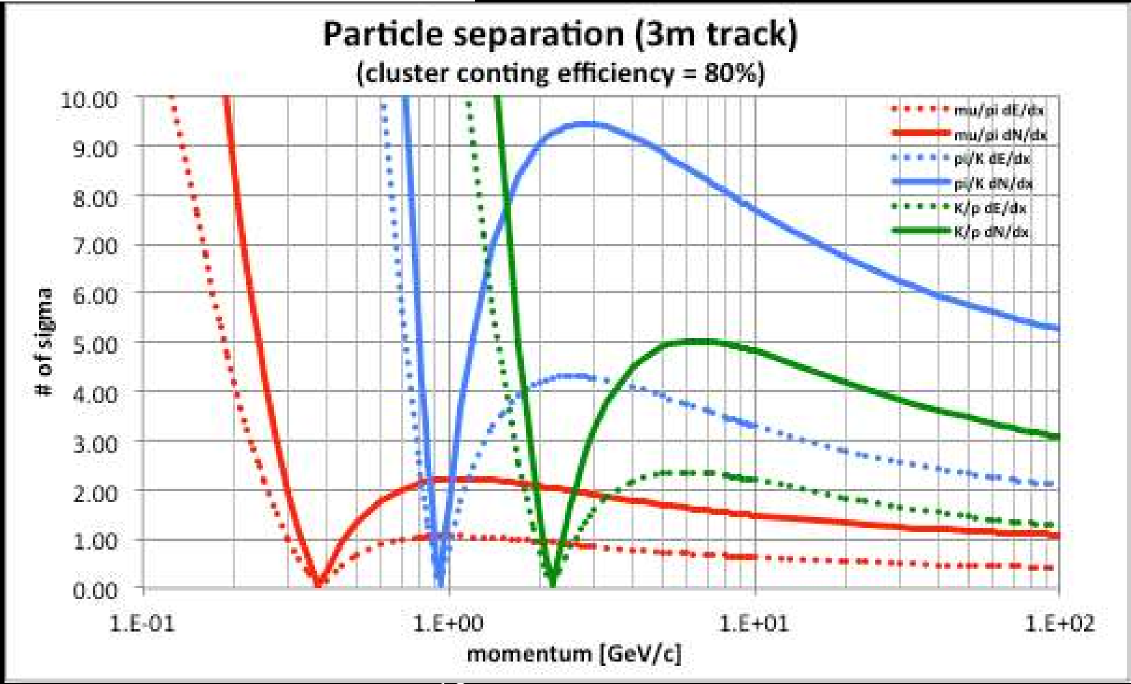
    - N = 112
  - dE/dx ~ 4%
  - dN/dx ~ 2%



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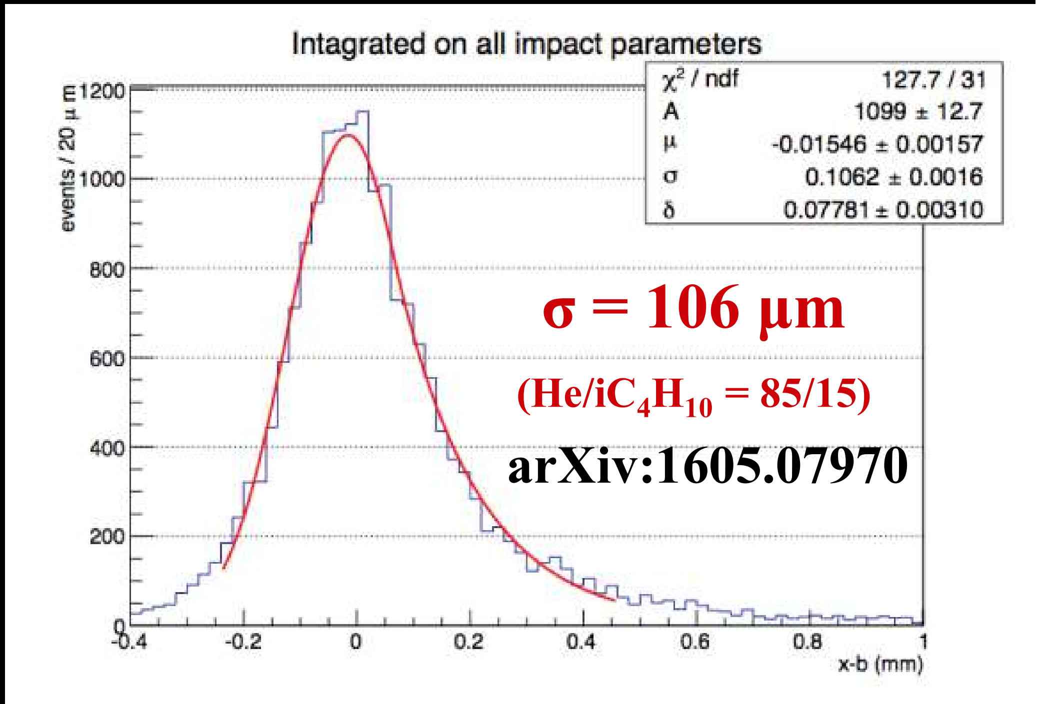
❖ Minimal performance established (MEG-II prototype)



