Overview of the IDEA detector

Franco Bedeschi,
3rd FCC Physics and Experiments Workshop,
CERN, January 2020

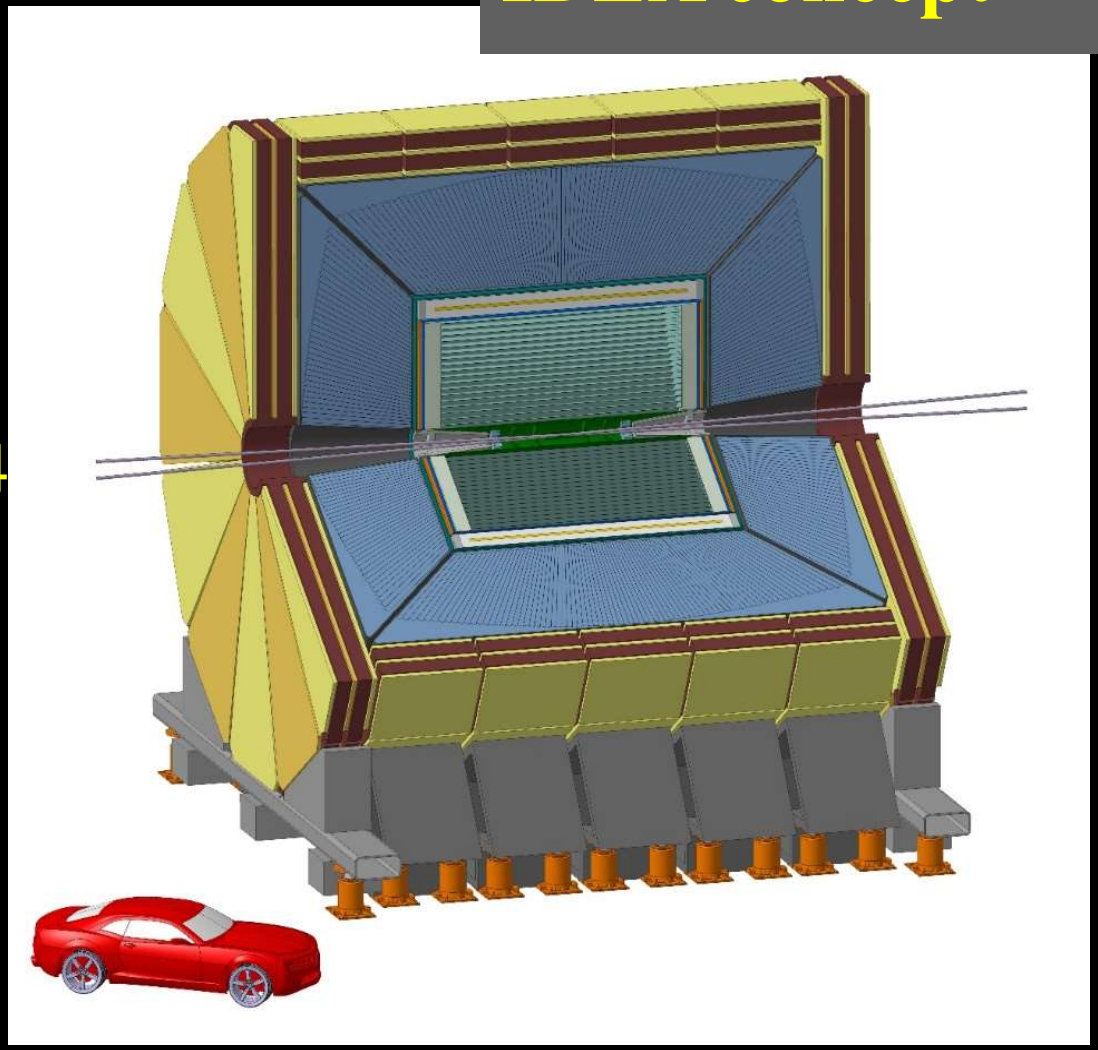
OUTLINE

- The detector
- Detector design guidelines
- Ongoing R&D
- Concluding comments

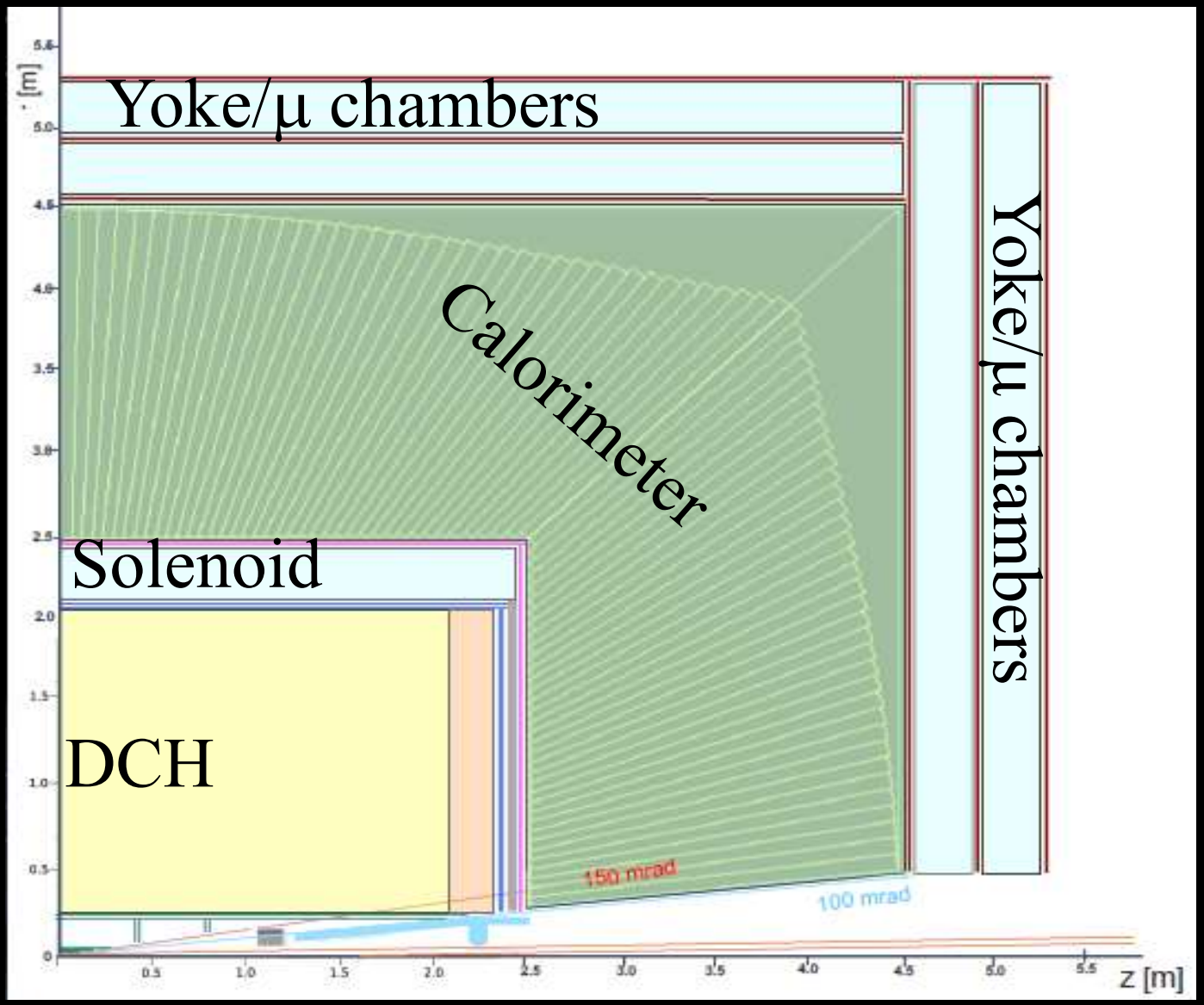
Detector concept IDEA

- Si pixel vertex detector
  - 5 MAPS layers
    - R = 1.7 – 34 cm
- Drift chamber (112 layers)
  - 4m long, r = 35 – 200 cm
- Si wrapper: strips
- Solenoid: 2 T - 5 m, r = 2.1-2.4
  - 0.74 X_0, 0.16 λ @ 90º
- Pre-shower: μRwell
- Dual Readout calorimetry
  - 2m deep/8 λ
- Muon chambers
  - μRwell

IDEA concept



IDEA details



Small magnet

Small yoke

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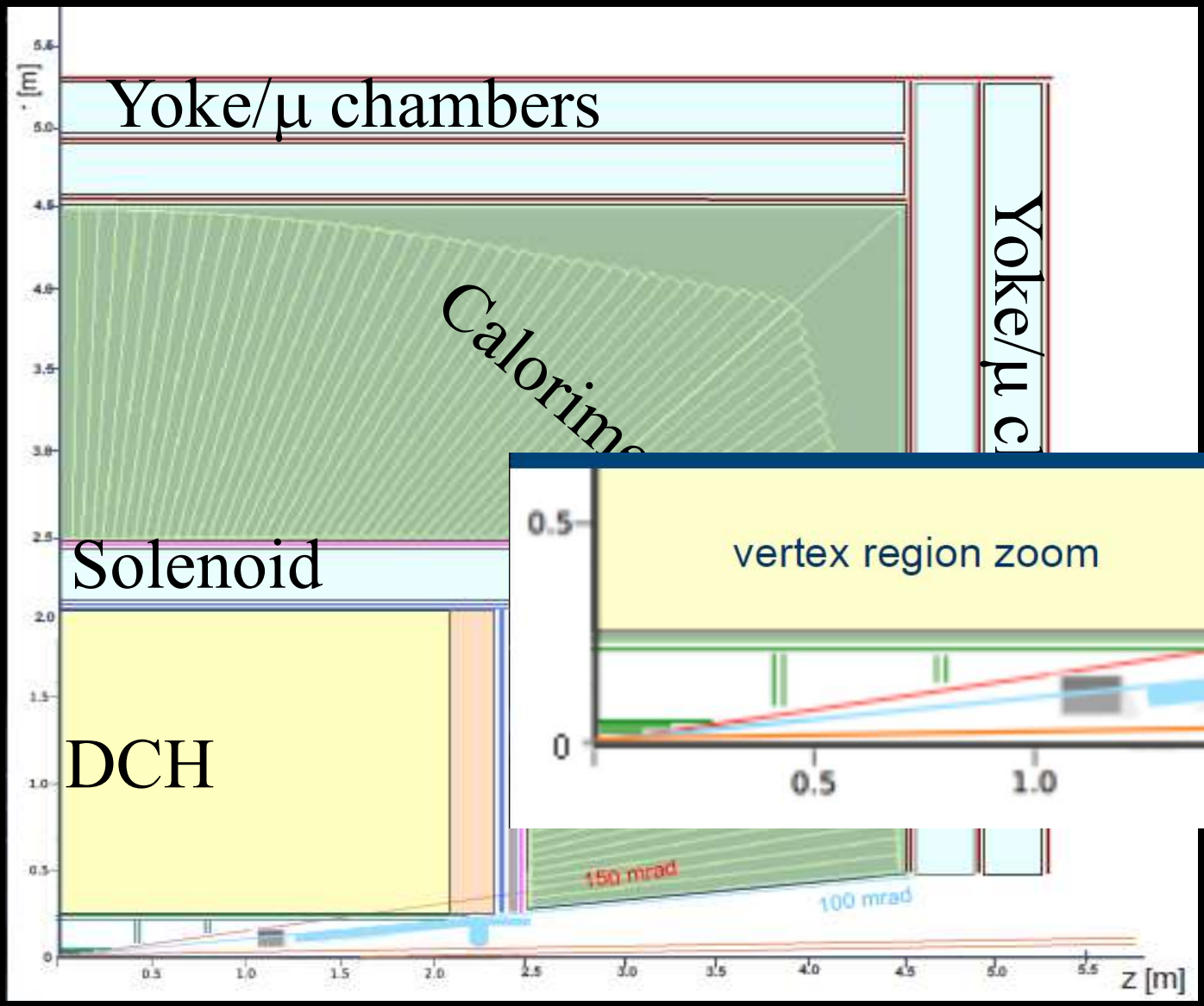

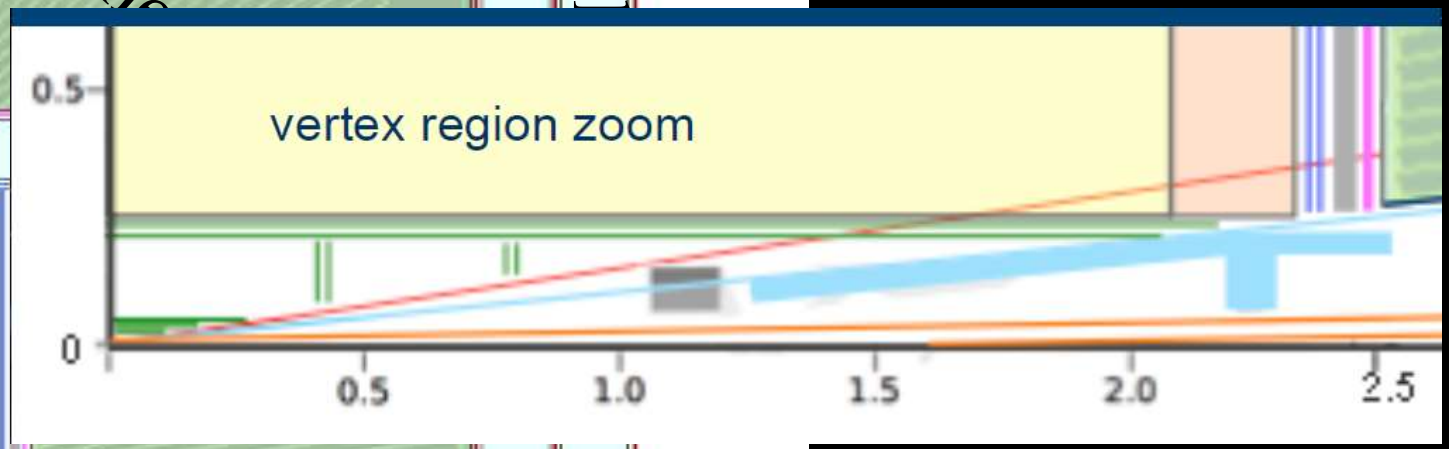

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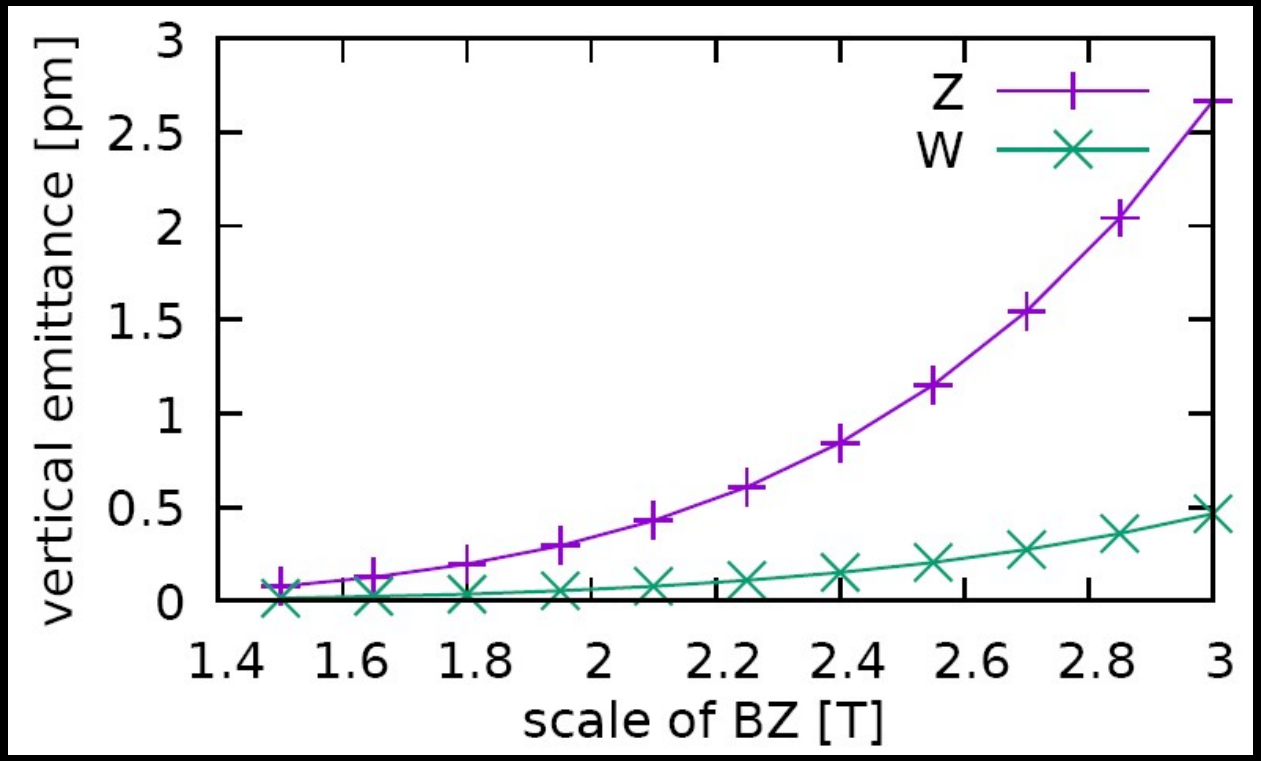
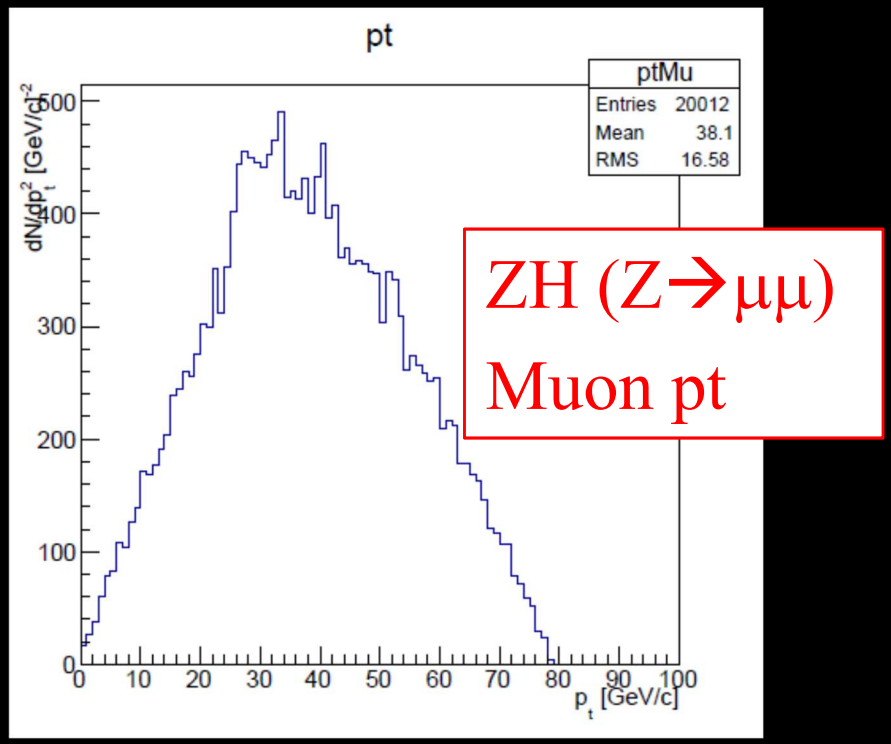
Design guidelines: Luminosity

