Conceptual Design of CEPC Muon Detector

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On Behalf of the CEPC Study Group

CEPC Detector Overview

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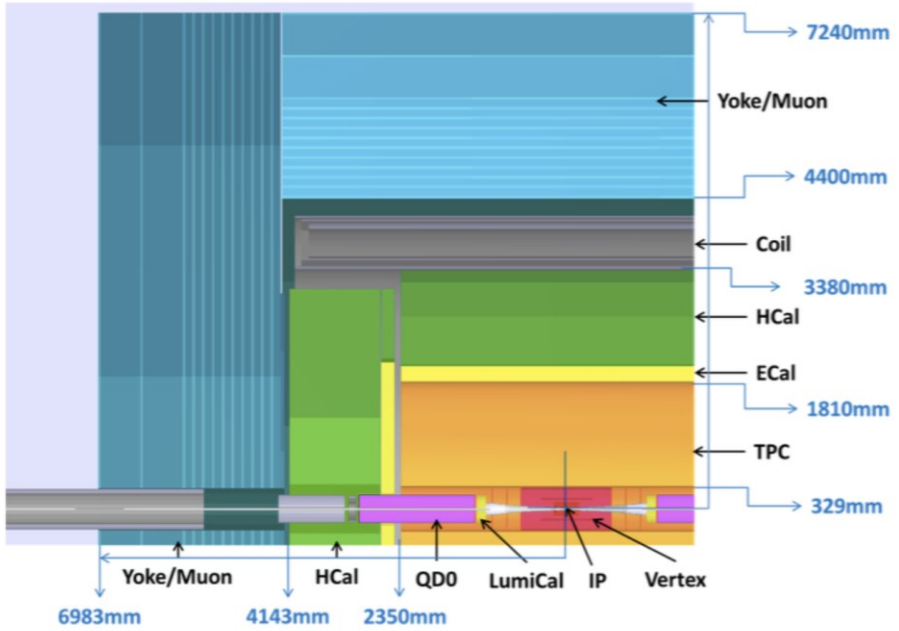
Baseline: ILD-like

- TPC tracking + Imaging calorimetry (ECAL+HCAL)
- PFA-oriented



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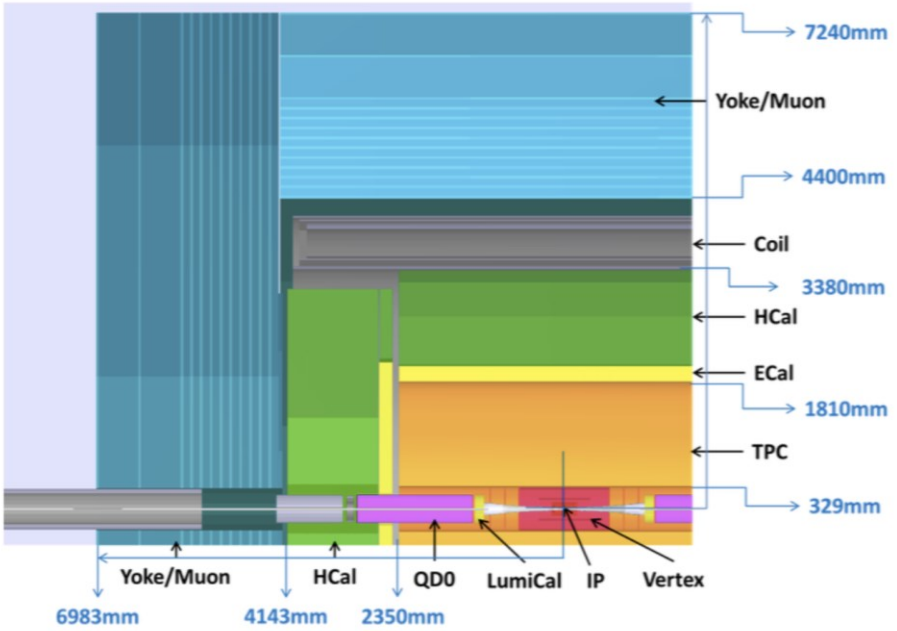
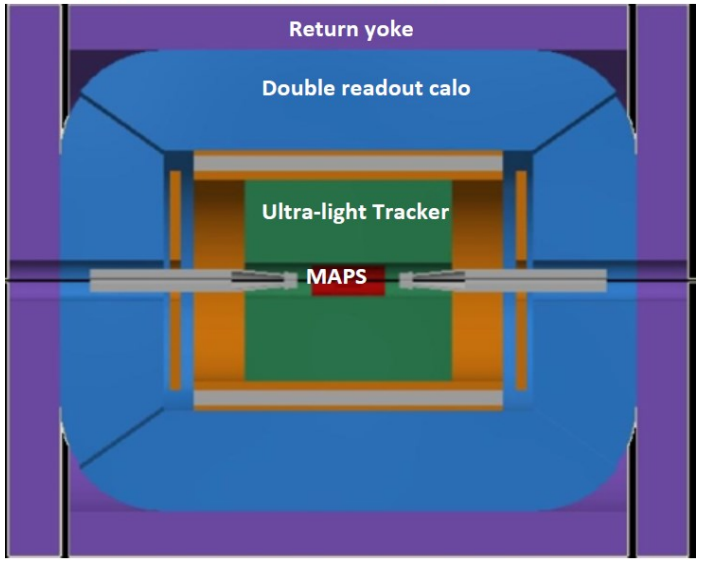
  - IDEA