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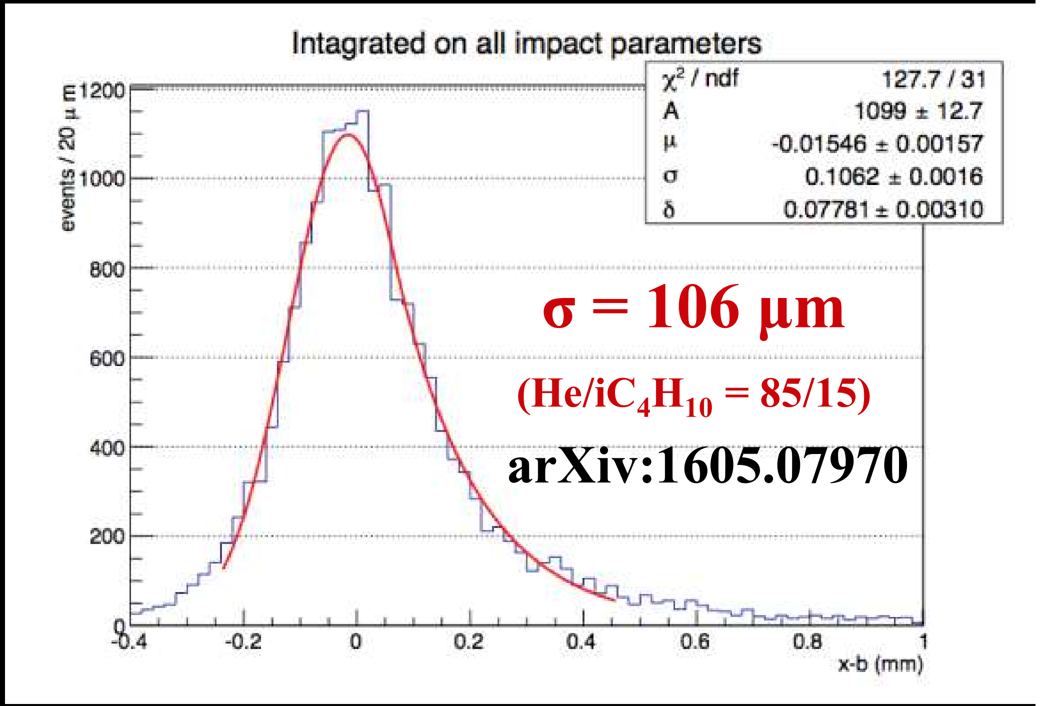
- Technical solutions engineered (MEG-II)