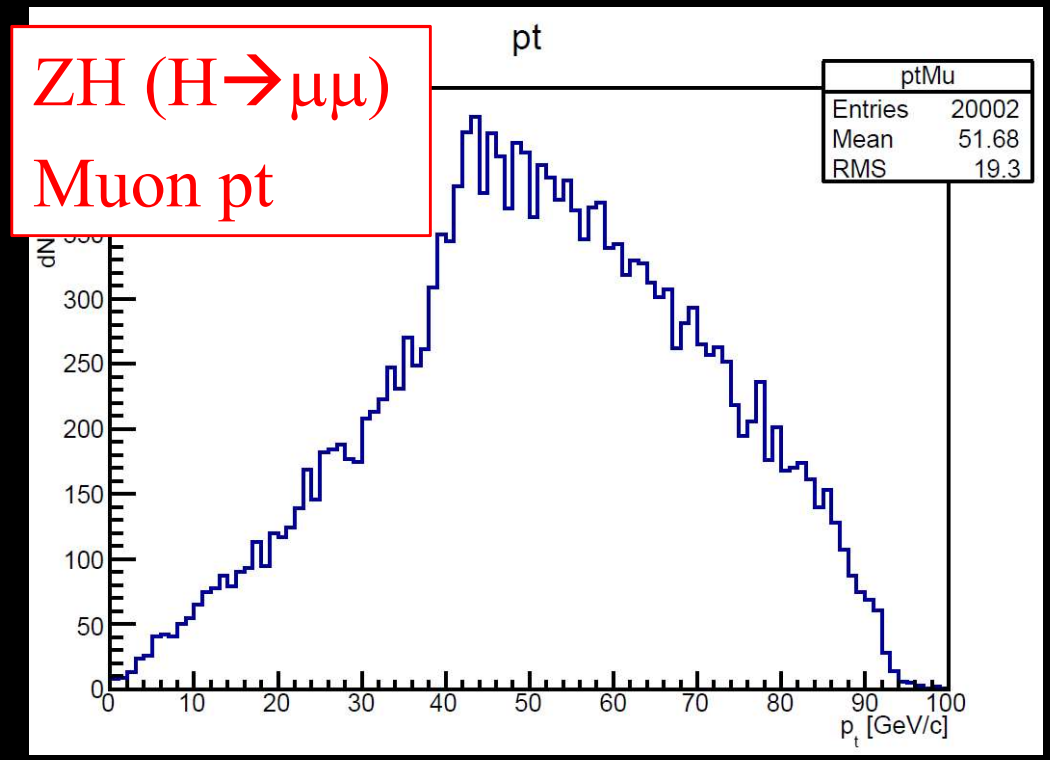
- Maximize luminosity → Low field detector solenoid
  - Optimized at 2 T
  - Large tracking volume → calorimeter outside → very thin coil



Design guidelines: Momentum resolution

- Z or H decay muons in ZH events have rather small p_t





Design guidelines: Momentum resolution

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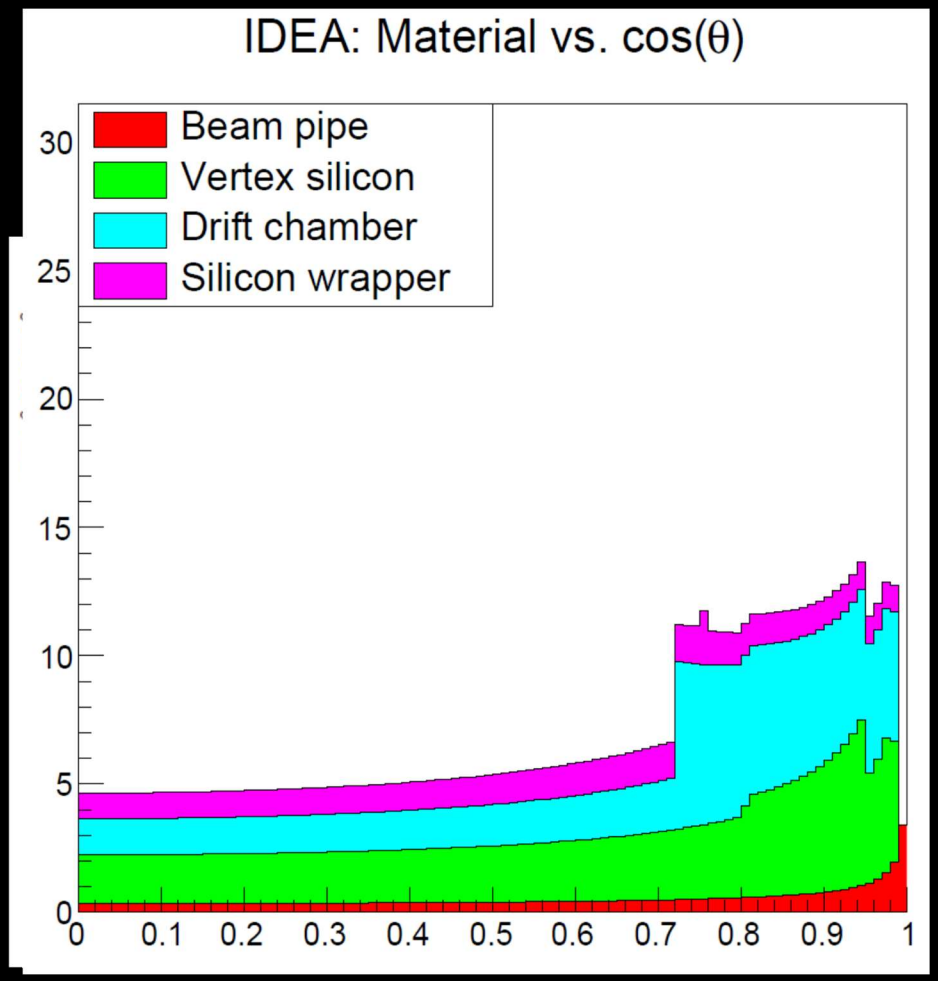
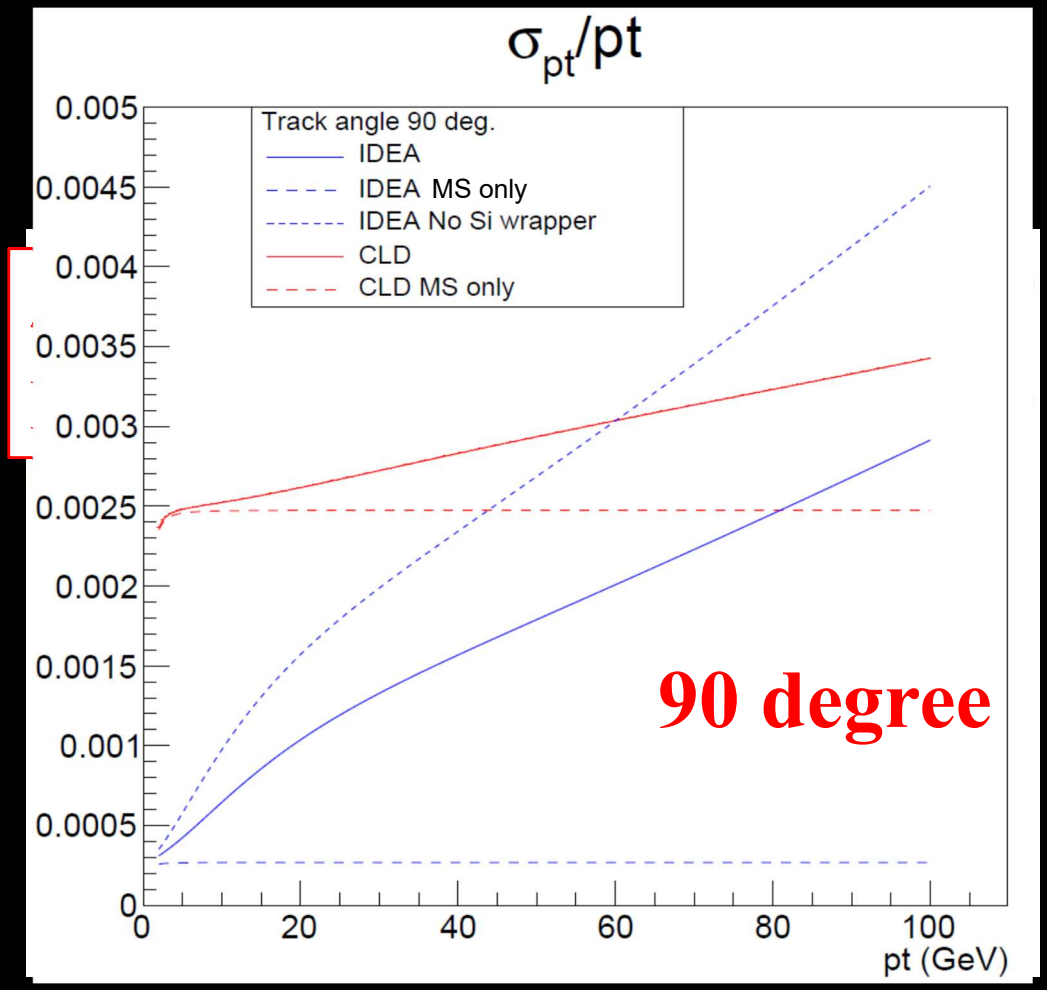
  - Transparency more relevant than asymptotic resolution





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  - Low power (< 20 mW/cm^2) to allow air cooling

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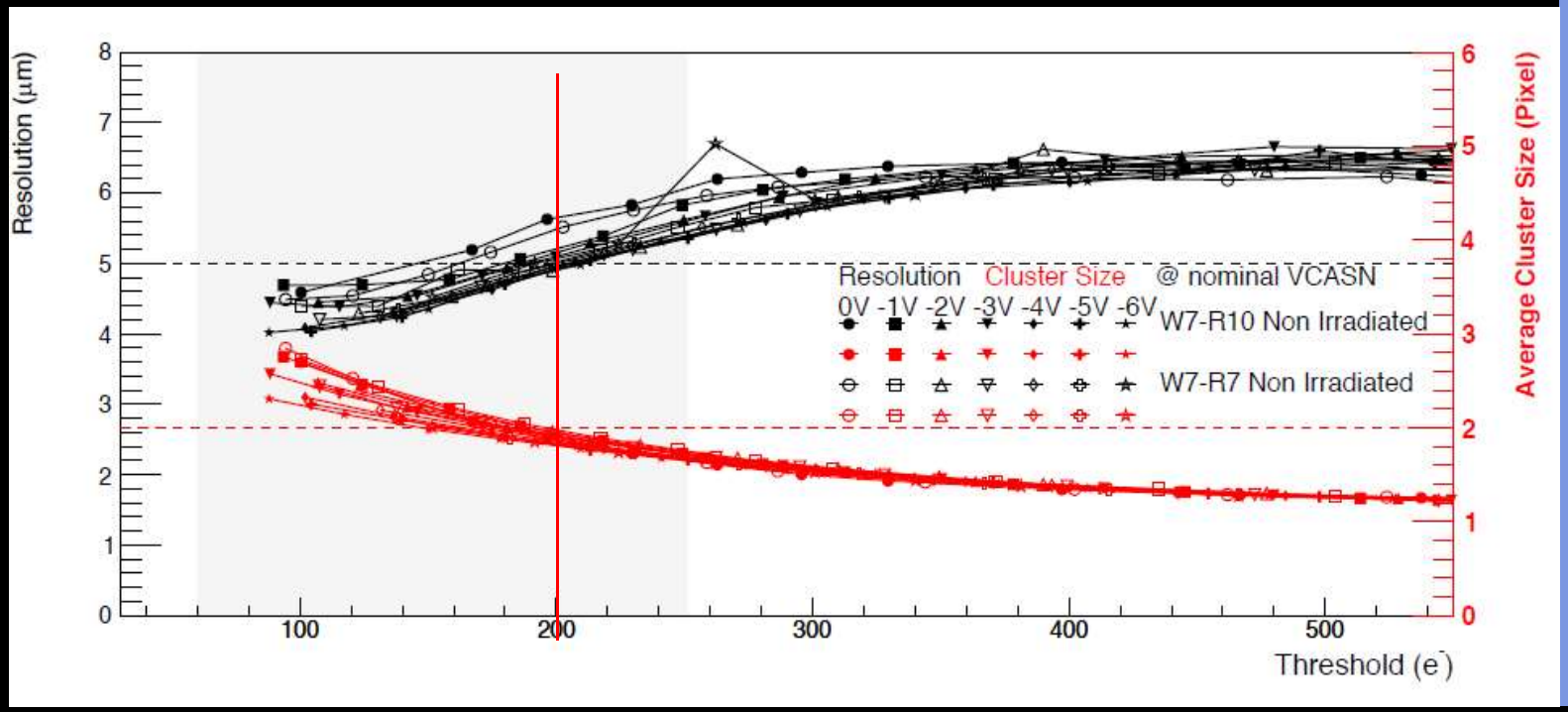
- Resolution:
  - 5 μm shown by ALICE ITS (30 μm pixels)
  - Aim at ~20 μm pixels for ~ 3 μm point resolution



Courtesy of ALICE J.W. van Hoorne

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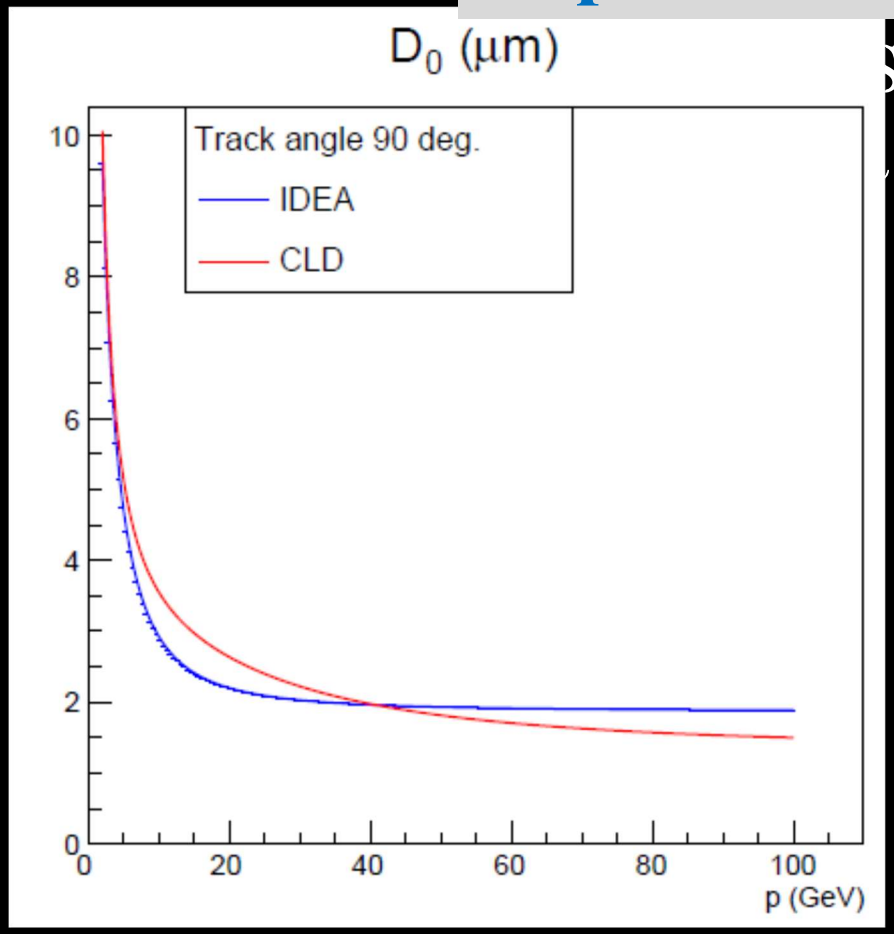
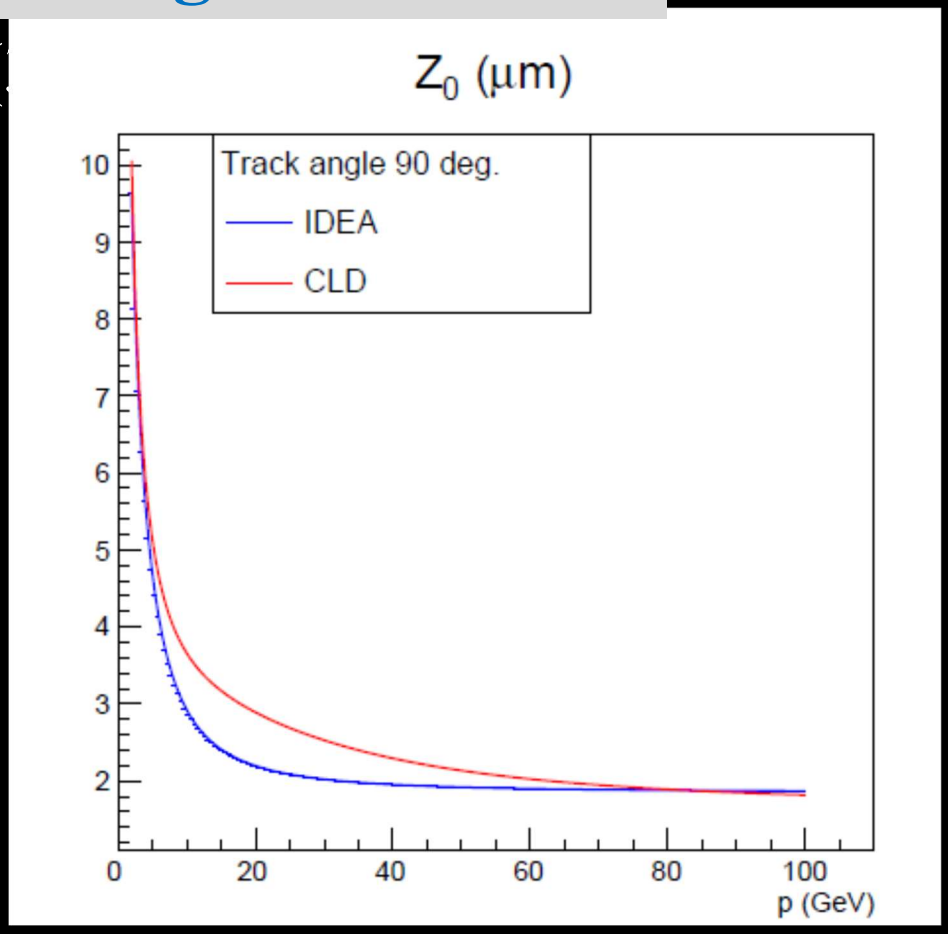
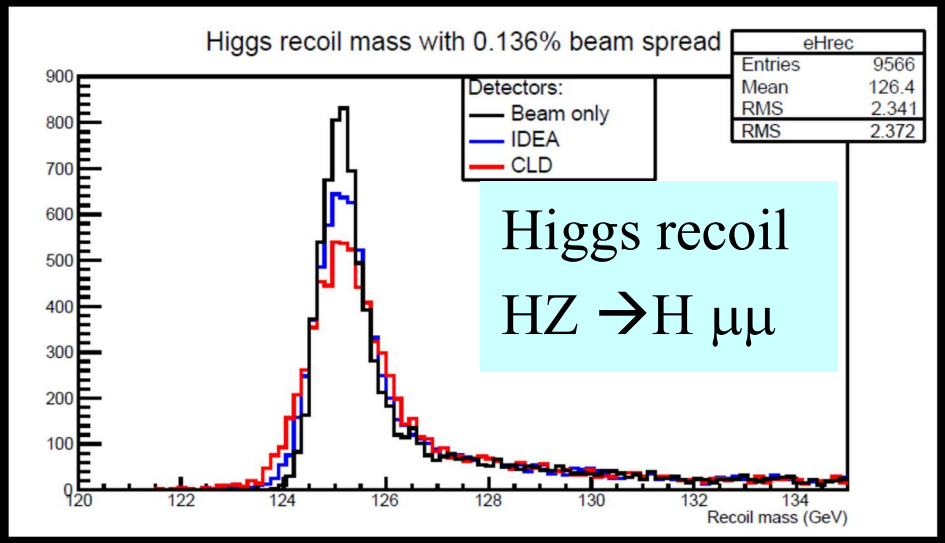
- Resolution: **Expected vertexing resolutions**