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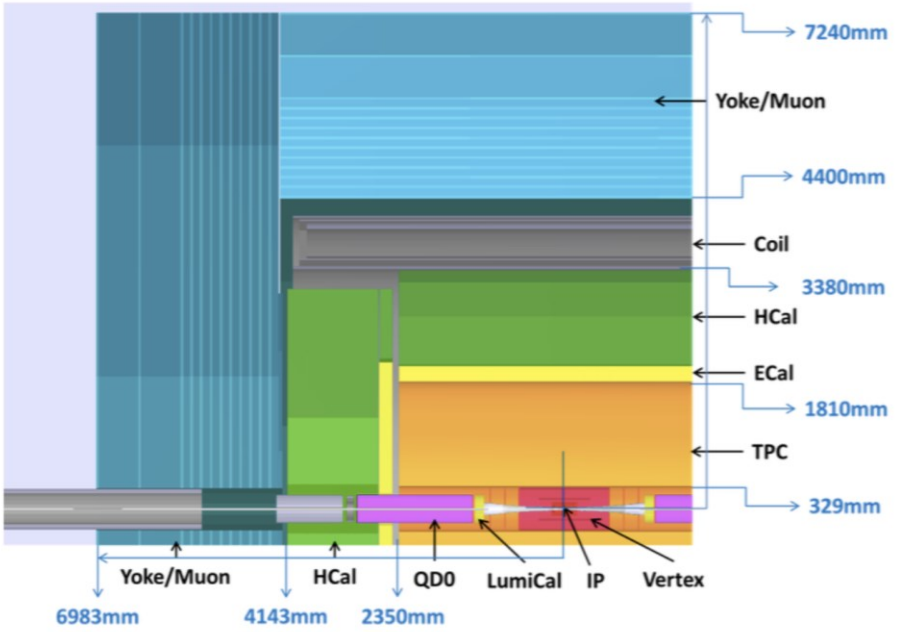
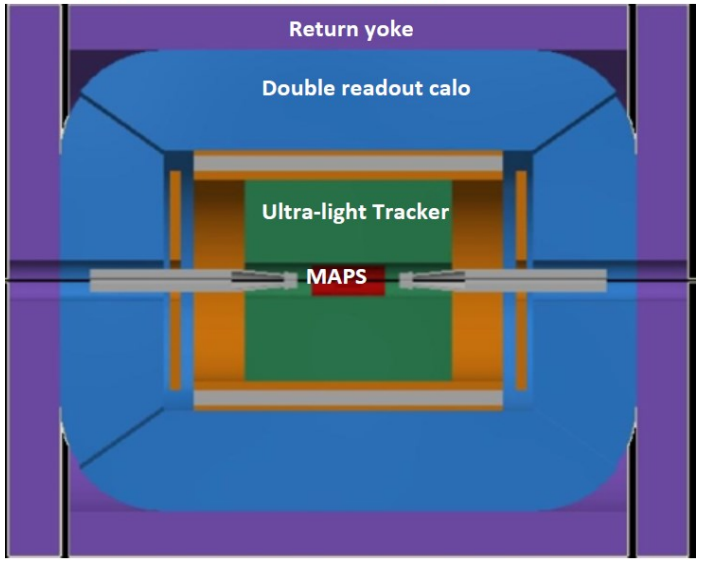
- Full-silicon concept
  - SiD





Muon Detector Requirement

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Identify muons with high efficiency:

- **> 95 % down to low P_T (> 3 GeV)**
- **Low fake rate: < 1%**
- **Large coverage**
- **Modest rate requirement for CEPC**

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- Non-isolated muon identification, long-lived particle detection
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Technology:

- Baseline: bakelite/glass RPC
- Many other options considered
  - *μ*RWell
  - Micromegas, GEM
  - MDT, Scintillator Strip

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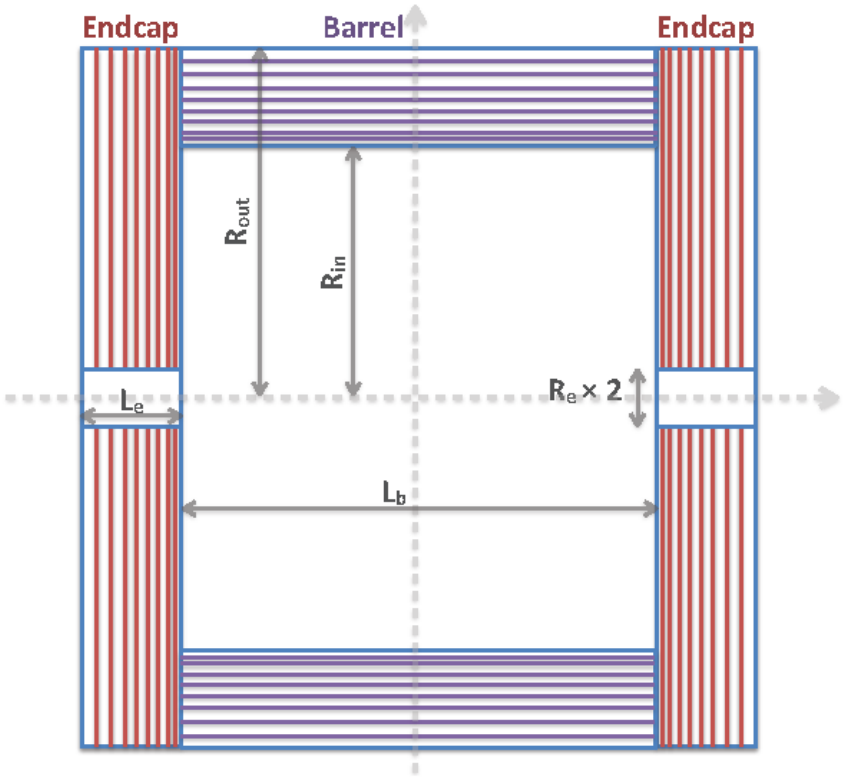