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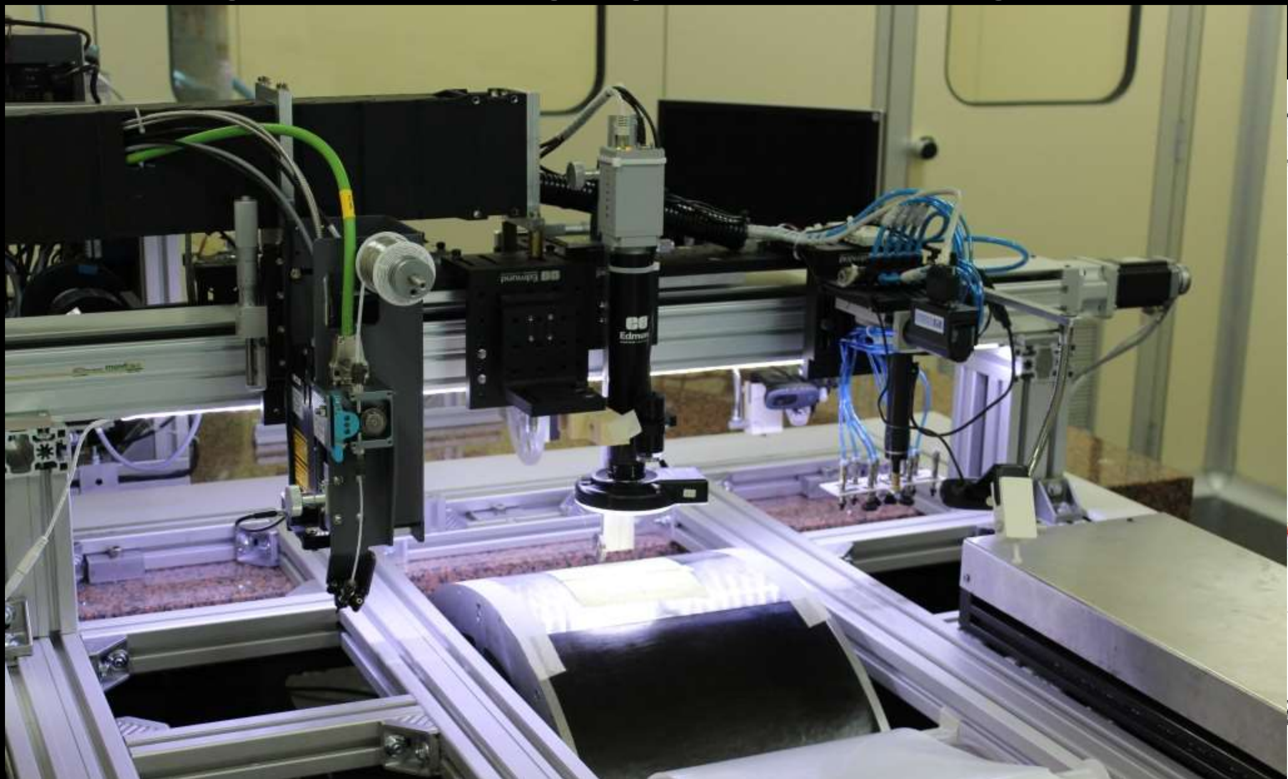
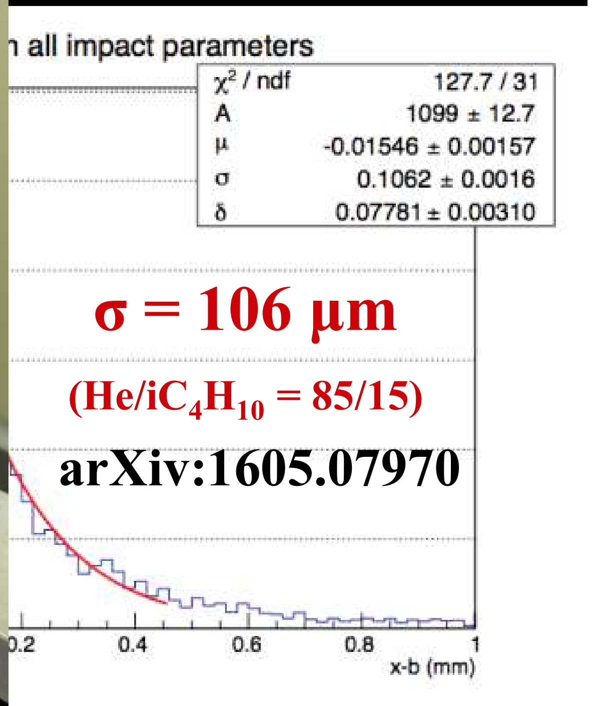
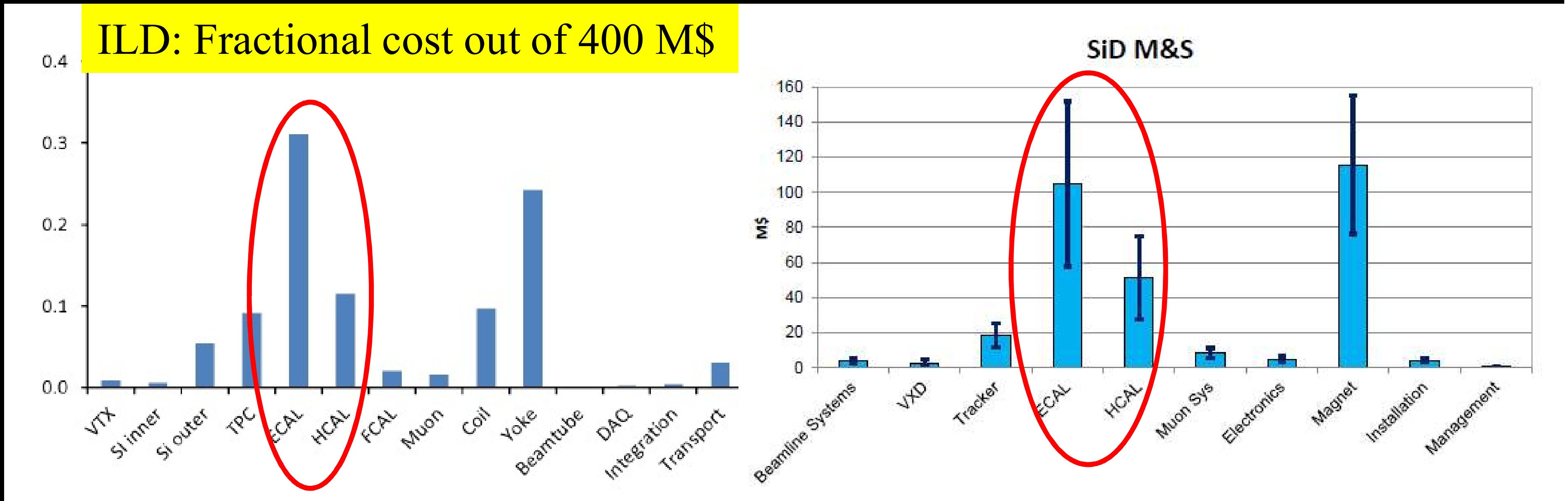
  - E.g. Wire stringing and soldering machine