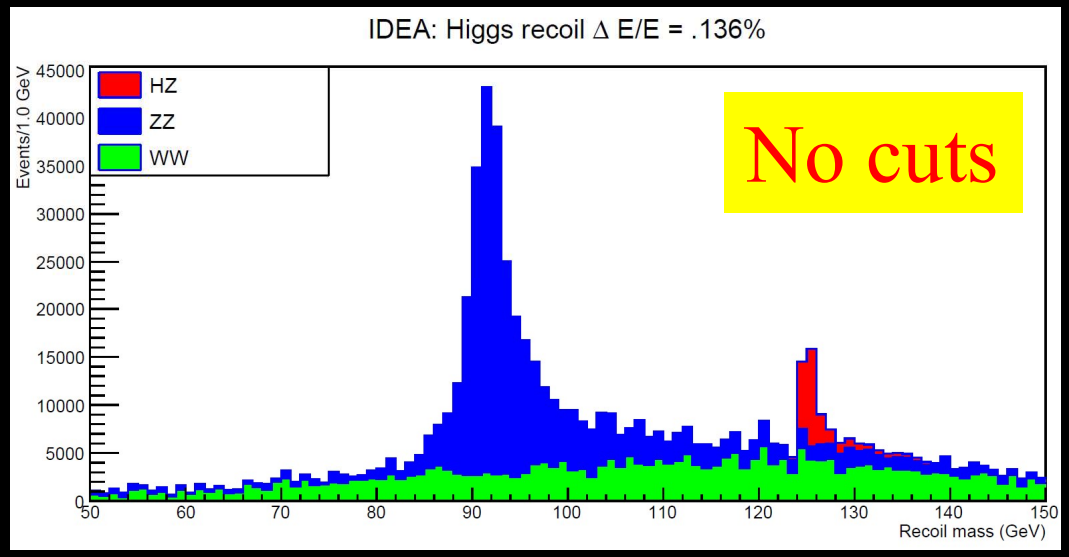




Tracking benchmarks

- Fast simulation with full covariance matrix





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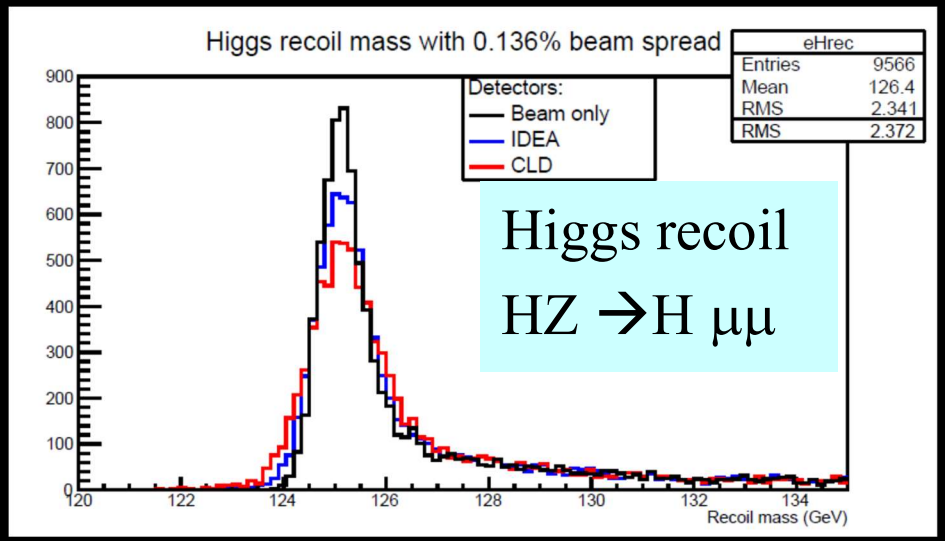

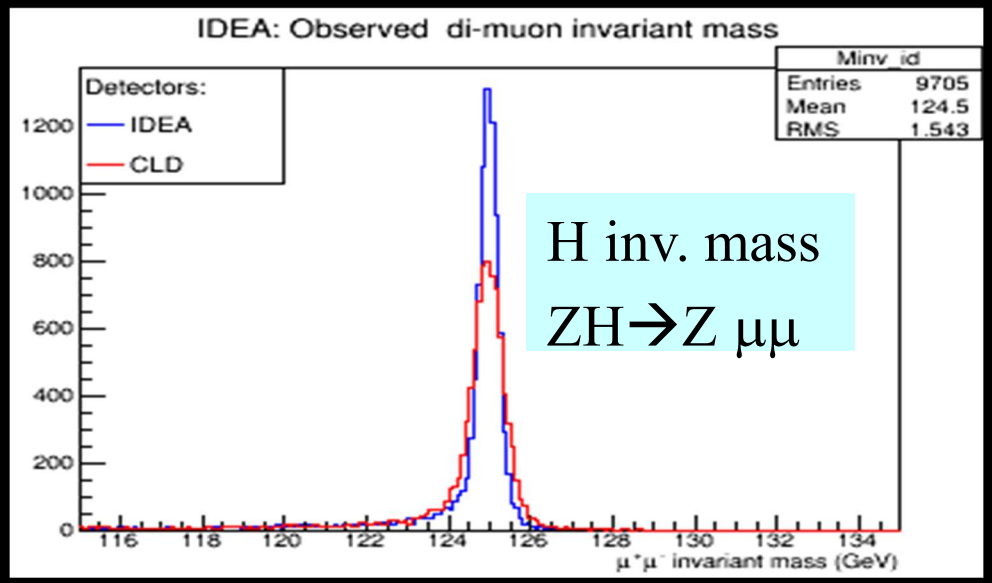

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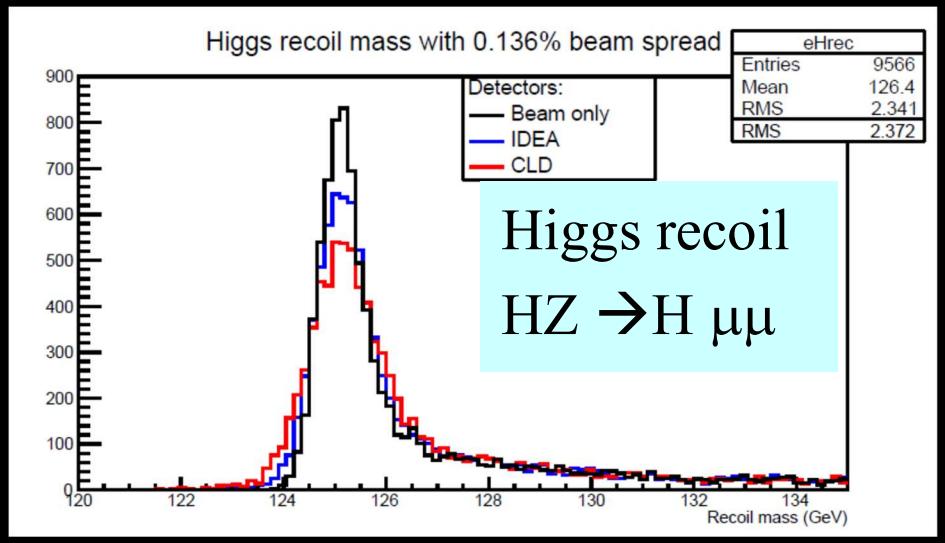
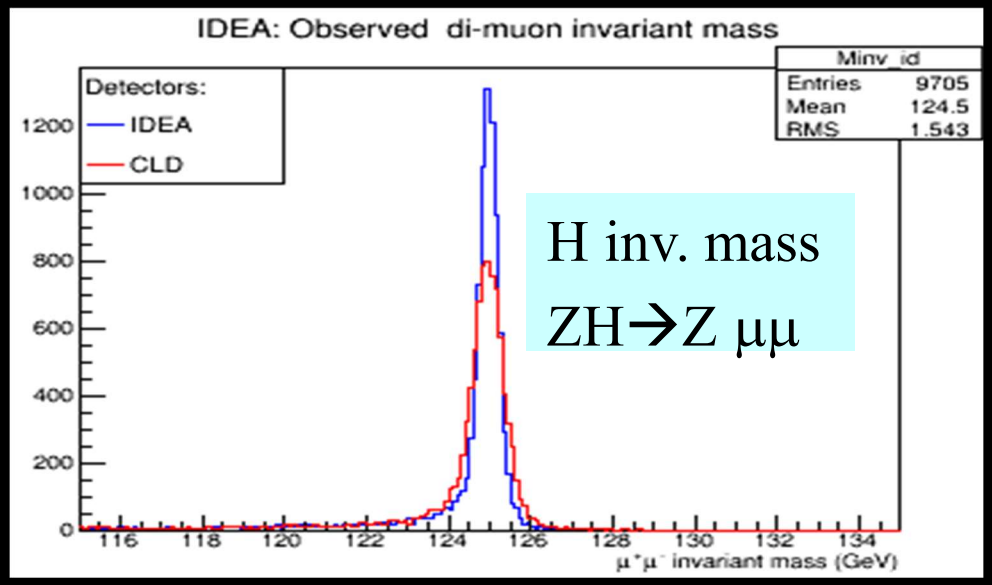
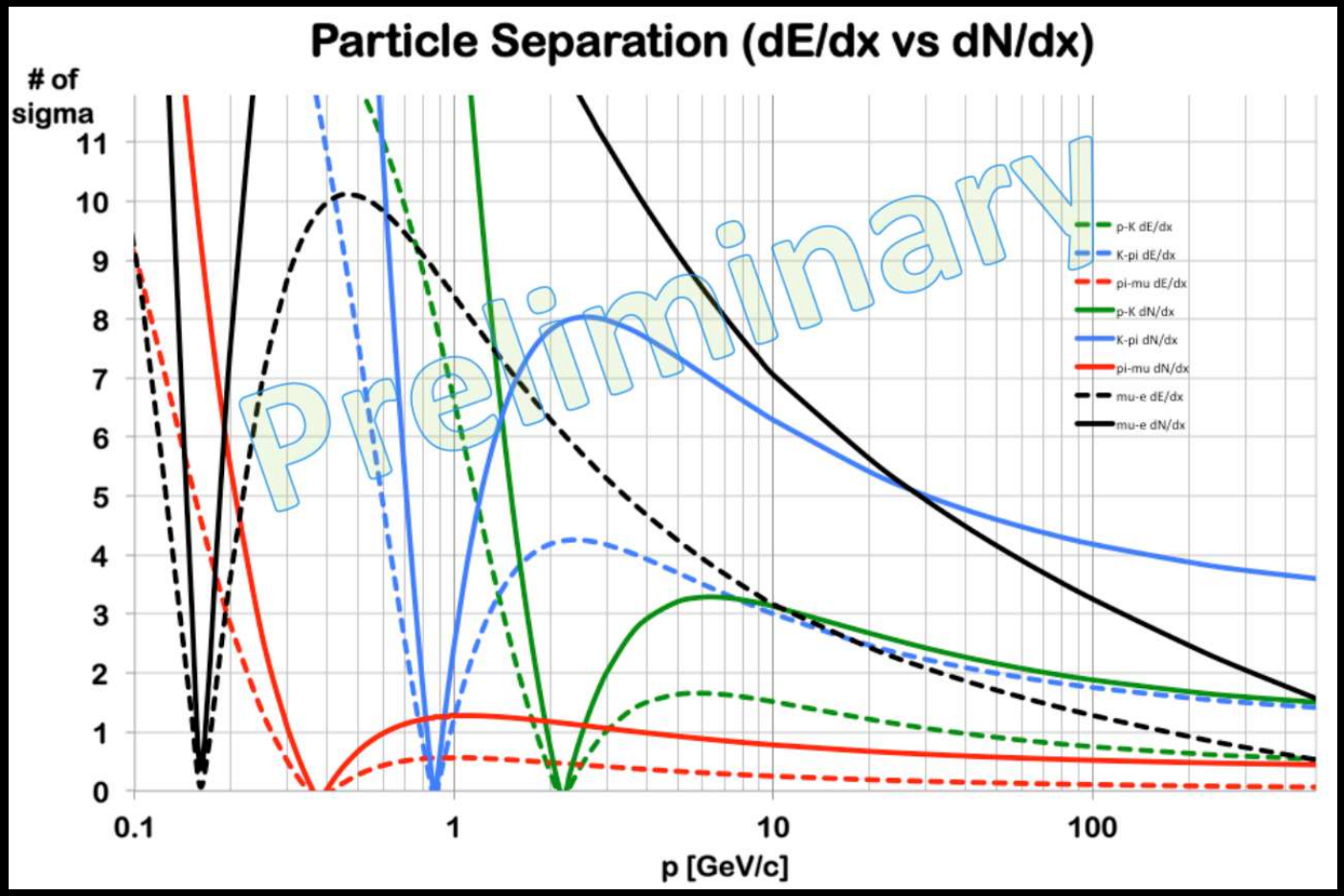




- IDEA card now in DELPHES

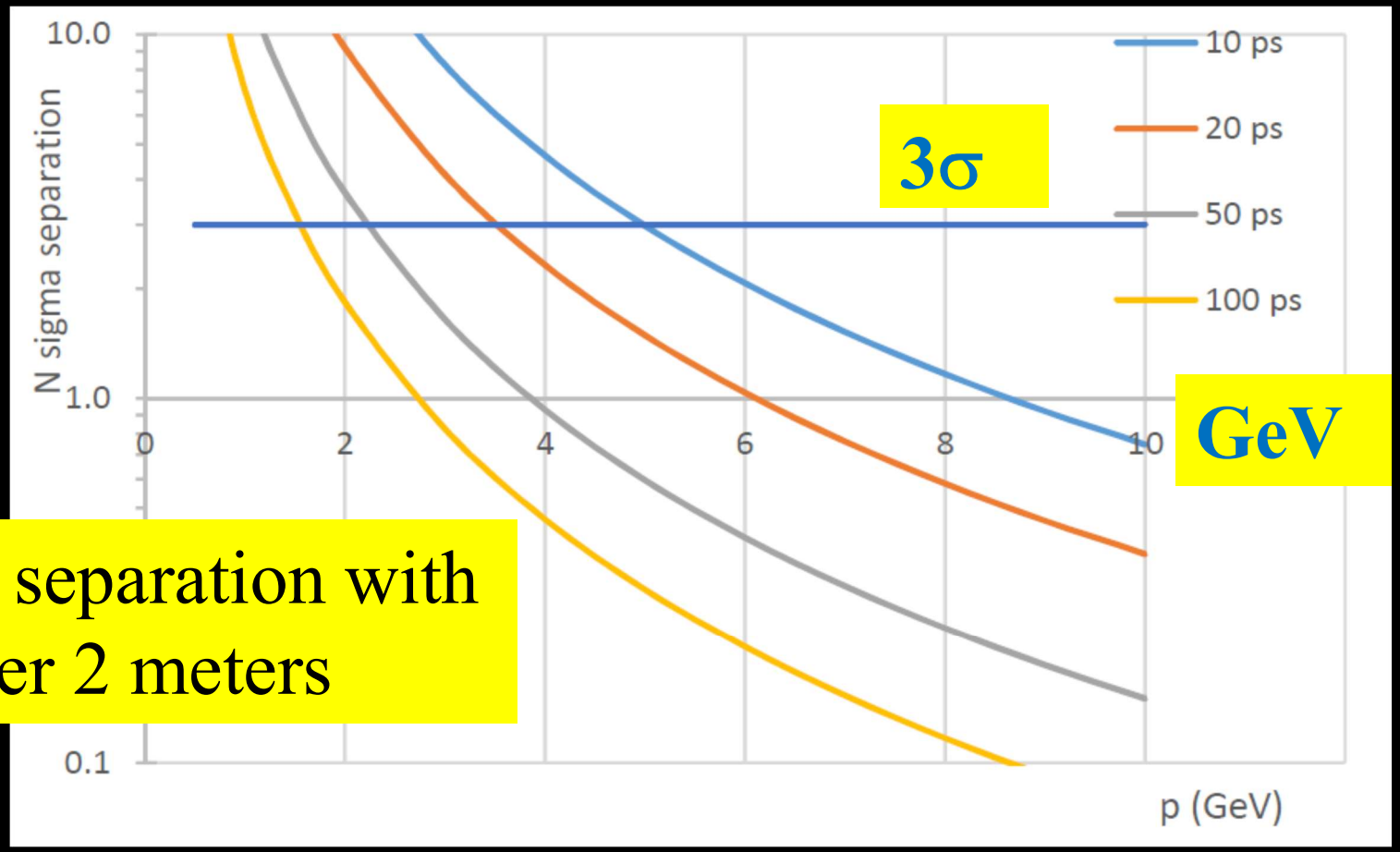
Design guidelines: PID

- Cluster counting in DCH for good dE/dx resolution
  - Excellent K/π separation except 0.75<p<1.05 GeV (blue lines)



Design guidelines: PID

- Cluster counting in DCH for good dE/dx resolution
  - Excellent K/π separation except 0.75<p<1.05 GeV (blue lines)
  - Could recover with timing layer



Nσ K/π separation with TOF over 2 meters

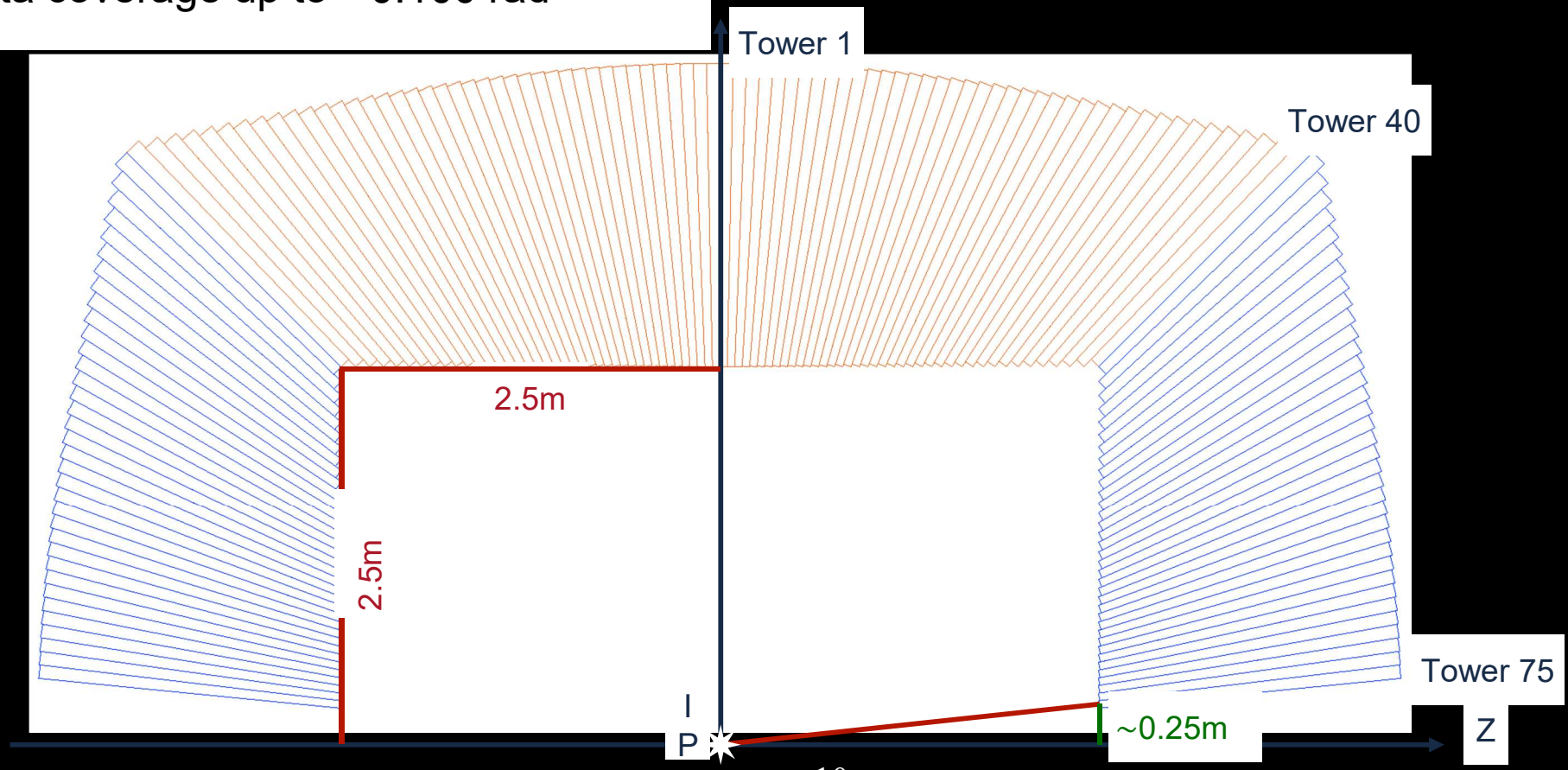
Design guidelines: calorimeter

- Good, but not extreme EM resolution
  - ~ $10\%/\sqrt{E}$ sufficient for Higgs physics
- Jet resolution ~ $30\text{-}40\%/\sqrt{E}$
  - Clearly identify W, Z, H in 2 jet decays
- Transverse granularity < 1 cm for τ physics
- All electronics in the back to simplify cooling and services
- Dual Readout calorimeter satisfies this requirements