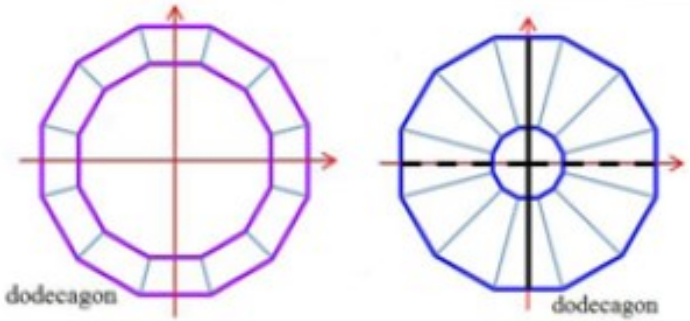

Structure:

- Between magnet iron yoke, outside HCAL
- Cylindrical barrel & two endcap system
- Solid angle coverage: 0.98 * 4π

Two detector designs:

- RPC as baseline
- μRWell as alternative

Baseline: RPC Option

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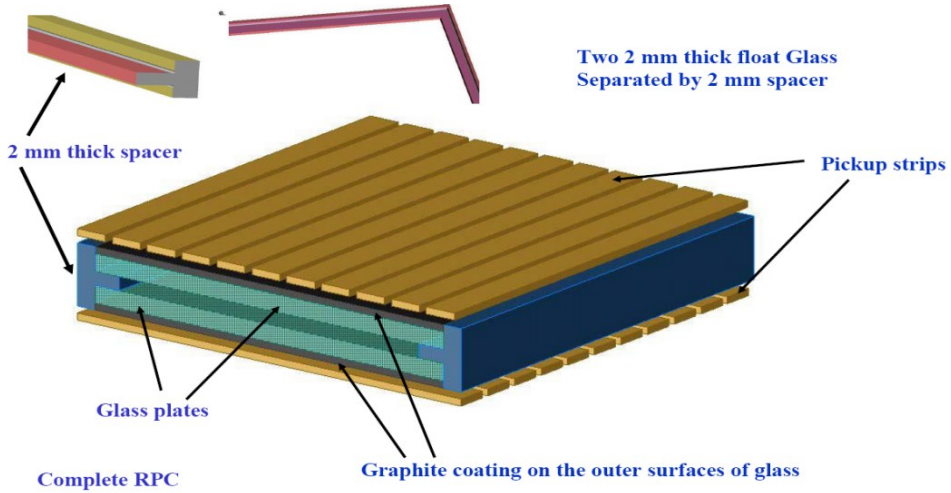

Resistive Plate Chamber (RPC)

- 12 Segmentation
- 8 layers
- Total absorber thickness: 6.7λ
- Total area
  - Barrel ~ 4450 m^2
  - Endcap ~ 4150 m^2
  - Total ~ 8600 m^2

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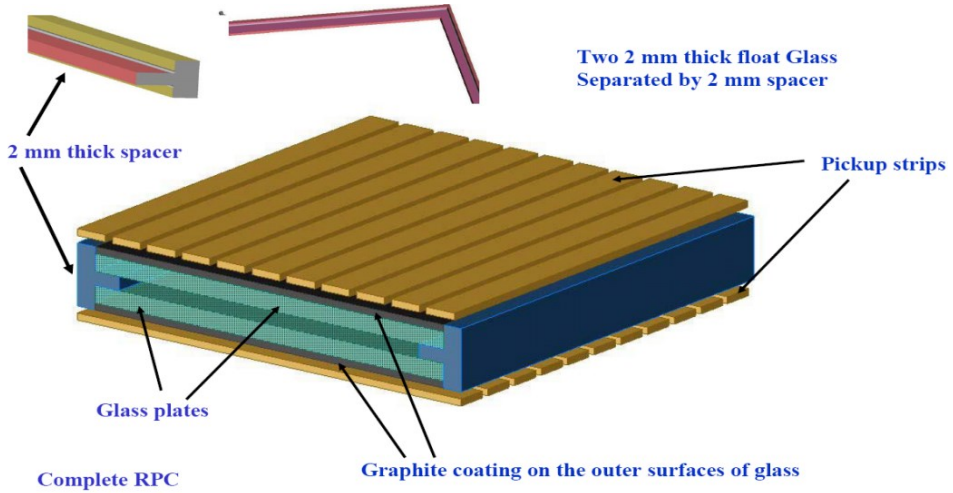

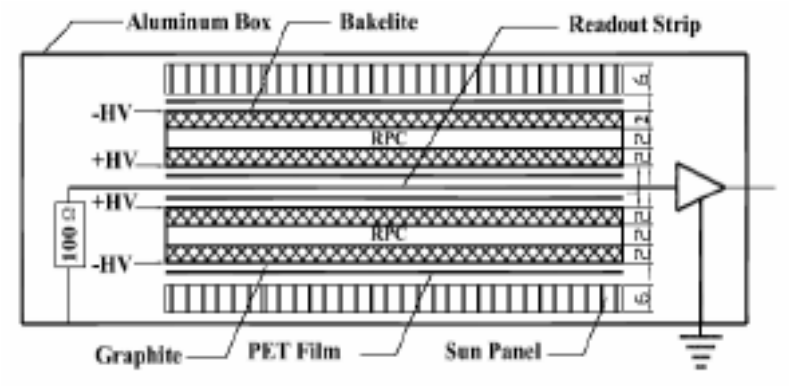

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- ✓ Low cost, easy construction
- ✓ Position resolution: 1-2 cm
- ✓ Time resolution: ~ 1 ns
- ✓ Rate capability: ~100 Hz