Calorimeter

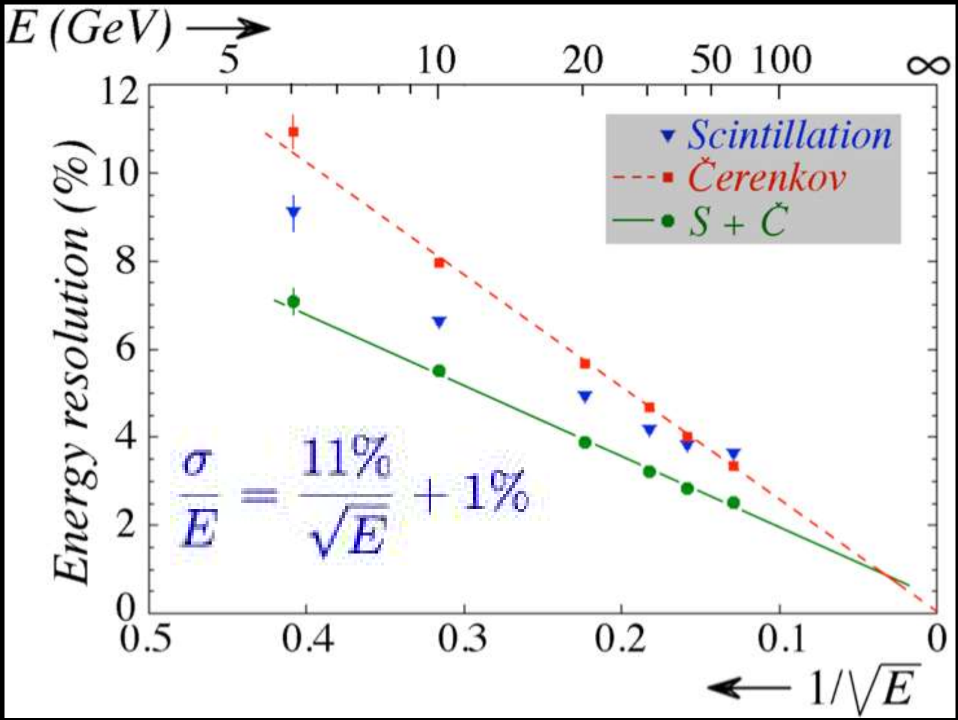
- Particle flow calorimeters are extremely expensive!
- Similar (or better) performances with dual readout
  - EM and HAD in same calorimeter
  - High transverse granularity

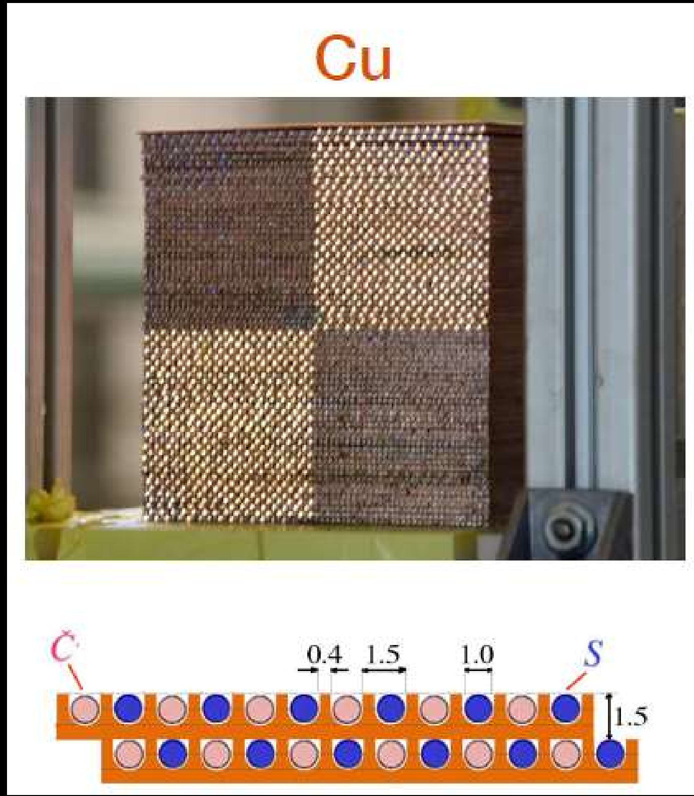


Calorimeter

- Copper 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

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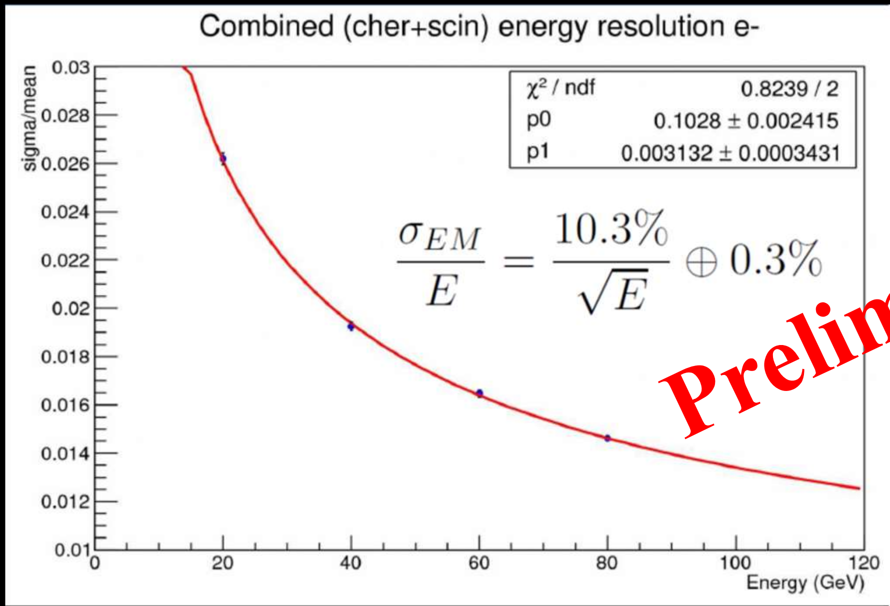