Calorimeter simulation

- 4π detector in GEANT4 tuned to RD52 test beam data

Tower segmentation: $\Delta\vartheta = 1.125°$, $\Delta\phi = 10.0°$
Number of towers in barrel: 40 x 2 x 36 = 2880
Number of towers per endcap: 35 x 36 = 1260
Theta coverage up to ~0.100 rad



Calorimeter simulation

- 4π detector in GEANT4 tuned to RD52 test beam data
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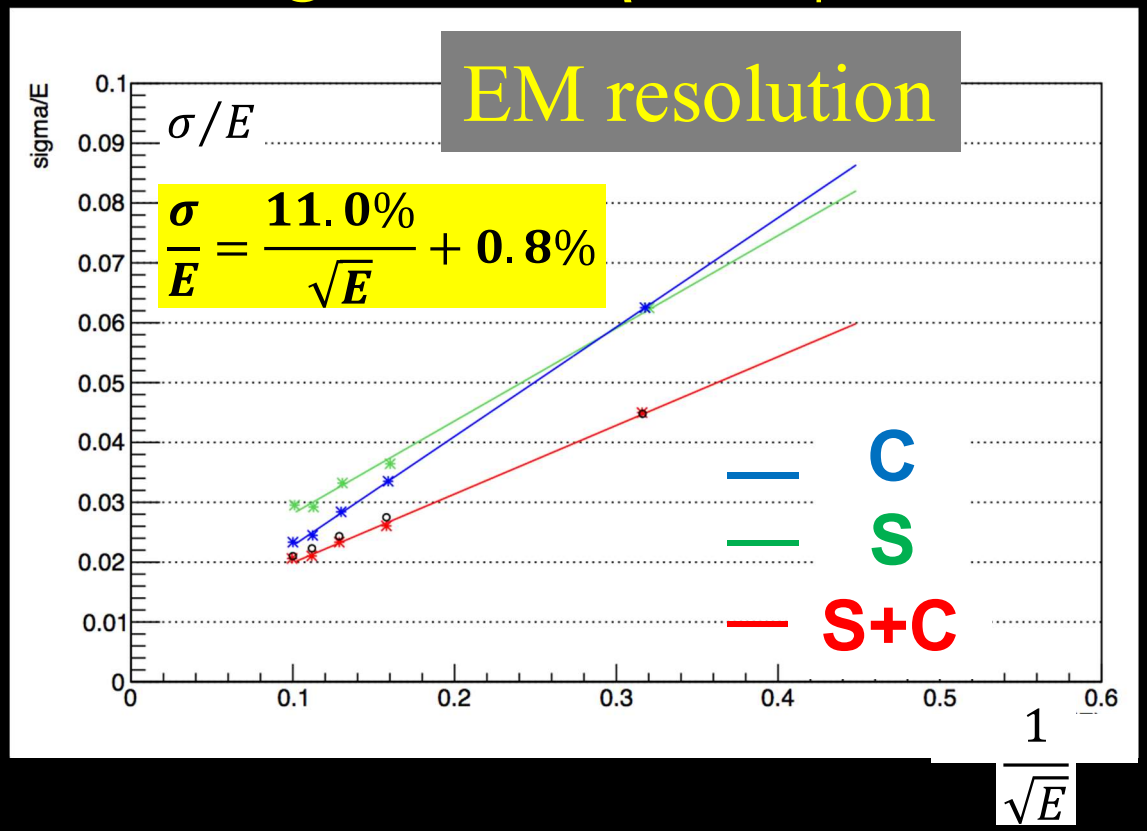

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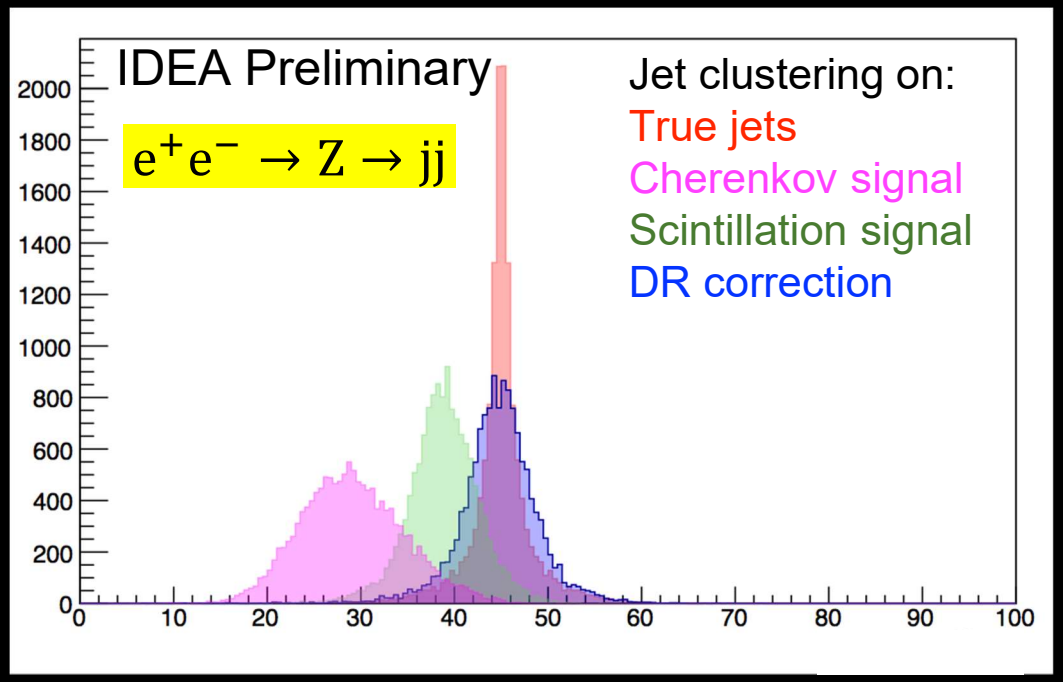


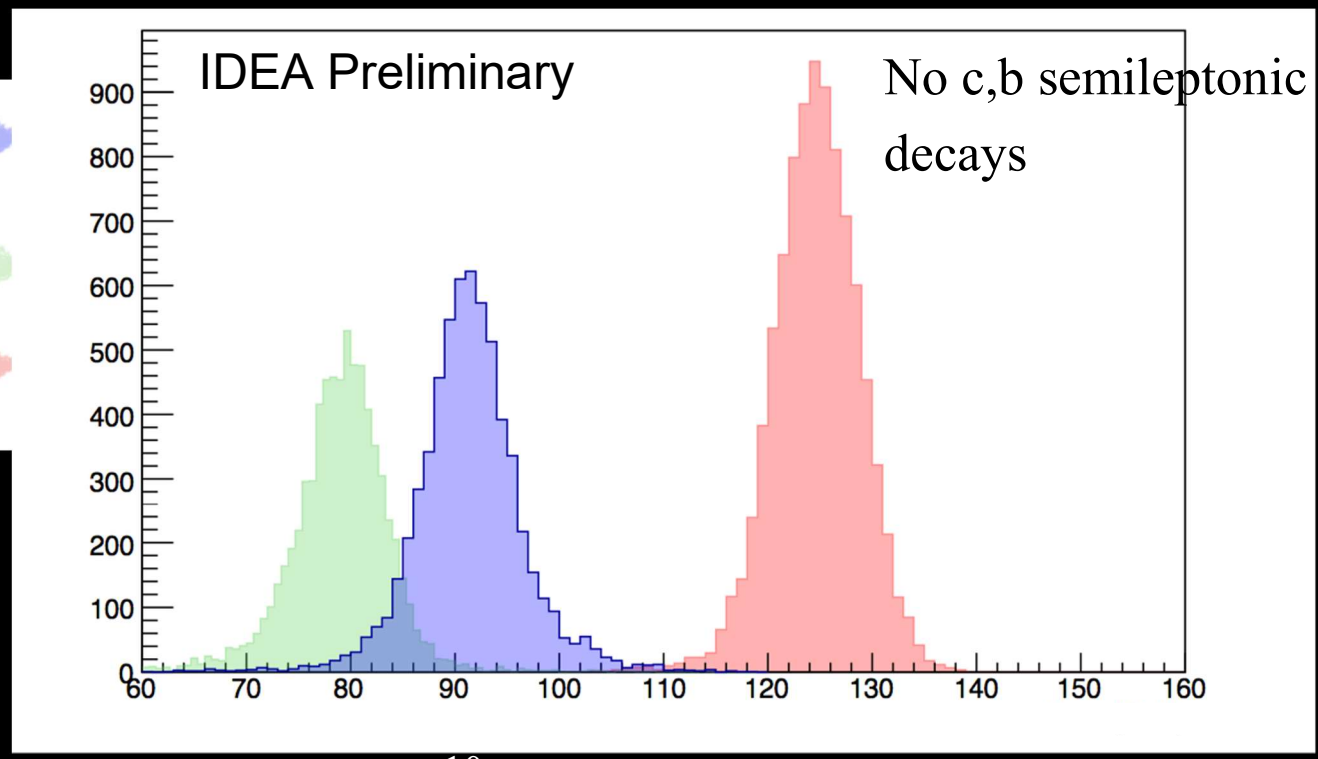
Calorimeter simulation

- 4π detector in GEANT4 tuned to RD52 test beam data
- Good EM resolution averaged over η and ϕ
- DR works well with jets
- Adequate separation of W/Z/H

$e^+e^- \rightarrow HZ \rightarrow \tilde{\chi}^0\tilde{\chi}^0 jj$

$e^+e^- \rightarrow WW \rightarrow \nu_\mu \mu jj$

$e^+e^- \rightarrow HZ \rightarrow bb\nu\nu$



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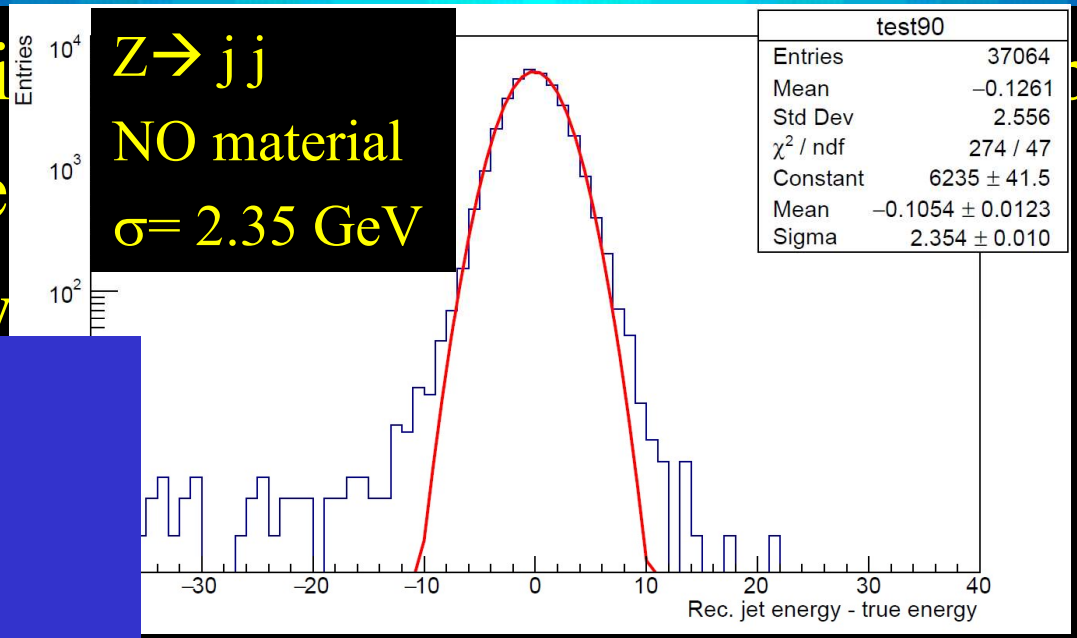

Effect of

1 X0 Fe

Distance:

30 cm barrel

10 cm endcap

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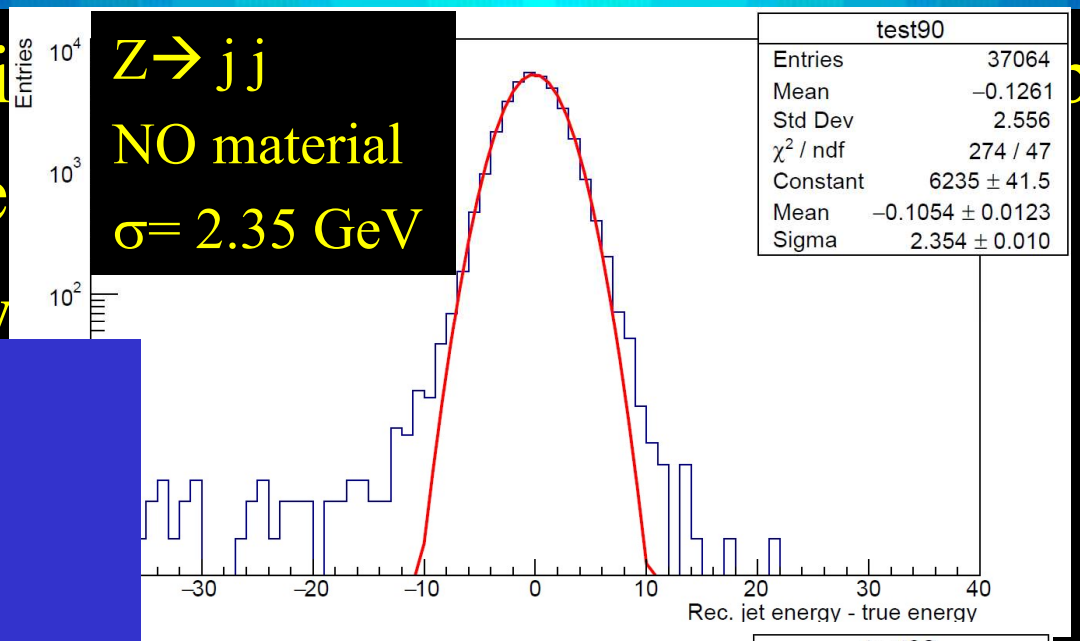