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Bakelite vs. Glass

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Bakelite vs. Glass

Parameters		Bakelite	Glass
Bulk resistivity [$\Omega \cdot$ cm]	Normal	$10^{10} \sim 10^{12}$	$> 10^{12}$
	Developing	$10^{8} \sim 10^{9}$	
Max unit size (2 mm thick) [m]		1.2×2.4	1.0×1.2
Surface flatness [nm]		< 500	< 100
Density [g/cm^3]		1.36	2.4∼2.8
Min board thickness [mm]		1.0	0.2
Mechanical performance		Tough	Fragile
Rate capability [Hz/cm^2]	Streamer	100@92% [97]	
	Avalanche	10K	100@95% [98]
Noise rate [Hz/cm^2]	Streamer	< 0.8	0.05 [99]

Baseline Parameters

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Parameter	Possible range	Baseline
Lb/2 [m]	3.6 – 5.6	4.14
Rin [m]	3.5 – 5.0	4.40
Rout [m]	5.5 – 6.2	6.08
Le [m]	1.0 – 2.0	1.72
Re [m]	0.6 – 1.0	0.50
Segmentation in ϕ	8/10/12	12
Number of layers	3 – 10	8
Total thickness of iron	6 – 10λ ($\lambda = 16.77$ cm)	6.7λ (112 cm) (8/8/12/12/16/16/20/20) cm
Solid angle coverage	(0.94 – 0.98)$\times 4\pi$	0.98
Position resolution [cm]	$\sigma_{r\phi}$: 1.5 – 2.5	2
	σ_z: 1 – 2	1.5
Time resolution [ns]	< 10	1 – 2
Detection efficiency ($P_\mu > 5$ GeV)	92% – 99%	> 95%
Fake($\pi \to \mu$)@30GeV	0.5% – 3%	< 1%
Rate capability [Hz/cm^2]	50 – 100	~60
Technology	RPC	RPC (super module, 1 layer readout, 2 layers of RPC)
	μRWell	
Total area [m^2]	Barrel	~4450
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- Full simulation sample not available yet and no test beam data
- Preliminary study done with simple geometry and simulation configurations
- Muon efficiency > 95%
- Pion fake rate < 1%
- Position and time resolution as expected

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  - Room for improvement
    - Tune PFA in harsh environment, add timing information
    - Combine muon detector information

μ-RWELL Technology

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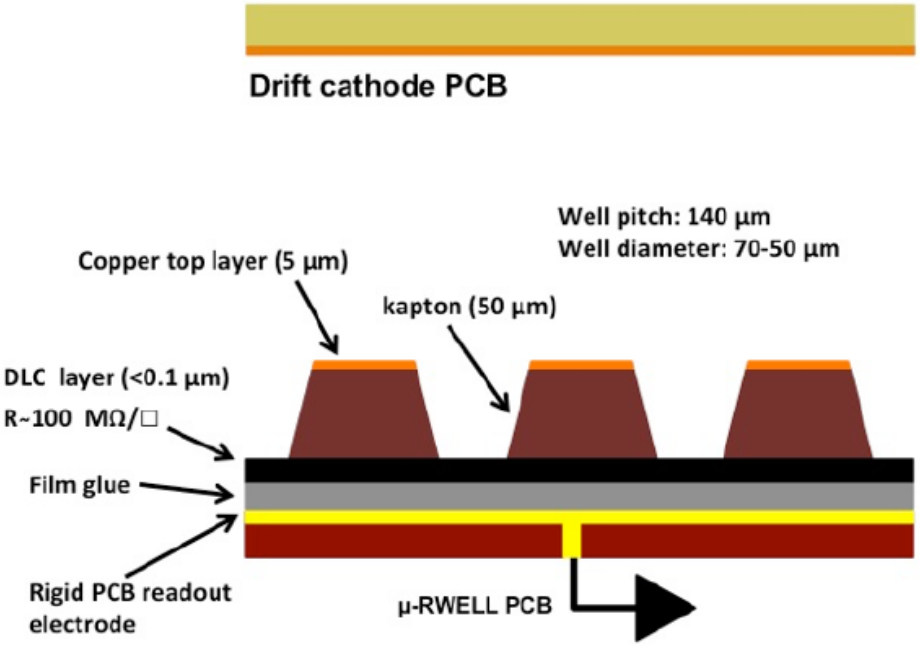
MPGD with two PCBs: standard GEM Drift cathode PCB and μRWell PCB



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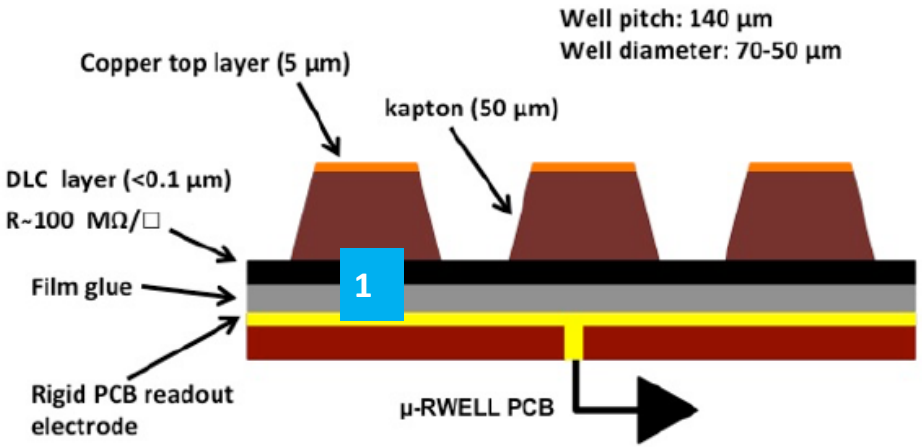
- **Amplification stage: suitable WELL patterned kapton foil**