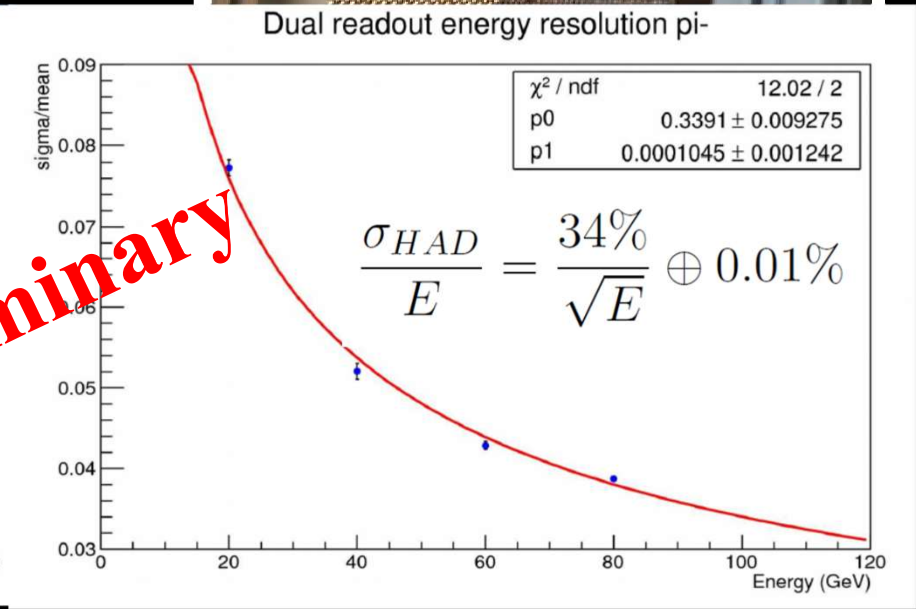

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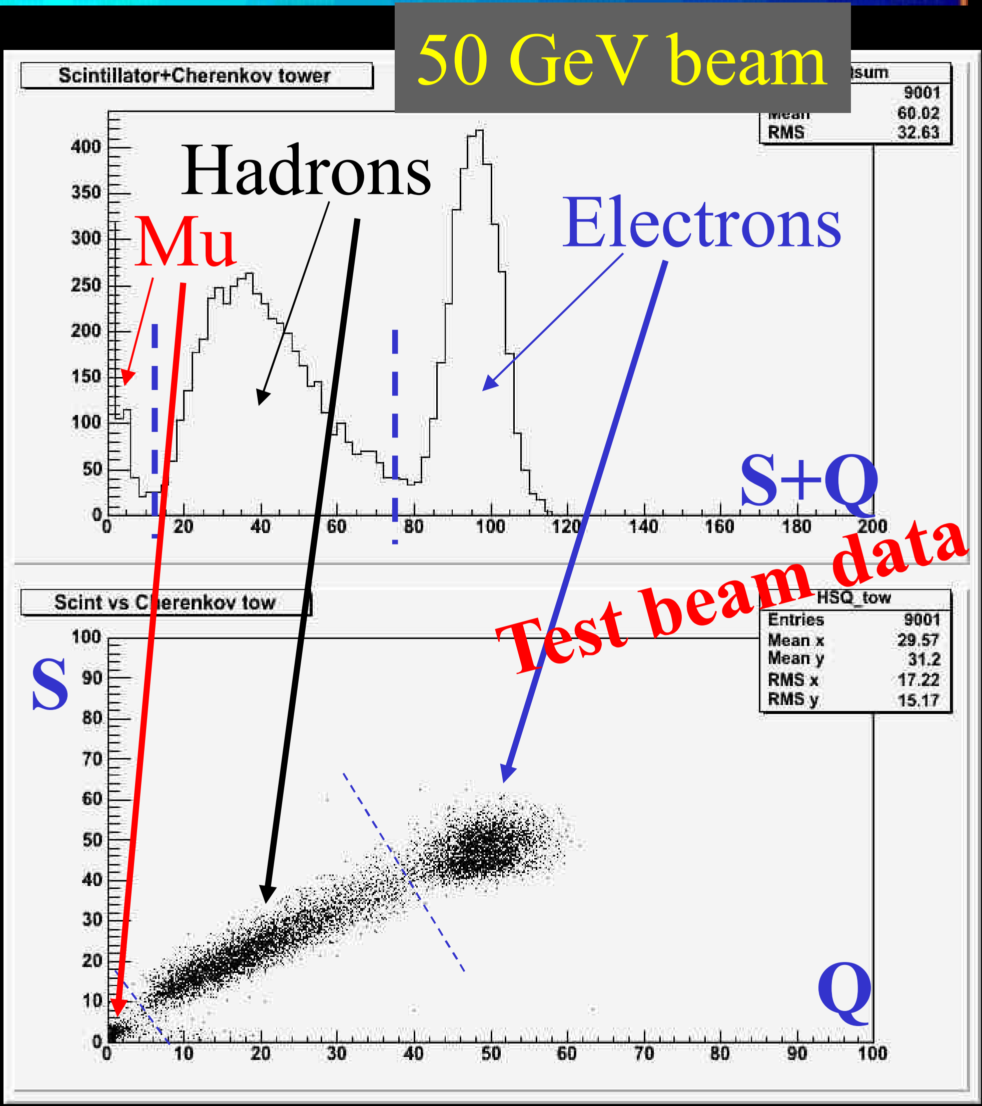