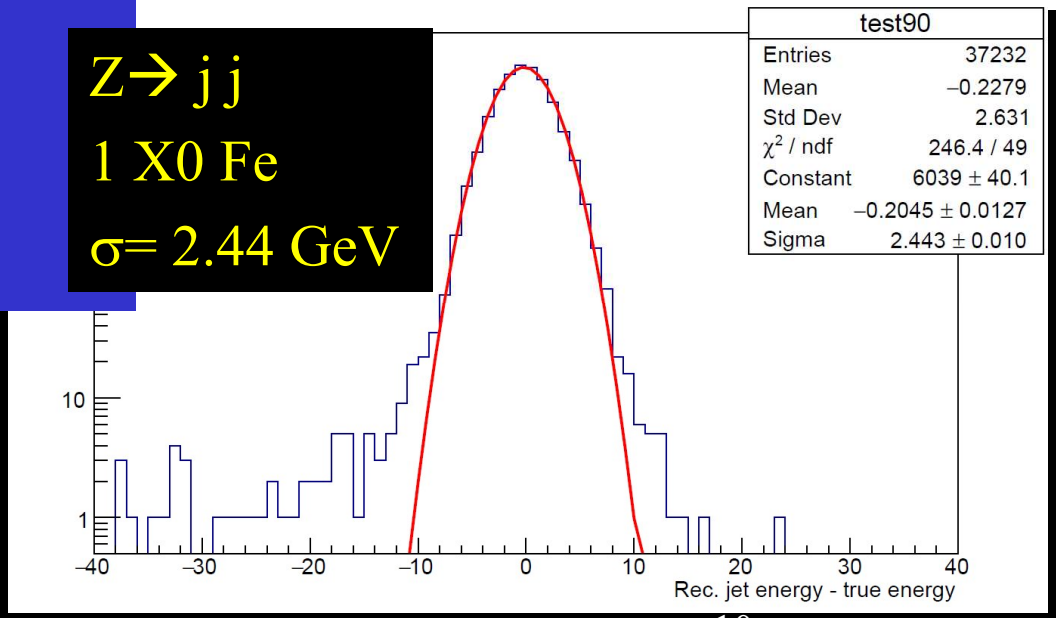

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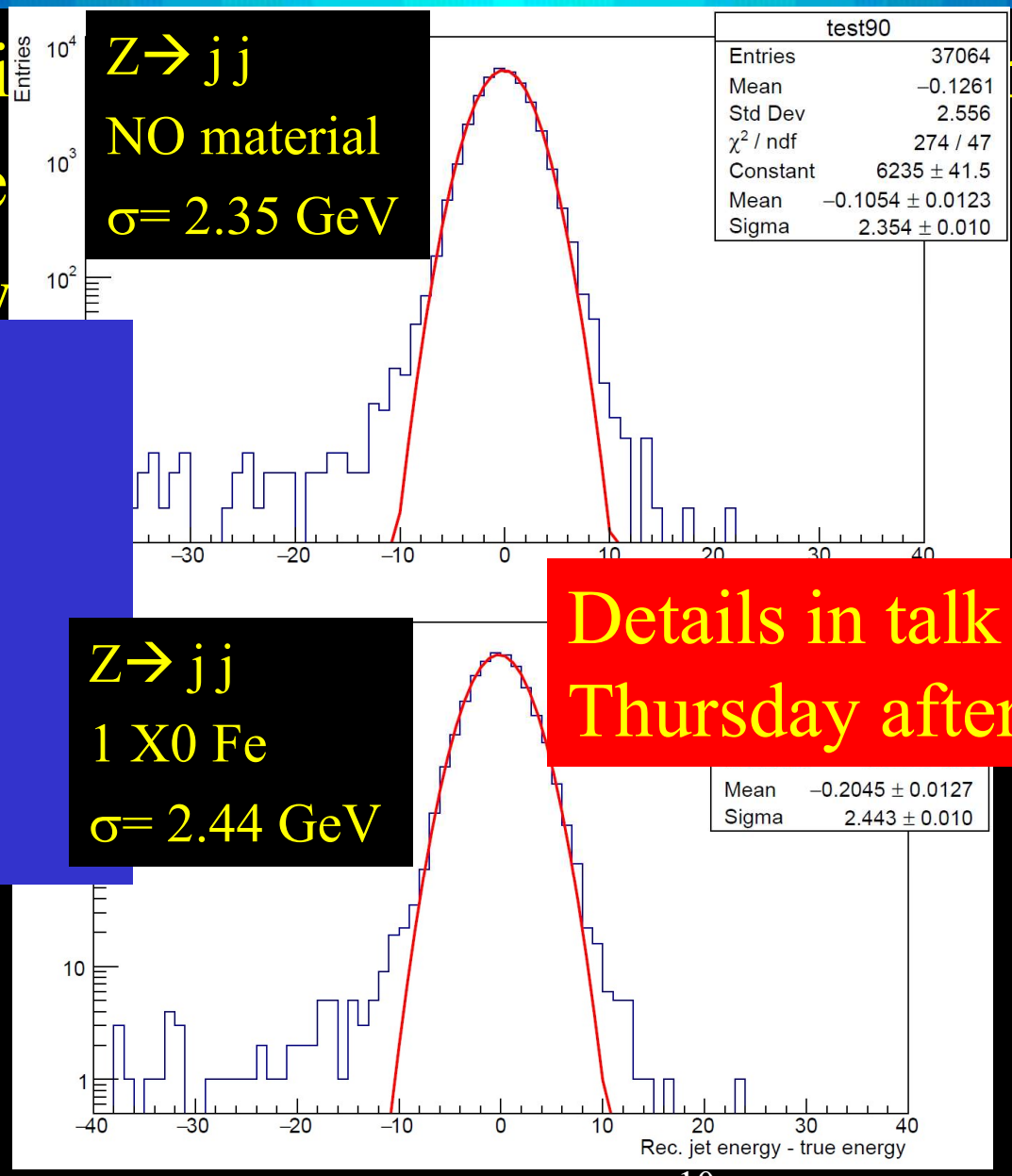
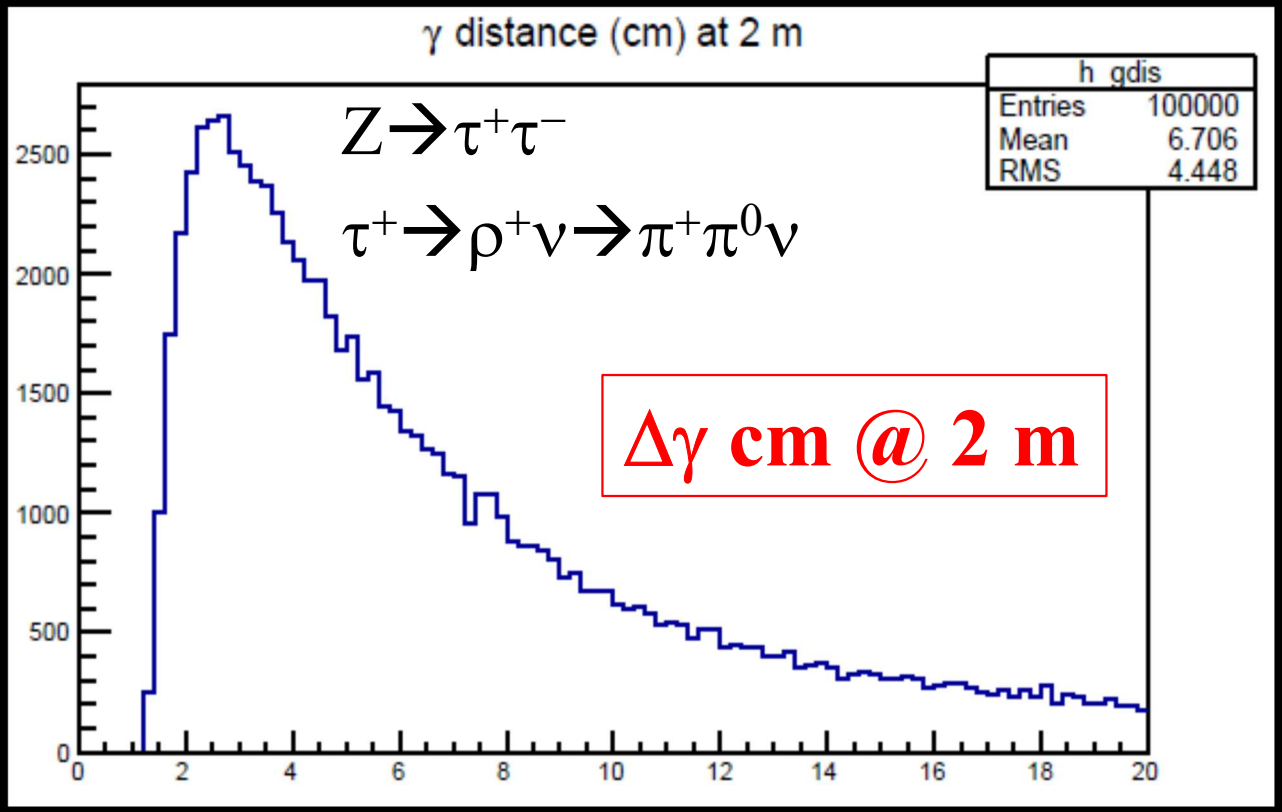


Details in talk of L. Pezzotti
Thursday afternoon

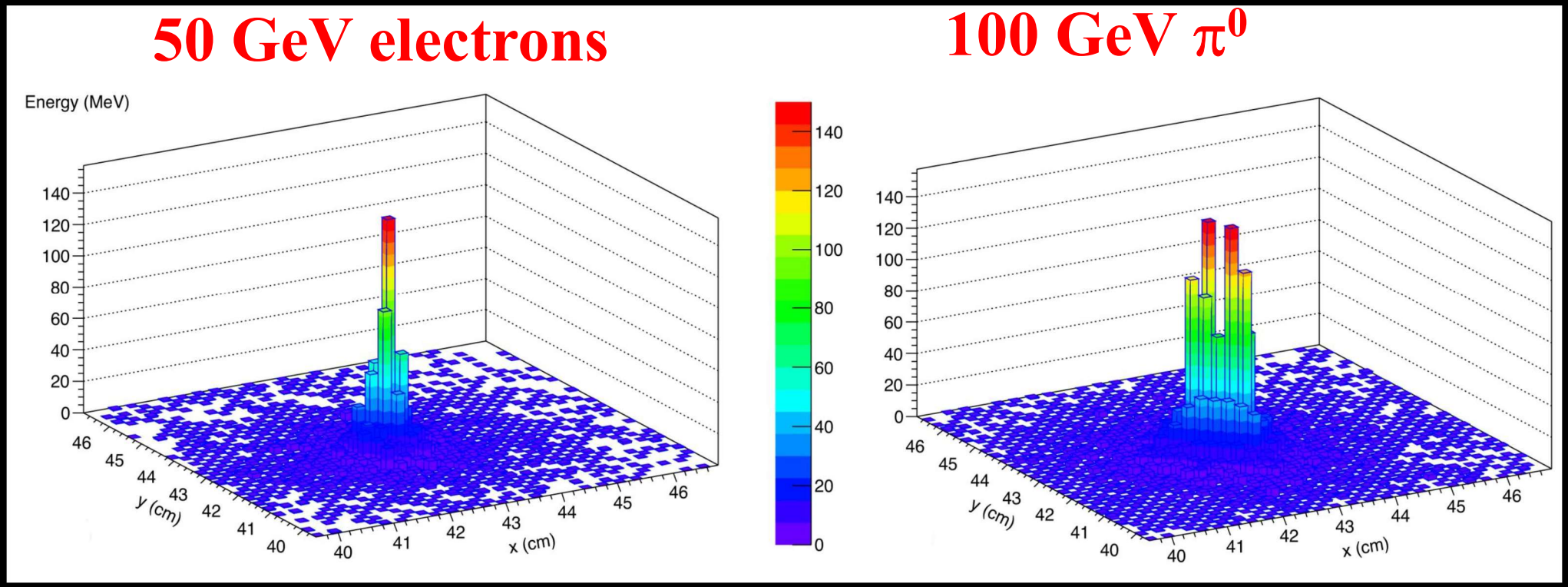
Calorimeter separation (γ)

- Transverse granularity below 1 cm seems adequate



Calorimeter separation (γ)

- Transverse granularity below 1 cm seems adequate
- Extreme granularity (~2 mm) achievable with DR
  - At a cost ….



(Some)
Detector R&D

VTX R&D

- Target key issues of pixel detectors:

VTX R&D

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  - Extreme spatial resolution (small pixels)
  - Time stamping
  - Stitching
  - Low power

VTX R&D

- Target key issues of pixel detectors:
  - Extreme spatial resolution (small pixels)
  - Time stamping
  - Stitching
  - Low power
- Funding:
  - ARCADIA project of INFN ~ 1 M€
  - Potential of additional support from AIDA++

VTX R&D

❖ Target key issues of pixel detectors:

Requirements	ARCADIA
Pixel pitch (um)	20 - 25
Thickness (um)	50 - 100
Scalability (cm)	Up to $\sim$ 4 x 4
Hit rate (MHz/cm^2)	10 $\rightarrow$ 100
Cluster size (pixels)	2-4
Timing res. (ns)	10
Power (mW/cm^2)	$<$ 20
Rad. Hard (Mrad)	1
Tiling	Side-buttable
Trigger	Triggerless

First Implementation

- Target hit rate: 100MHz/cm^2
- Target efficiency: 99.9% (in every regard)
- Pixel size: 20μm × 20 μm
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- Support for 2048 pixels in column (4cm)

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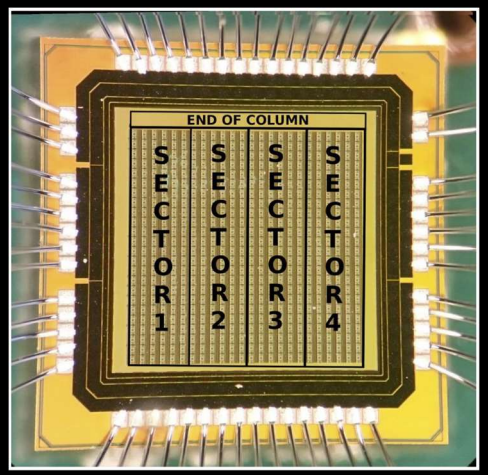

Matisse: small scale demonstrator

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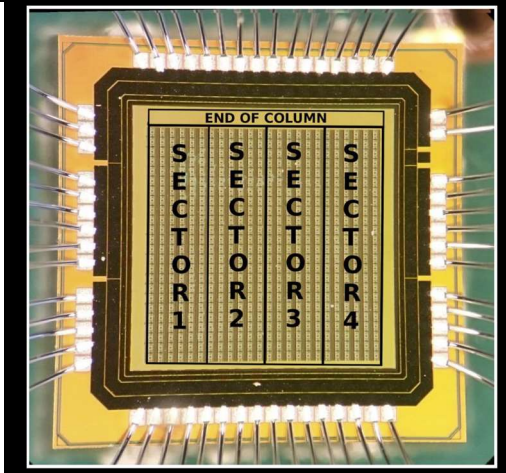

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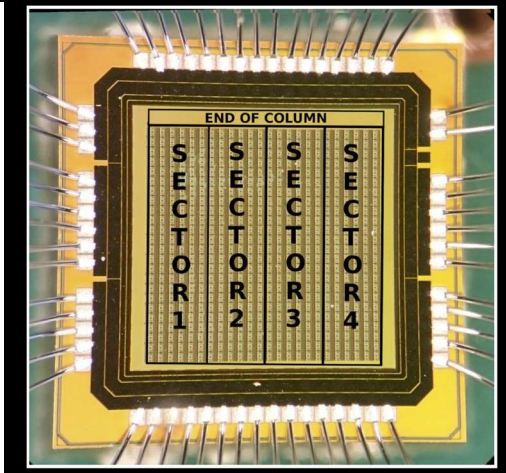

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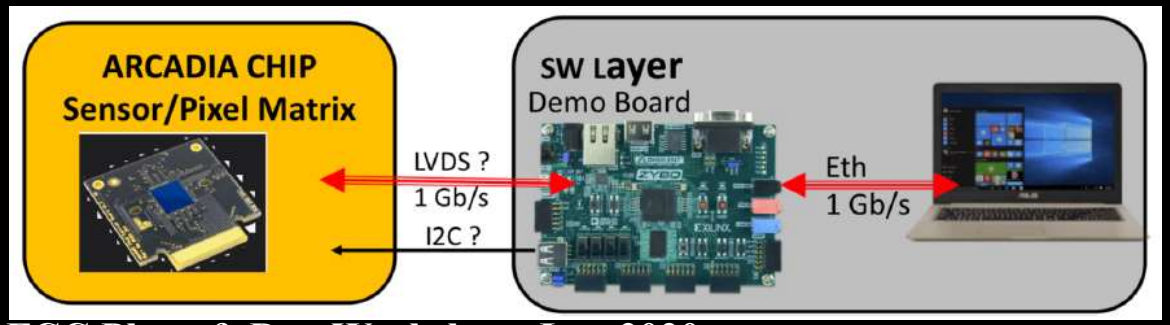
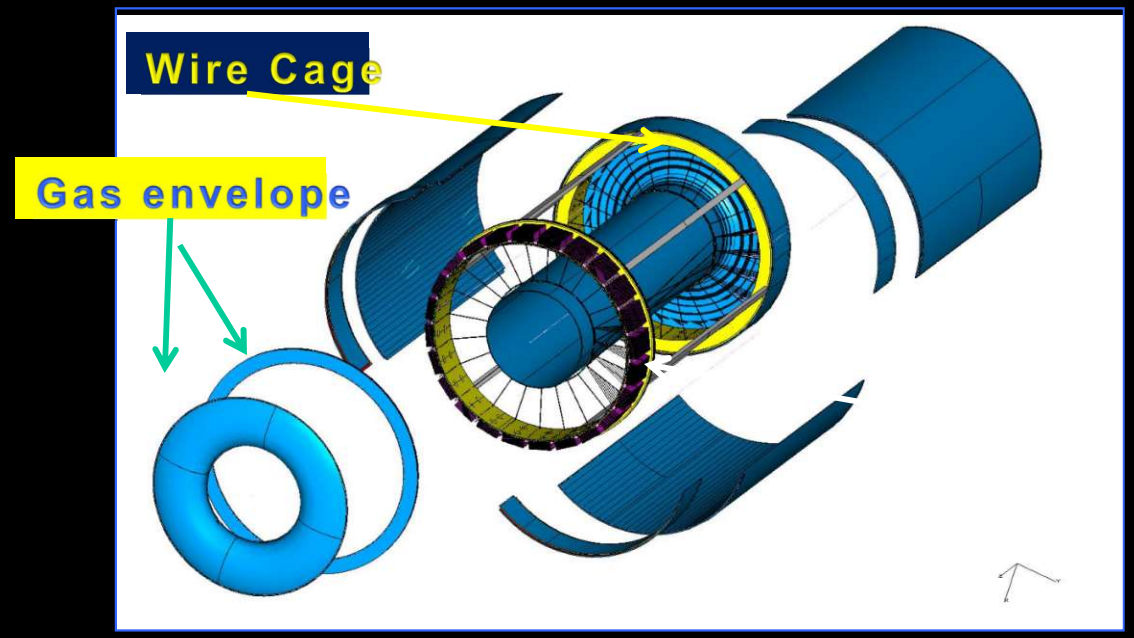


DAQ based on previous CERN experience

Drift Chamber R&D

- Main issues:
  - Mechanical structure



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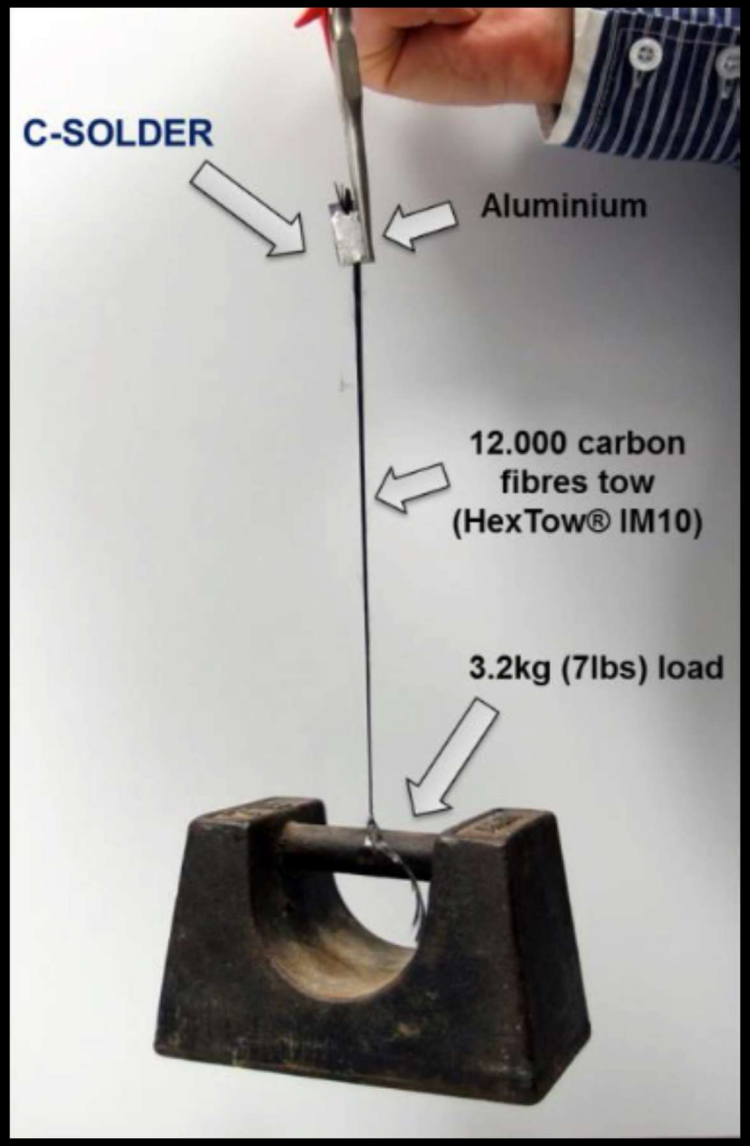

Soldering of Carbon Materials Using Transition Metal Rich Alloys

Marek Burda,*,† Agnieszka Lekawa-Raus,† Andrzej Gruszczyk,‡ and Krzysztof K. K. Koziol*,†

†Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, CB3 0FS, Cambridge, U.K. and ‡Welding Department, Silesian University of Technology, Konarskiego 18a, 44-100 Gliwice, Poland

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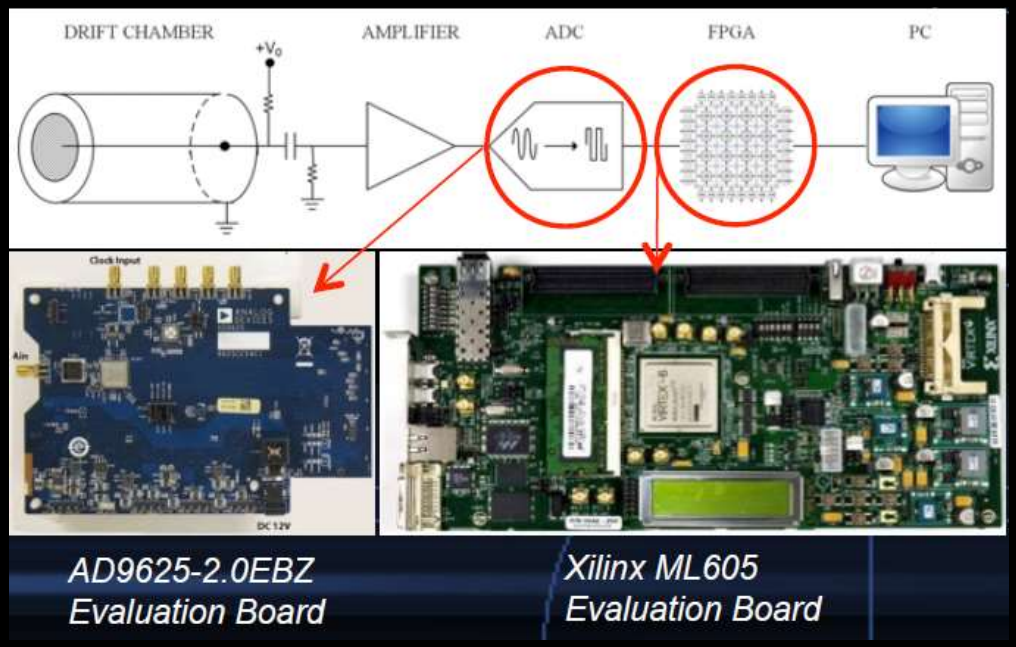