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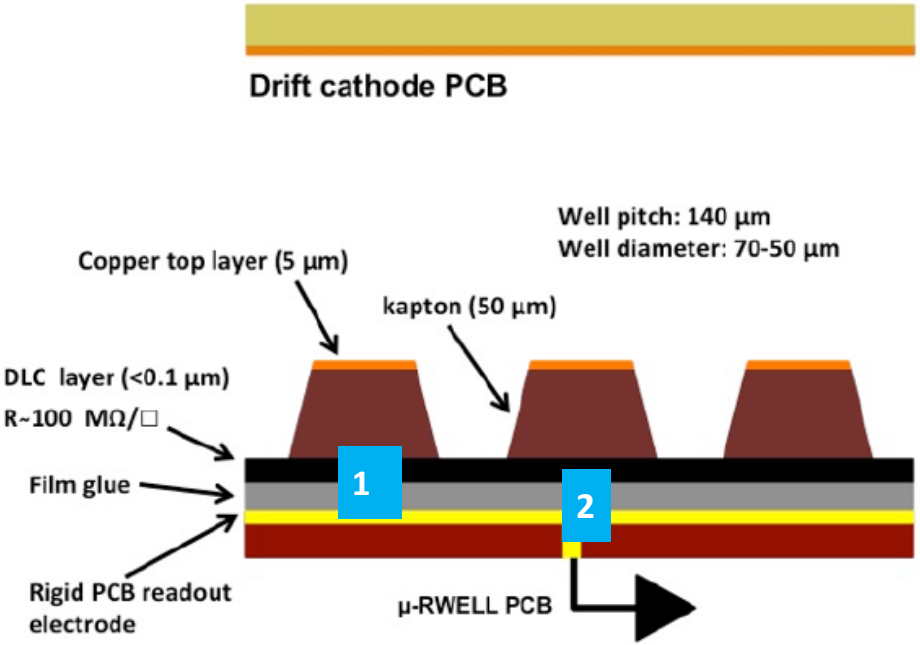

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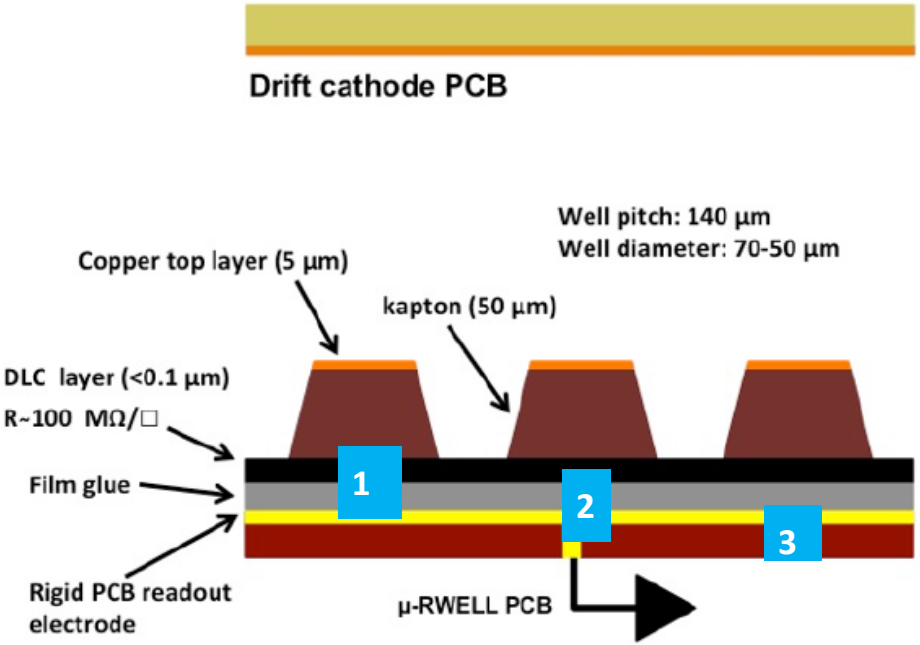

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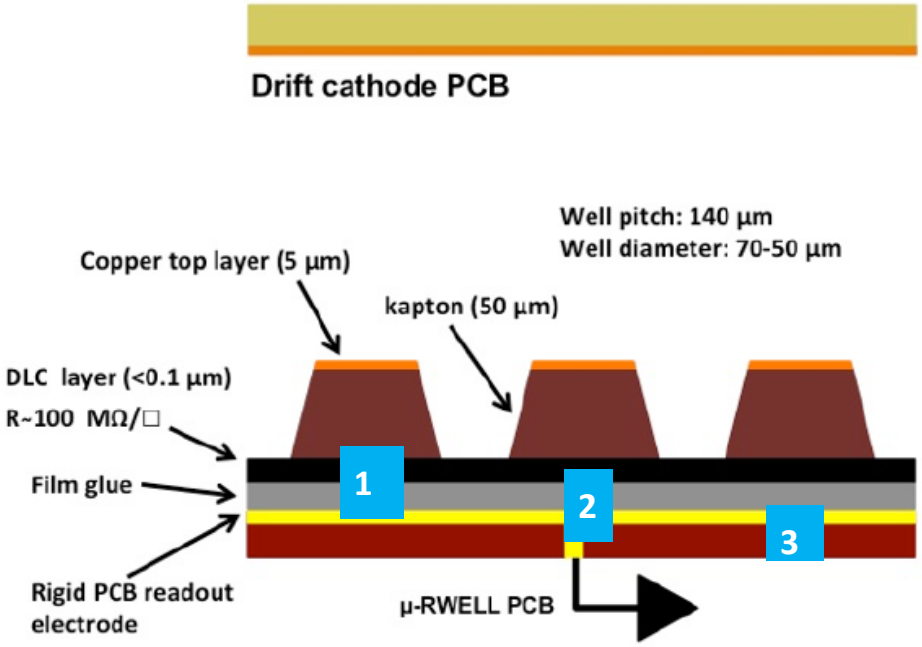