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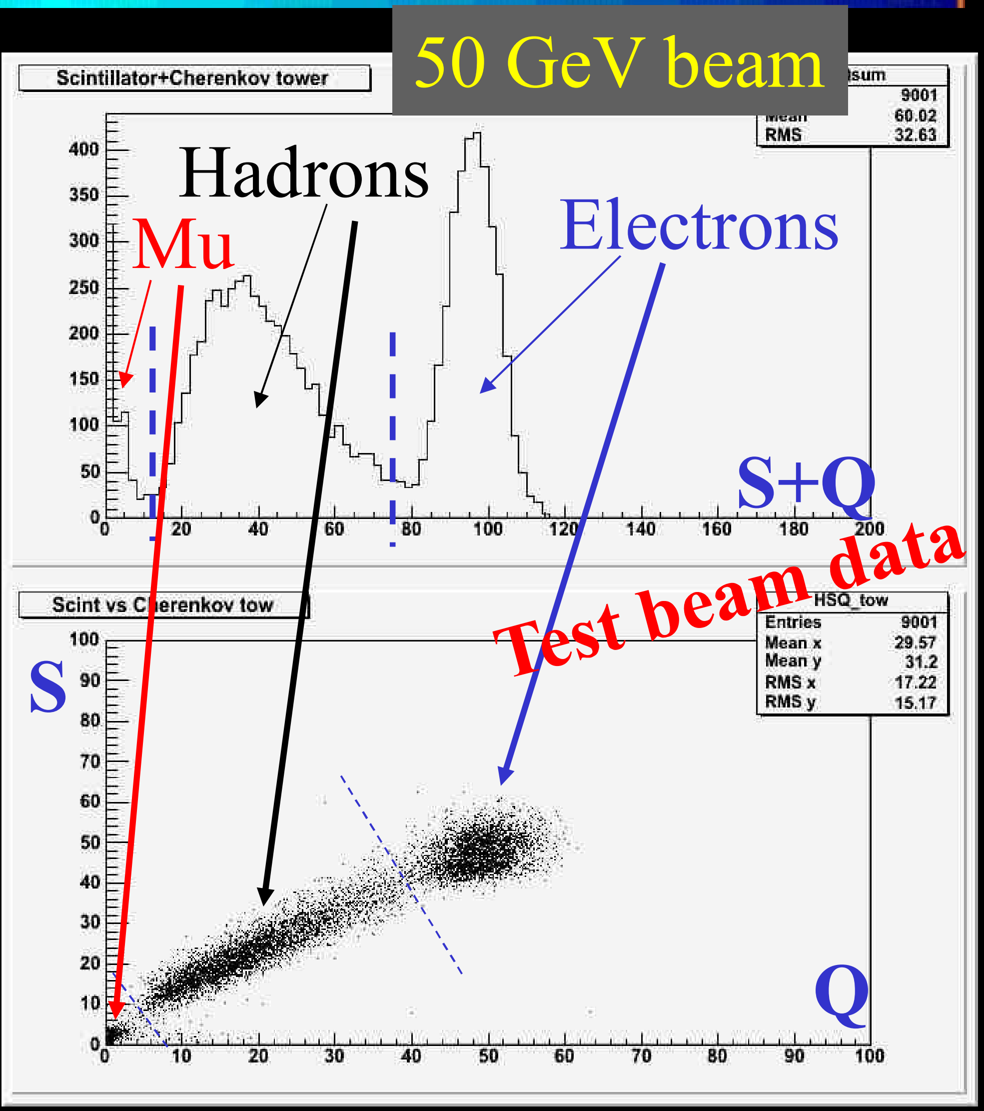
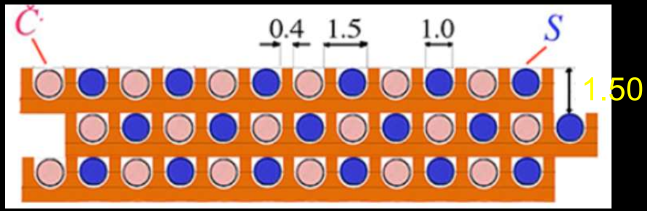
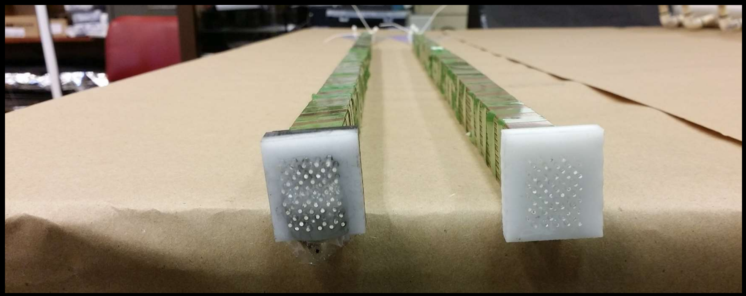
- Preshower (~2 X_0)
  - Acceptance determination
  - e/γ /π^0 separation near hadrons
    - Synergy with part. flow