Drift Chamber R&D

- Main issues:
  - Mechanical structure
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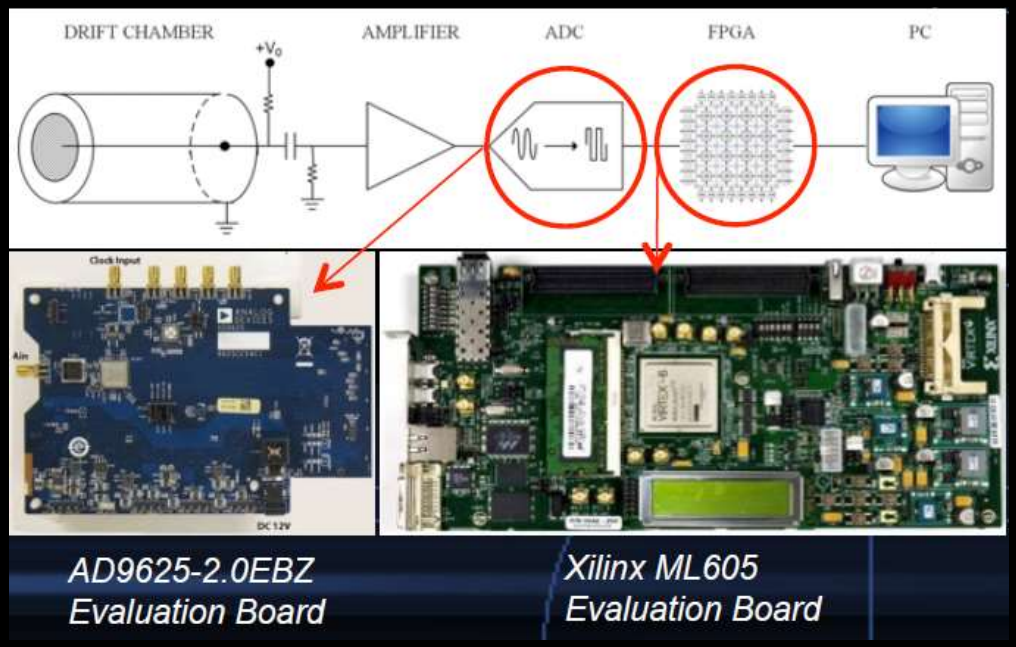
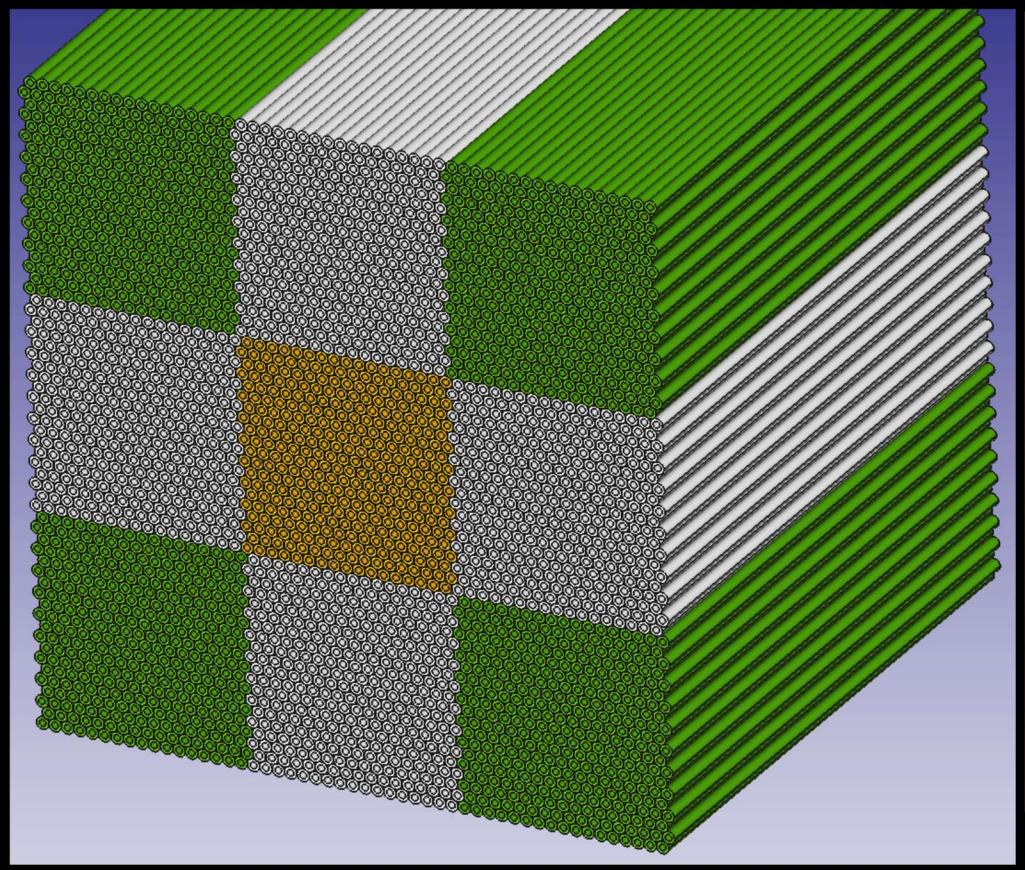
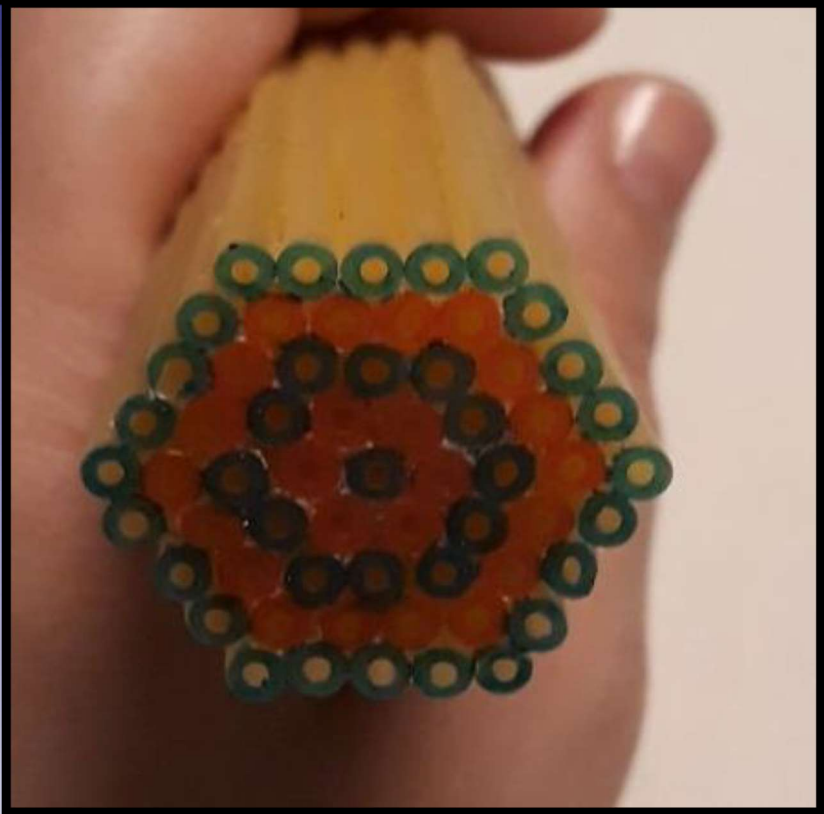
  - Cluster counting electronics for PID
- Funding:
  - CREMLIN+
    - Synergy with tau/charm factory
  - INFN CSN1
  - AIDA++ ?



DR calorimeter R&D

- Testing new mechanical options
  - Spaghetti → bucatini – Prototype in progress 10x10x100 cm^3





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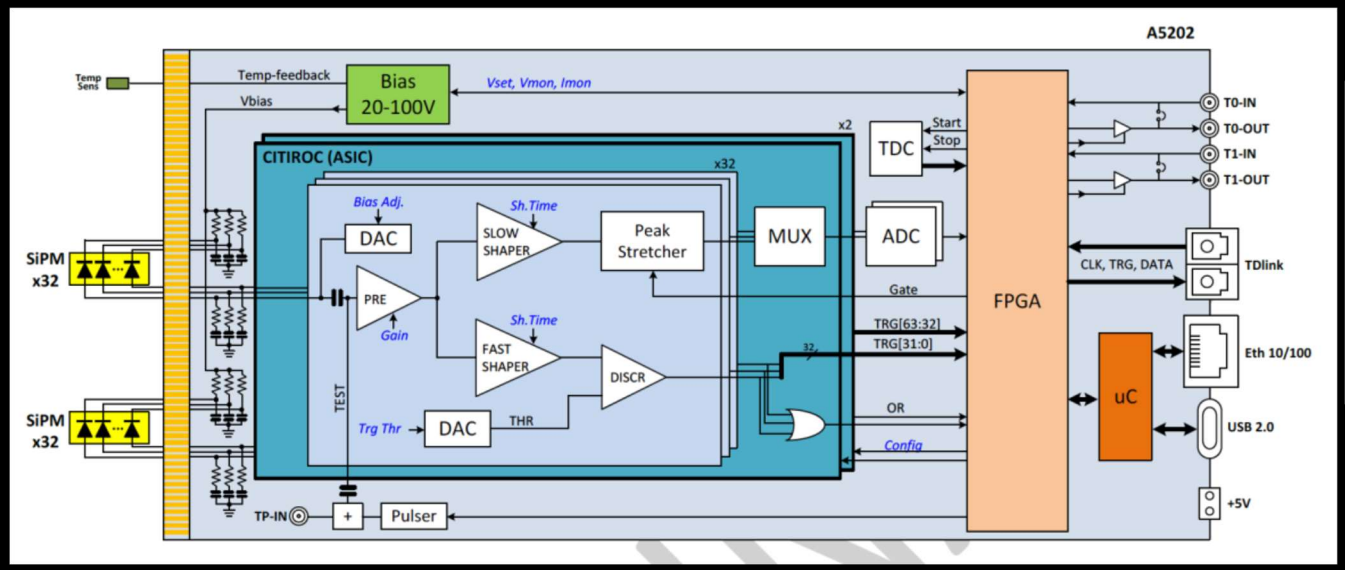
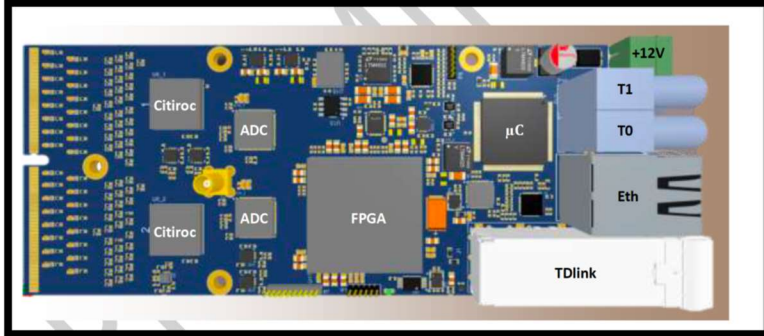
- Compact readout with CAEN FERS based on Citiroc





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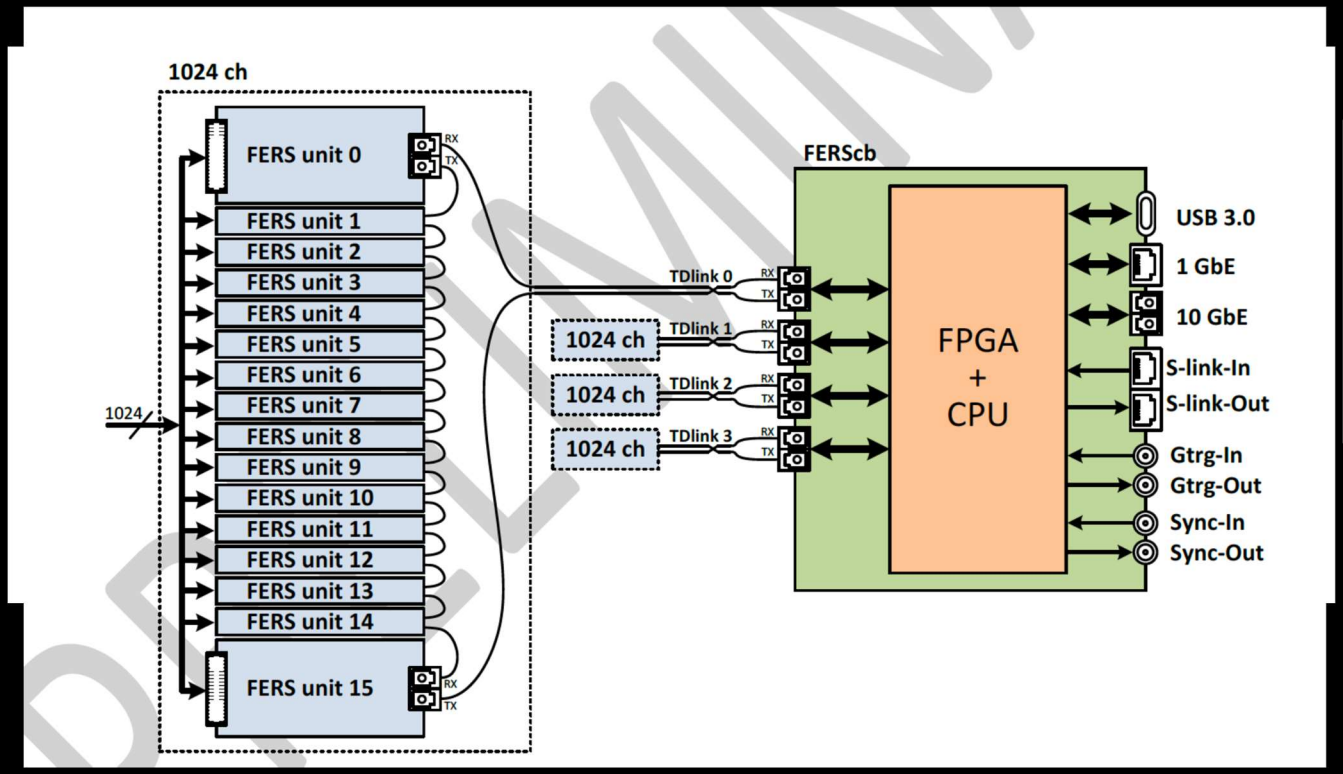

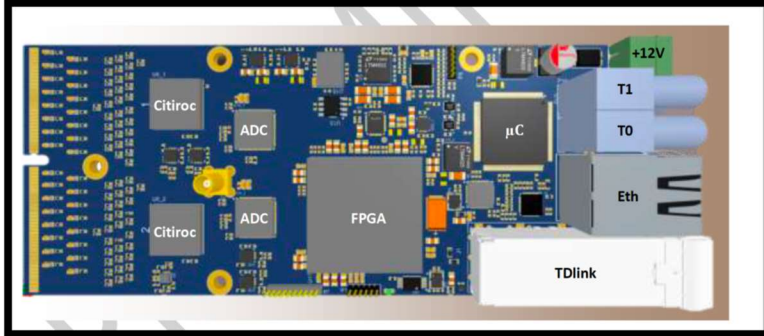

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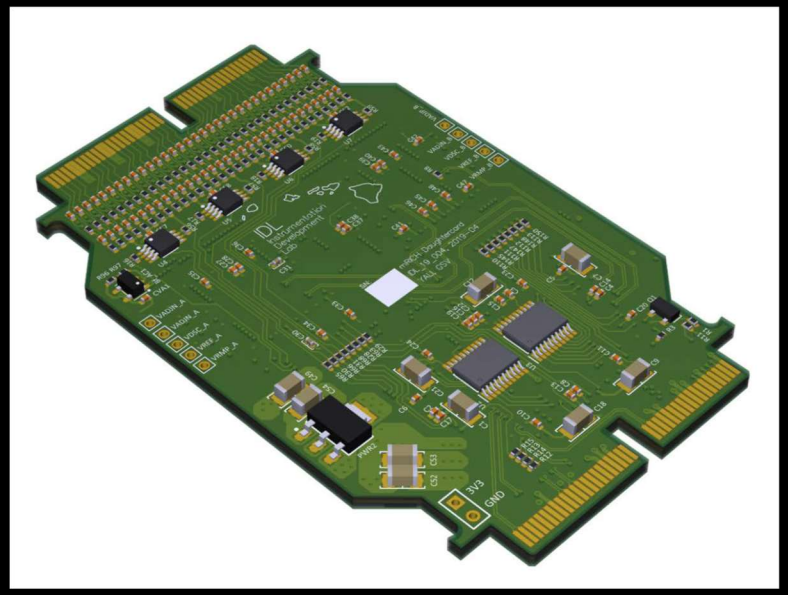
  - New version: 64 ch with 4 GHz ADC and feature extraction

SiREAD Parameter	Specifications
Channels	64
Sampling rate	1-4 GSa/s
Storage samples/ch	4096
Analog bandwidth	0.7-1.1 GHz
RMS voltage noise	<1mV
Dynamic range	10-11 bits
Signal voltage range	2.1 V
ADC on chip	12 bits
Readout	Serial LVDS
Power consumption	20-40 mW/ch



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Funding:
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- U. Sussex
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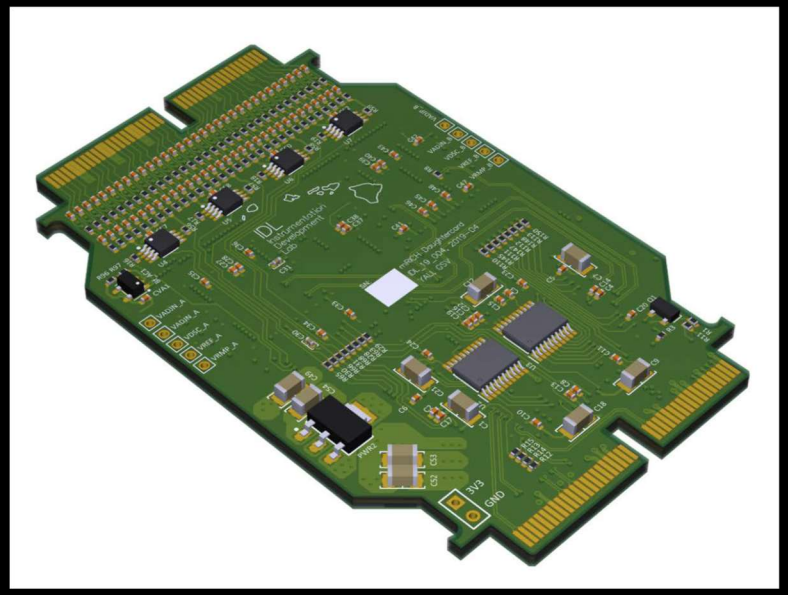