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Advantages compared to other MPGDs (GEM and MicroMegas)

✓ Improve resistance to sparks: resistive DLC layer

✓ Simpler construction: 1 kapton foil, single amplification layer, simpler etching and no stretching needed (Kapton foil glued to PCB)

✓ No reducing of detector performance, good time and position resolution

μ-RWELL Test Beam Results

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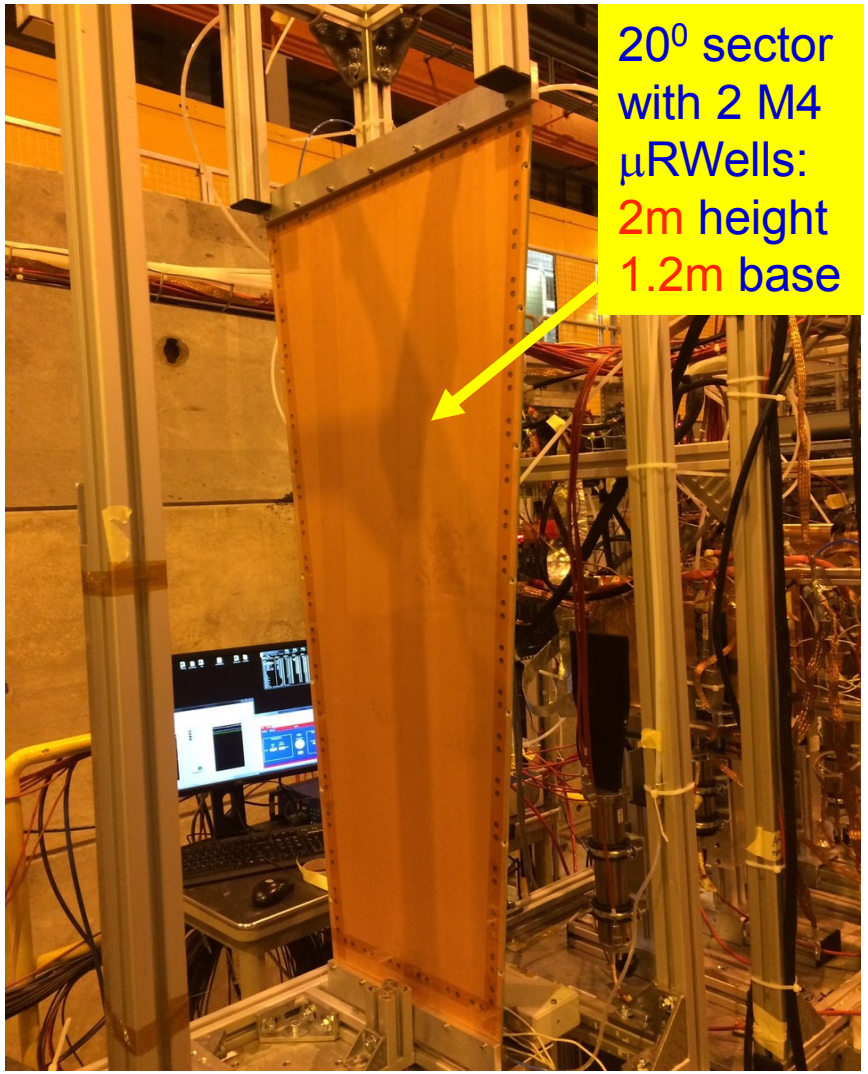

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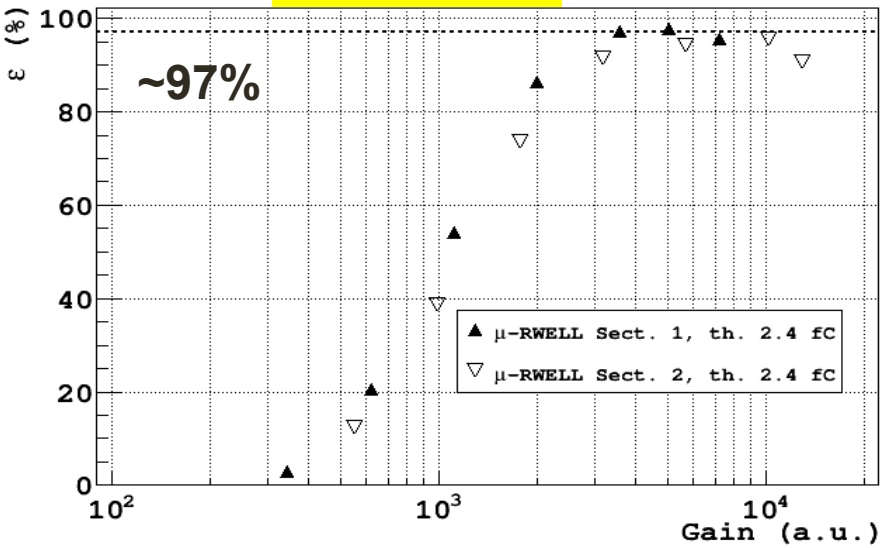