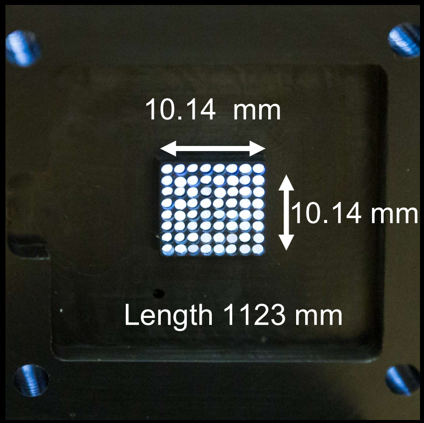


Calorimeter R&D

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







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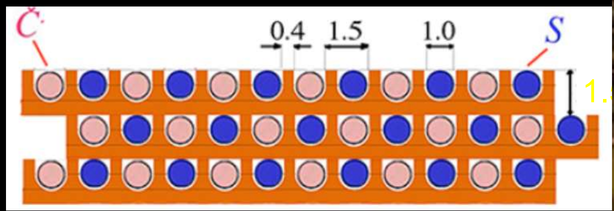
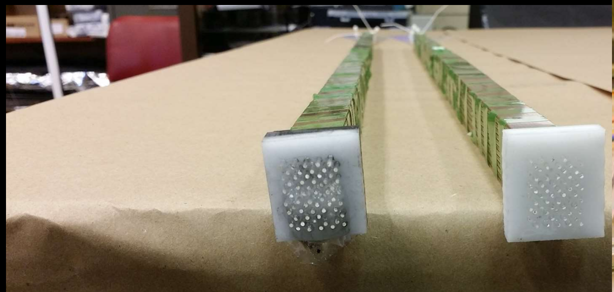
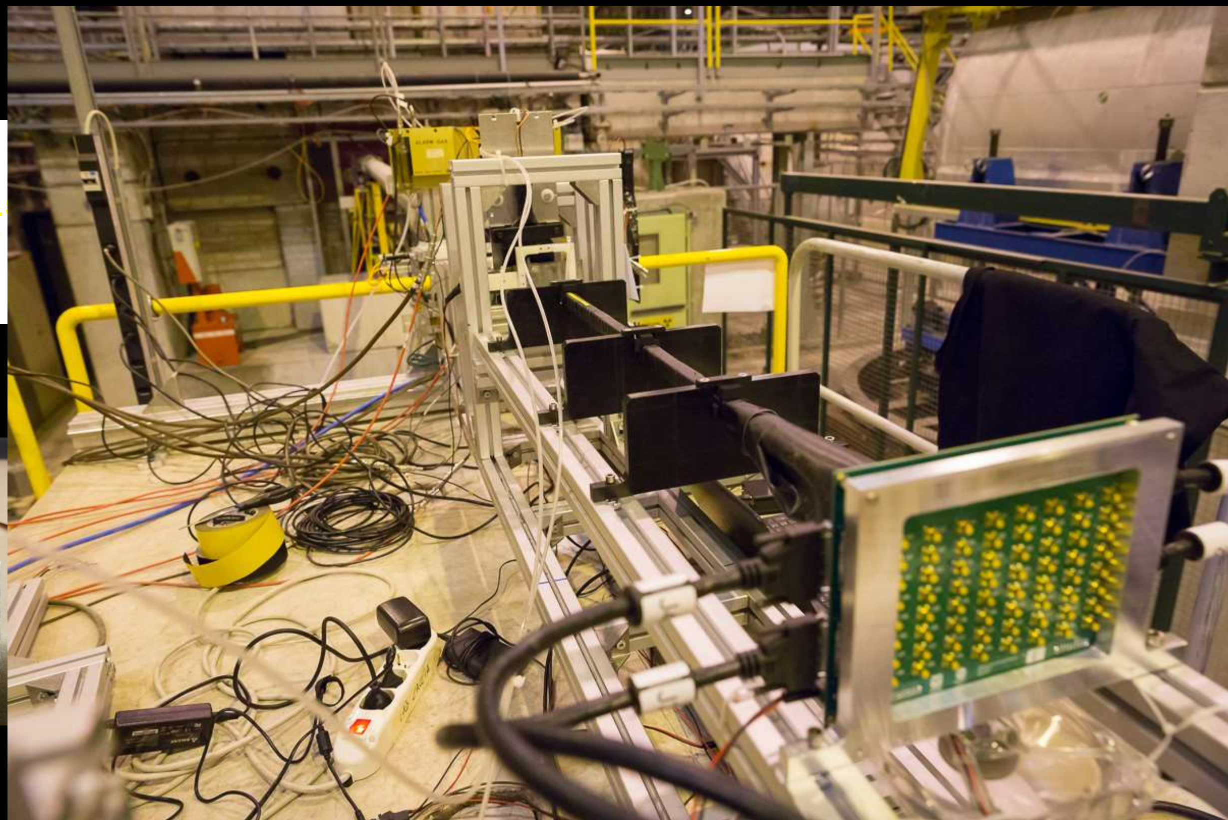
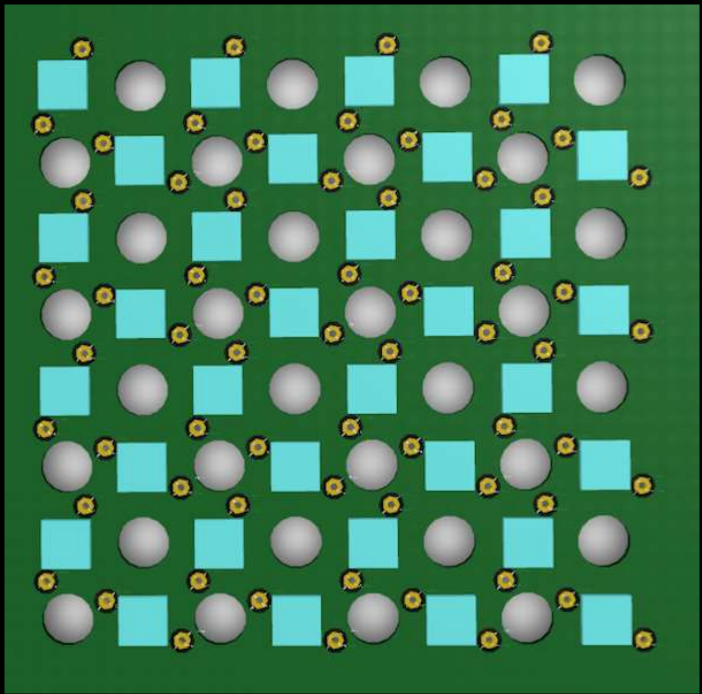