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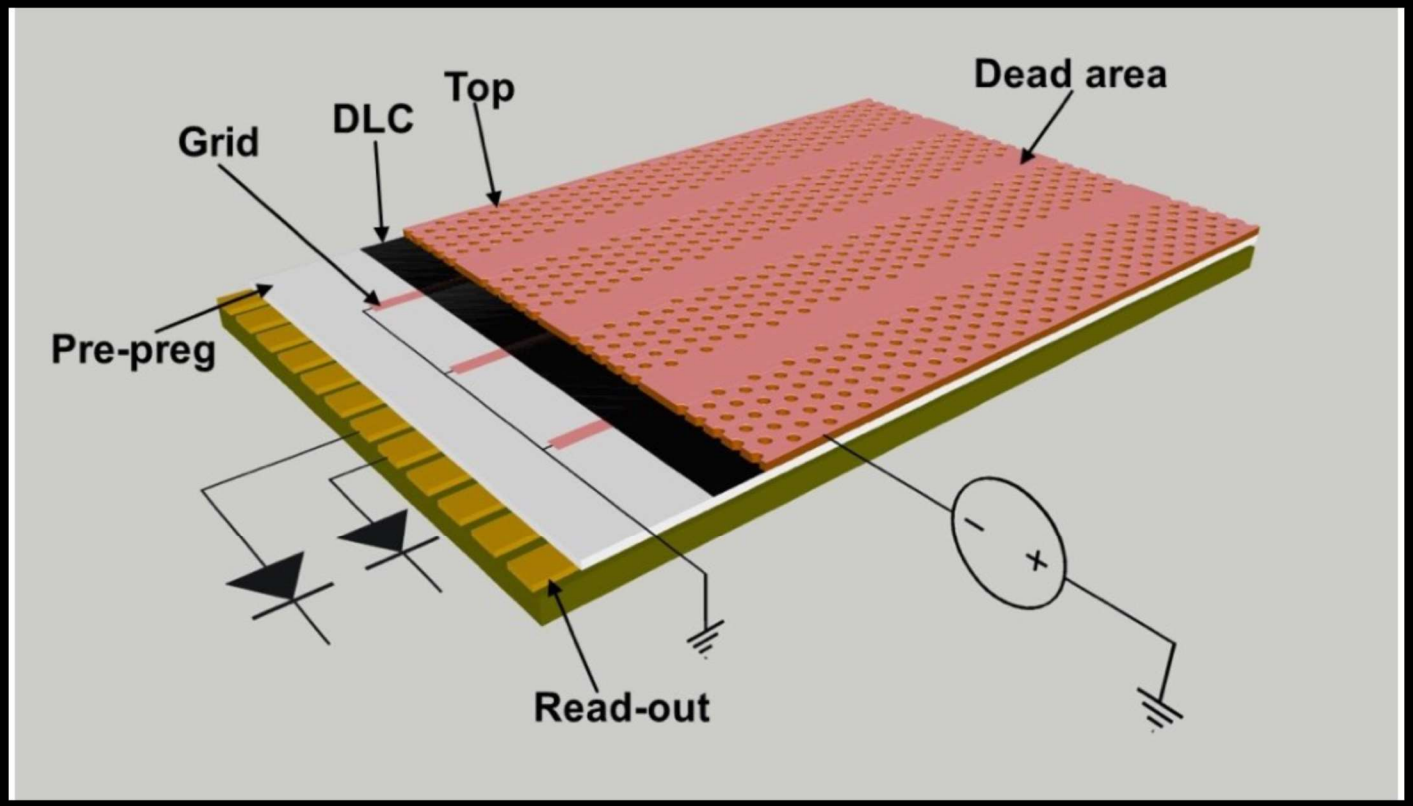

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    - Industrialization
    - Cost reduction
    - DLC+Cu sputtering
    - 2D readout

CMS GE2/1 with 2 μRwell 2 m x 1.2 m

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  - INFN CSN1
  - AIDA++ ?

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  - Large prototypes: vertex detector, DCH, DR calorimeter
    - Challenging and expensive
- Collaboration on all these R&D's is growing internationally, but there is still ample space for additional contributions.

Backup

BACKUP

Detector requirements

- Requirements:
  - Constraints from physics (similar to LC …. more or less)

From CDR

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) =$ $2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV})\sin^{3/2}\theta}$
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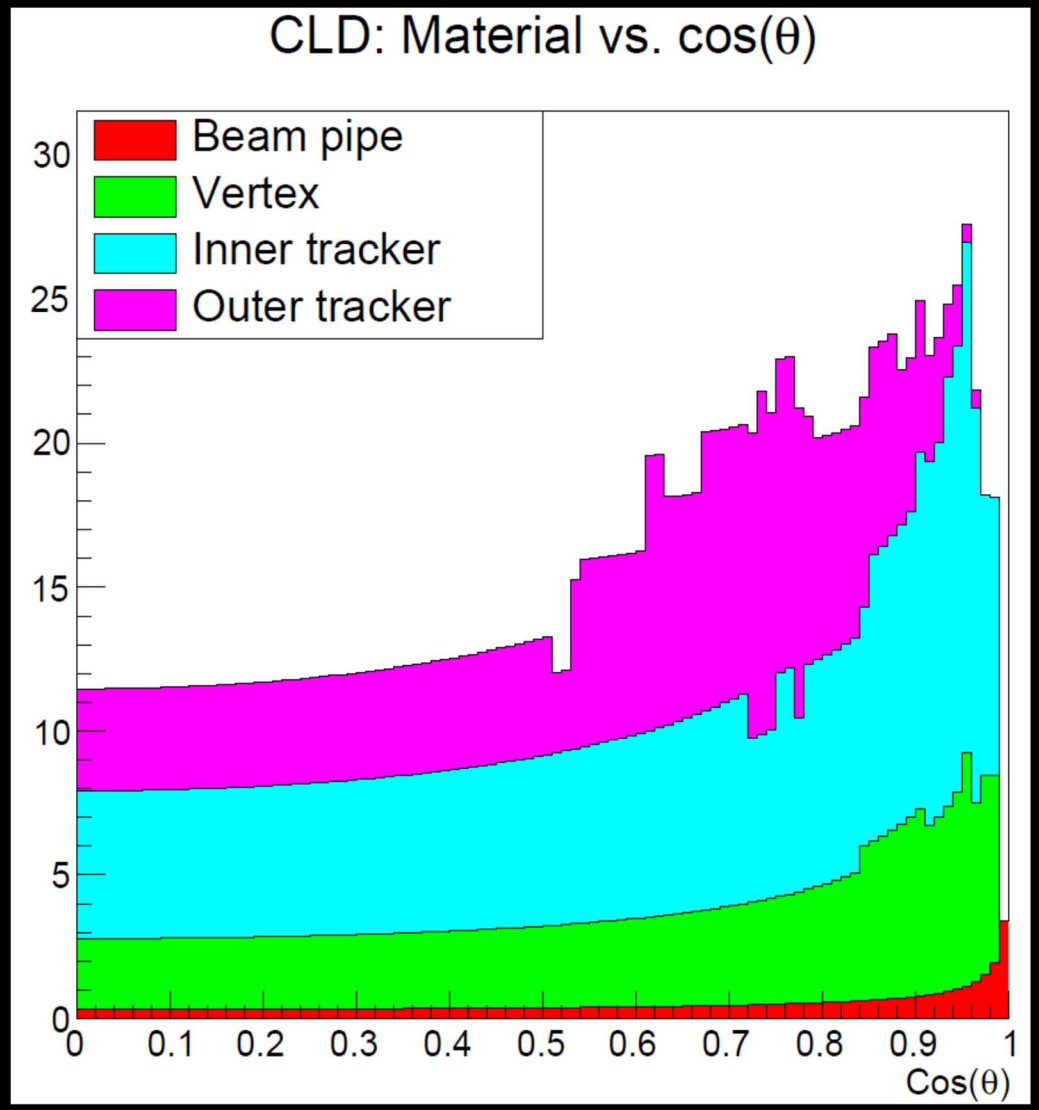
- Additional constraints
  - Excellent acceptance and luminosity control
  - PID & π^0 ID for HF/τ physics
  - Low B field to avoid emittance blow up
  - Power pulsing not allowed

Not present at LC

Transparency



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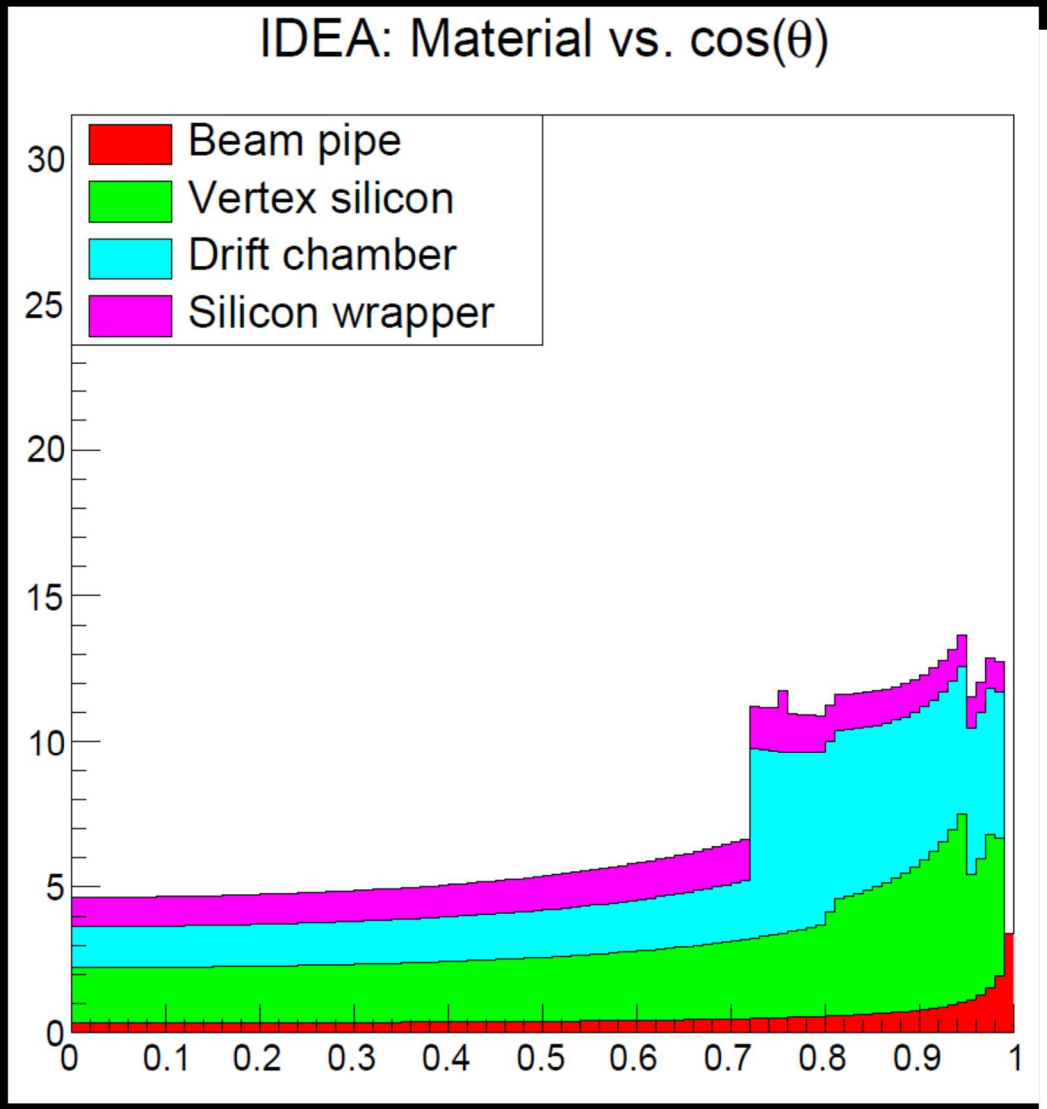
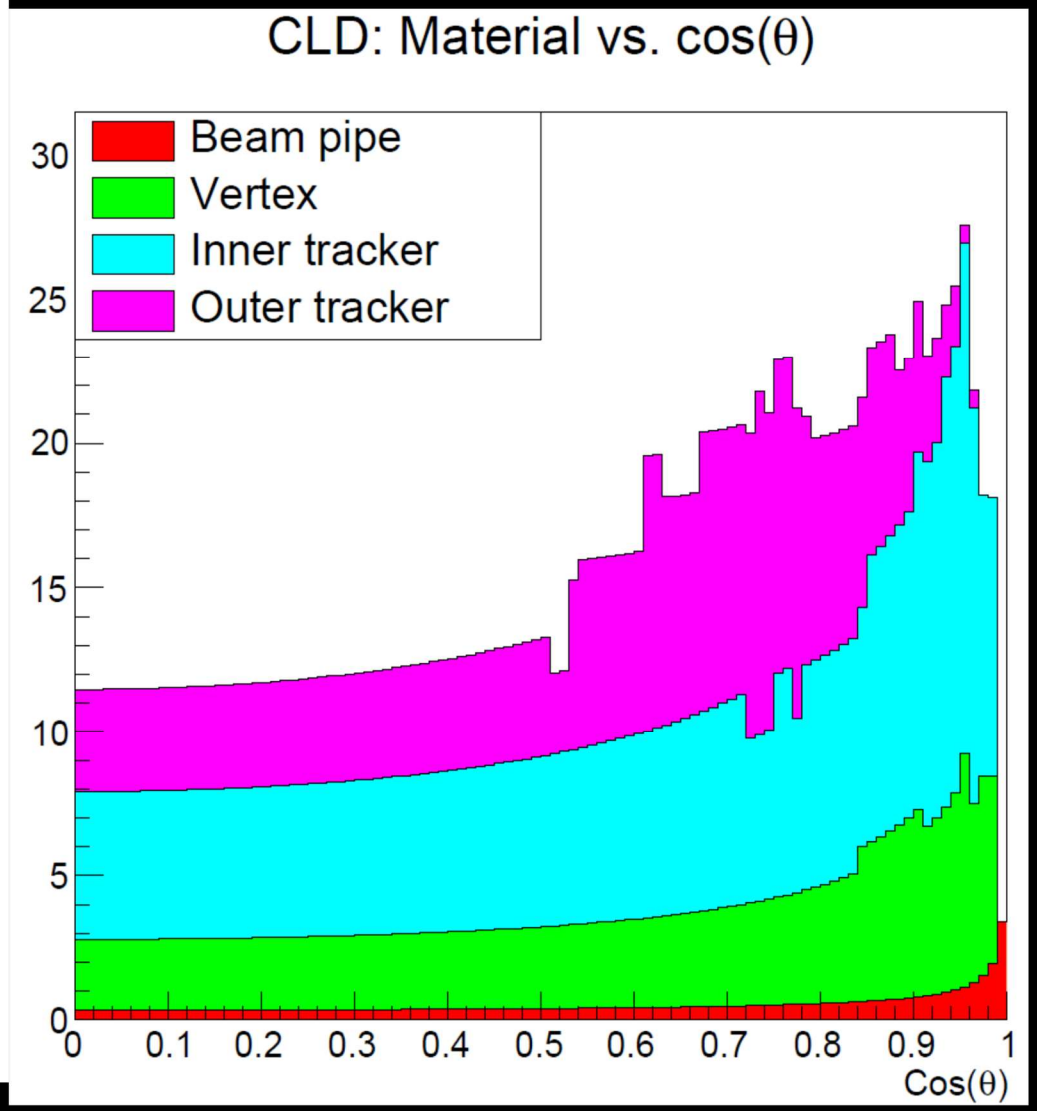
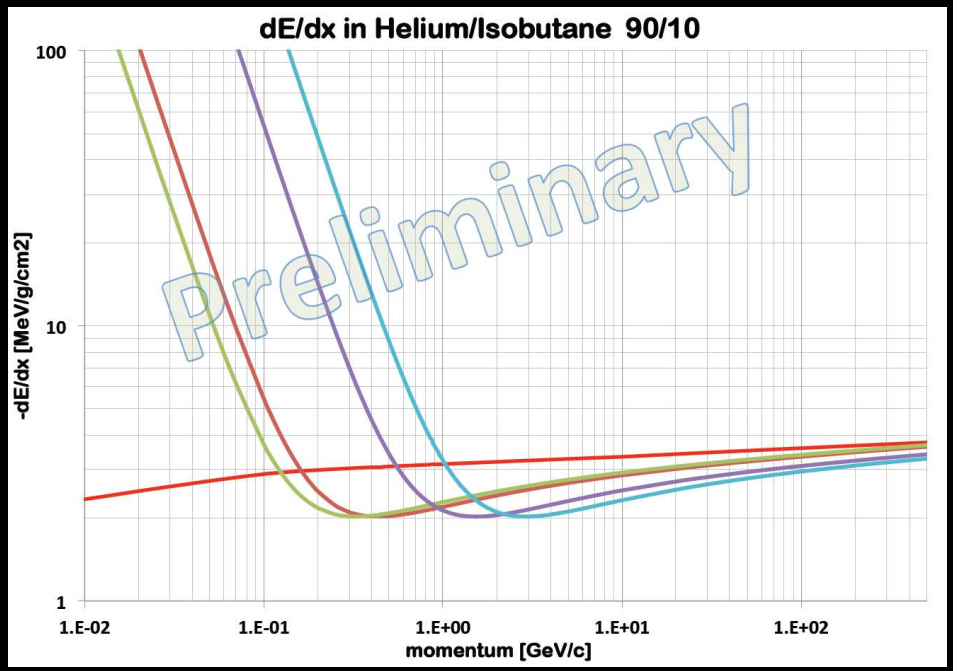
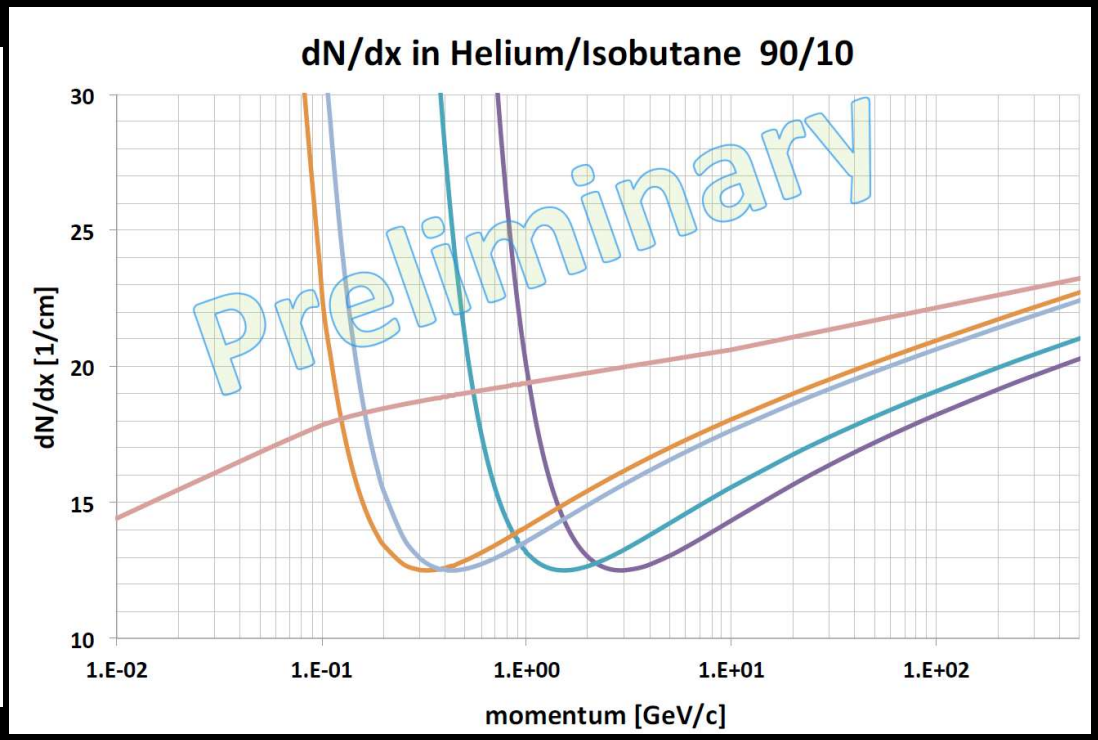