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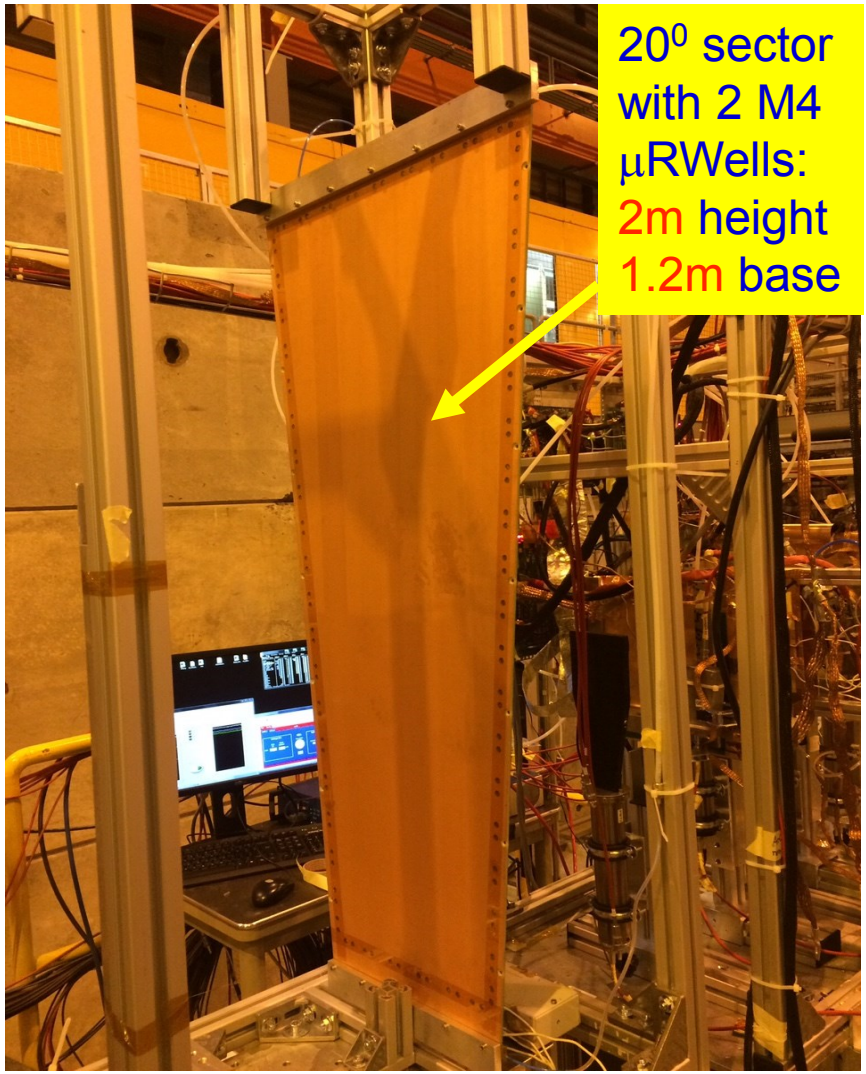

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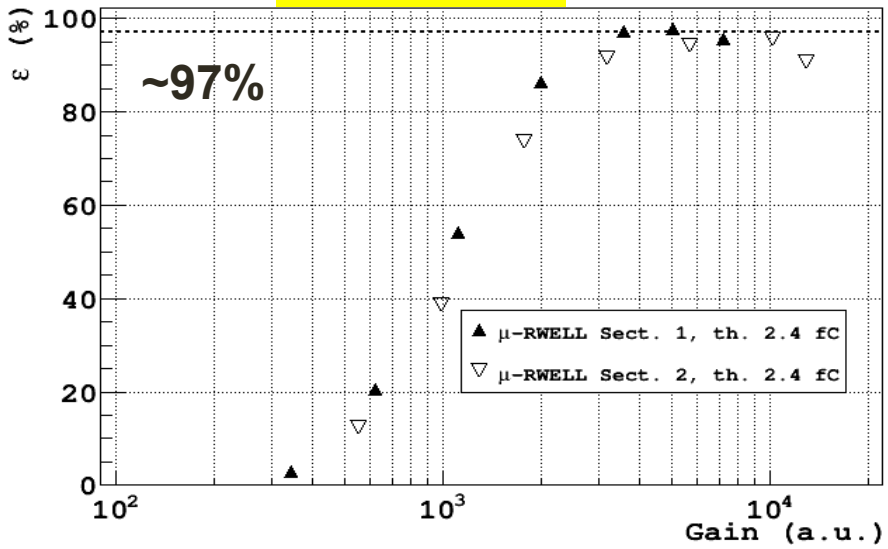
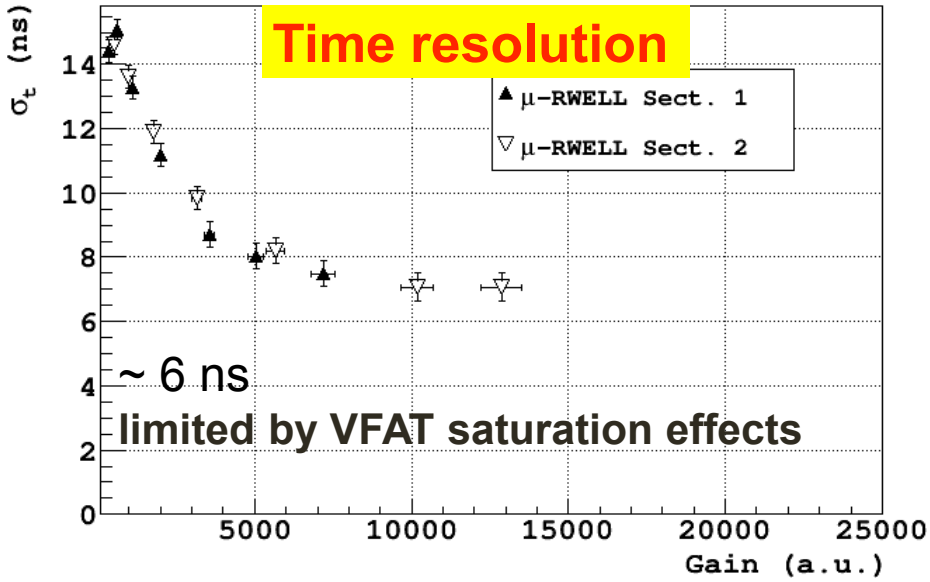