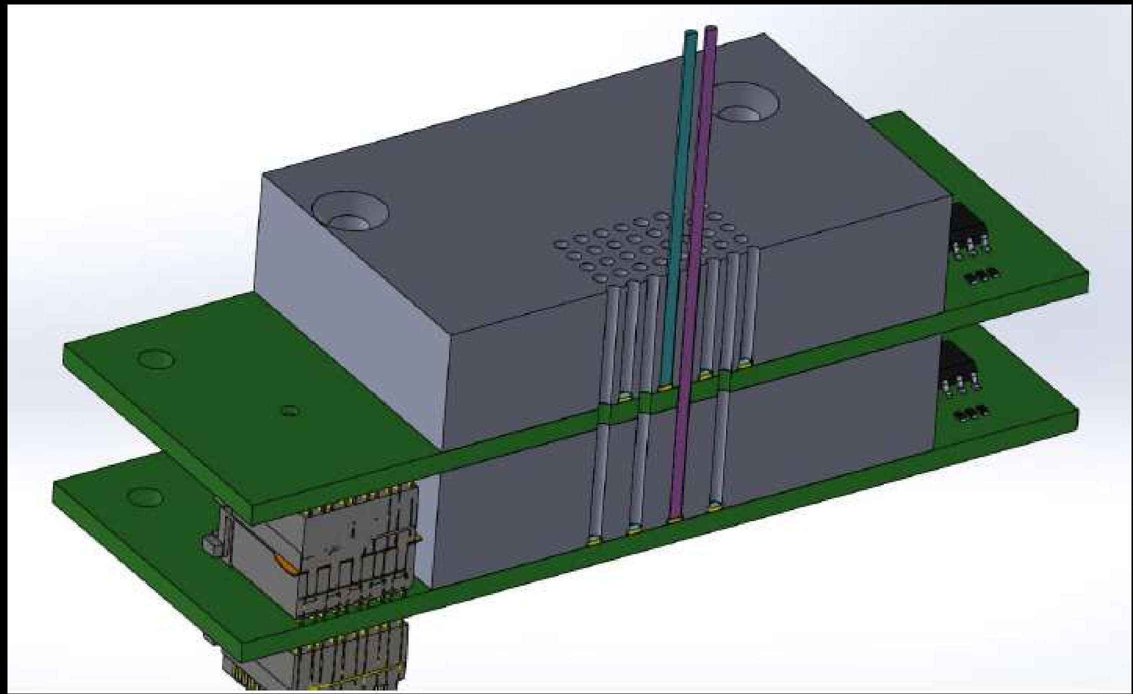




Calorimeter R&D

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





Muons

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  - 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)