dE/dx vs dN/dx

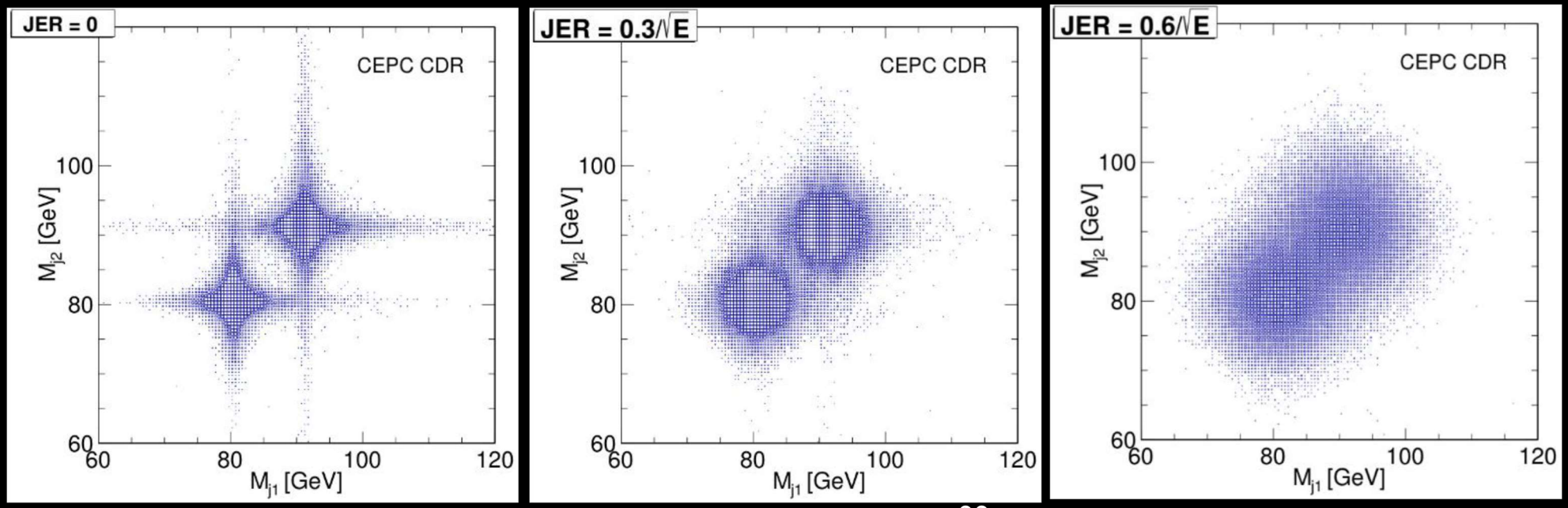
- Steeper high energy rise of #clusters than ionization E





Calorimeter resolution (jets)

- Separation of H→ZZ* from H→ WW*
  - 3-4% @ 100 GeV adequate – Can it be worse?



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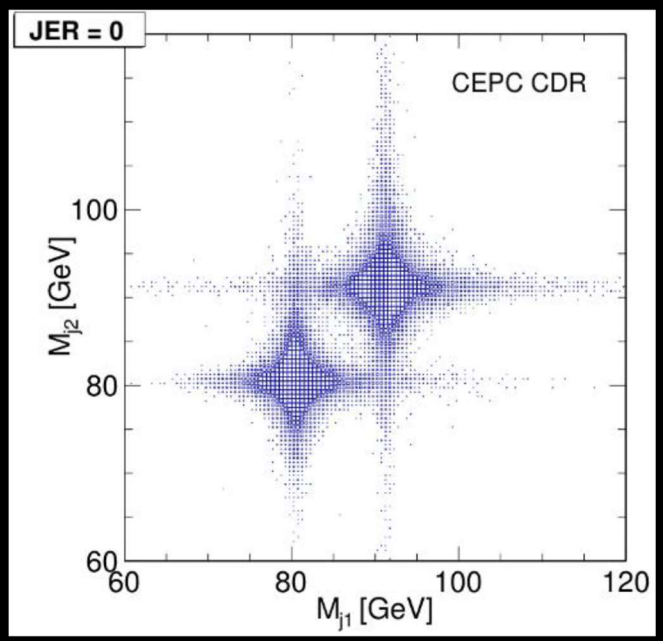

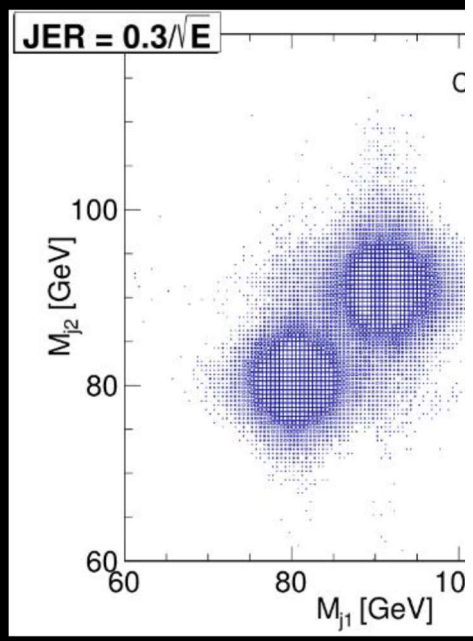

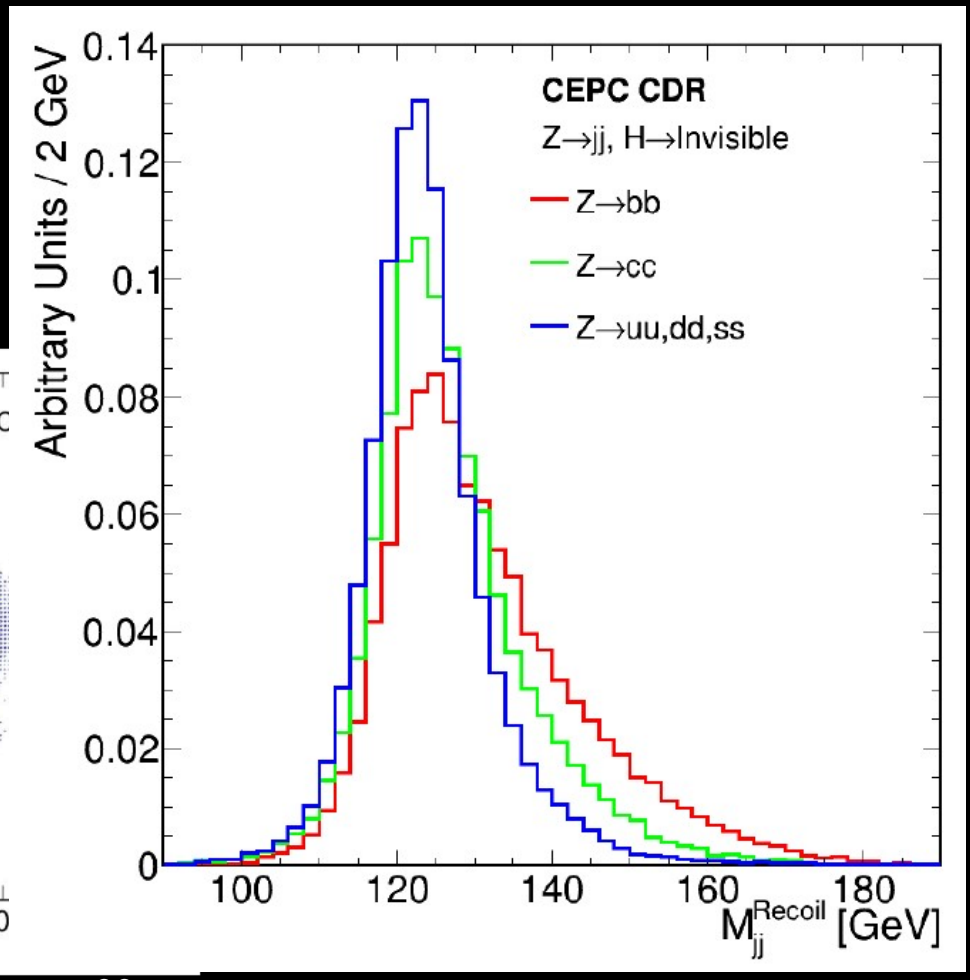

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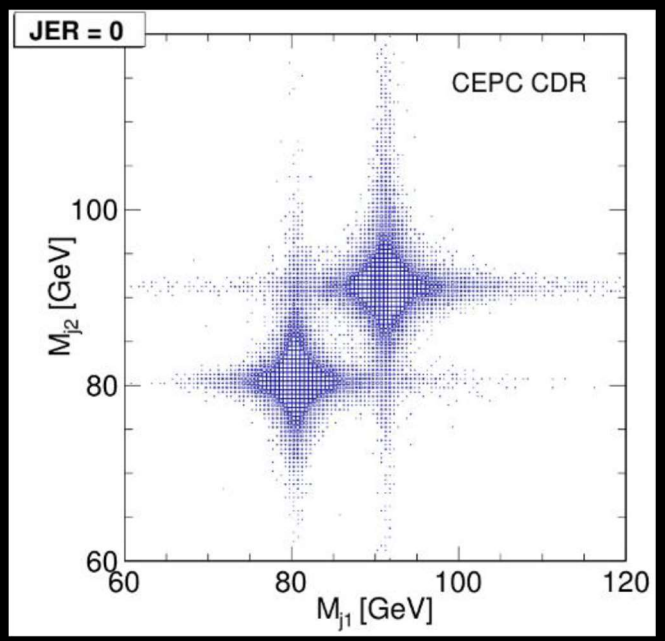

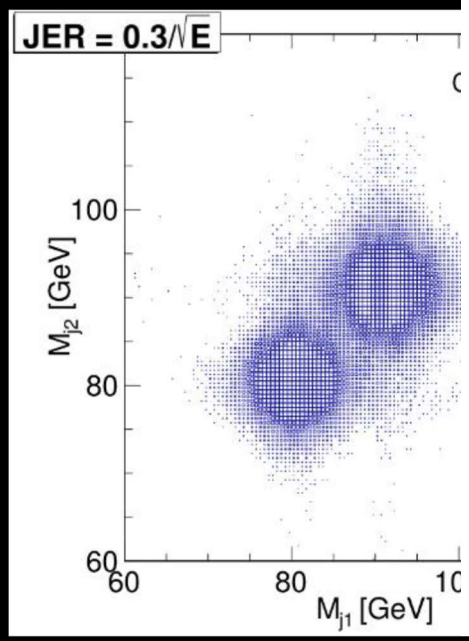

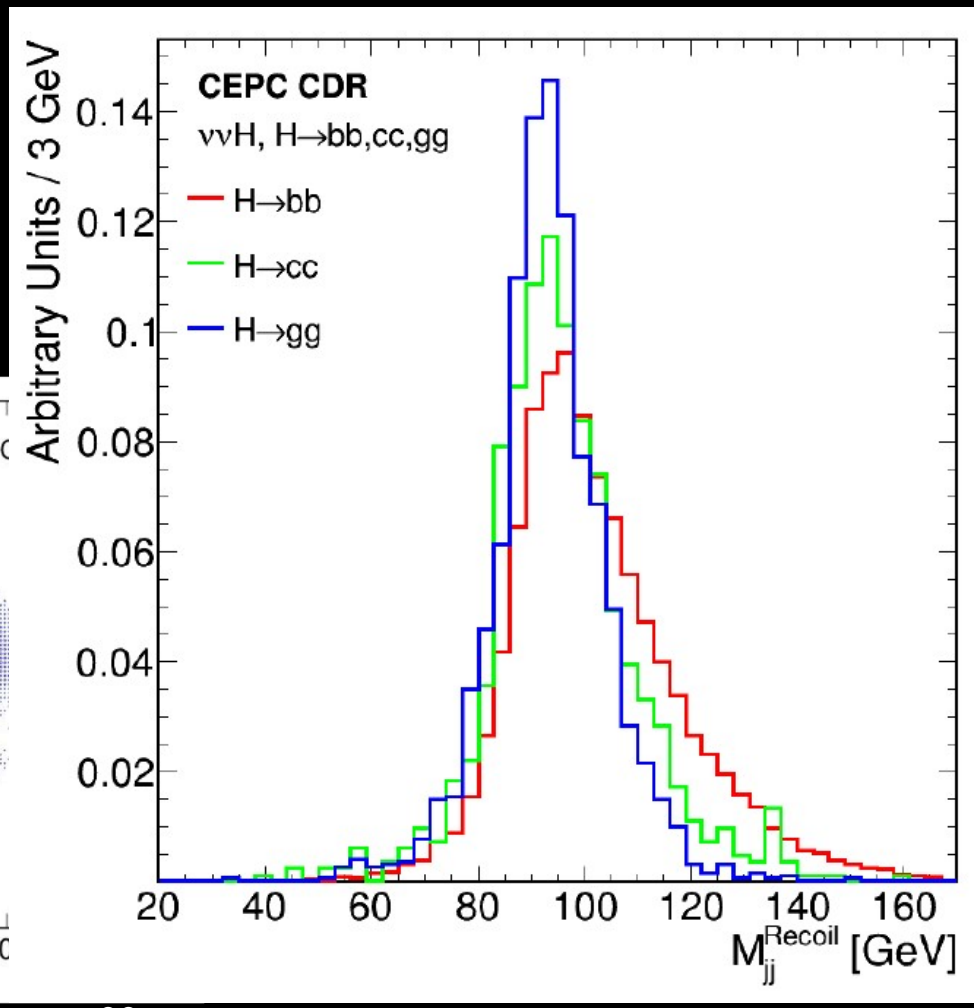

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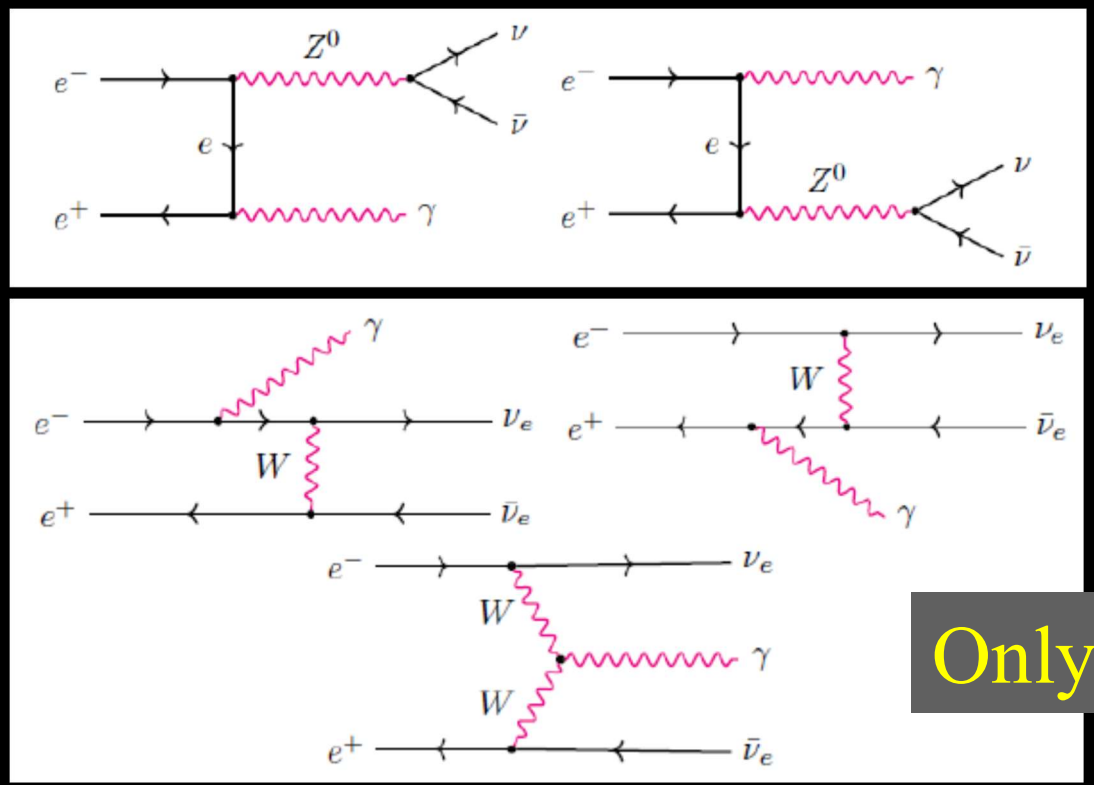
- What about radiative return analysis?
  - Eg. Nν, and Z→ ν_e ν_e



Only ν_e interfere

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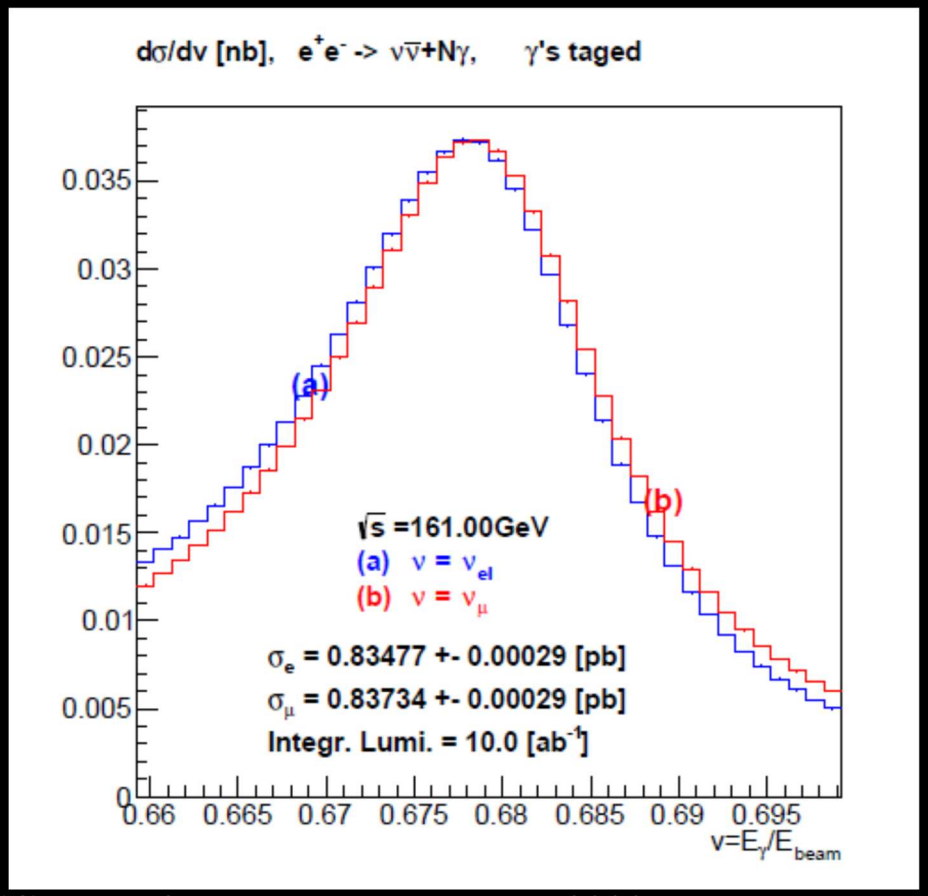

Need 5-10%/sqrt(E) for a good measurement

$\sigma(g_{\nu e})$: 18% →1.4-2.4%

- Worse resolution make separation difficult