Time resolution



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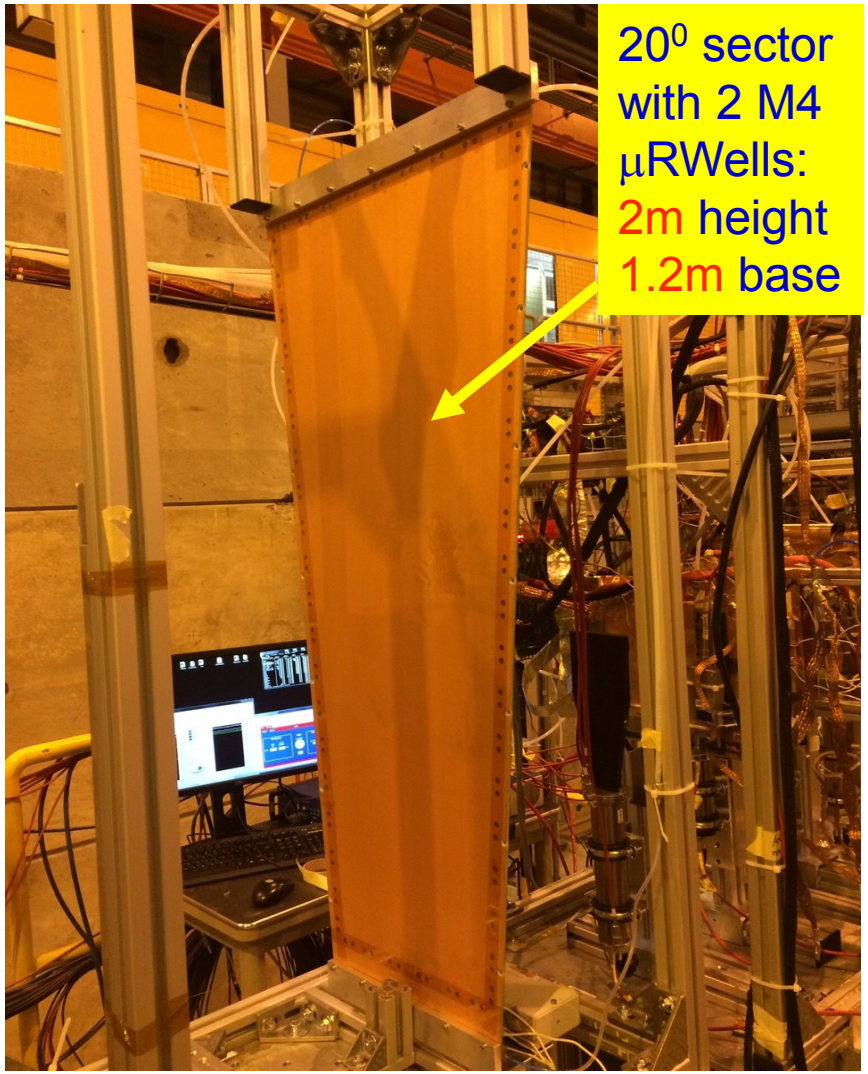

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- **Standalone muon momentum measurement**
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- **Capable of finer position resolution (~60μm) and high rate requirement (~100 kHz/cm^2) if needed**

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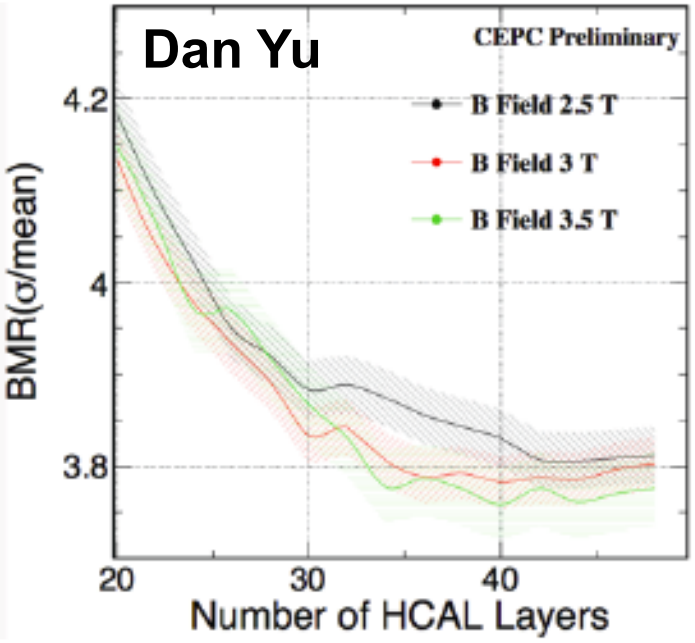
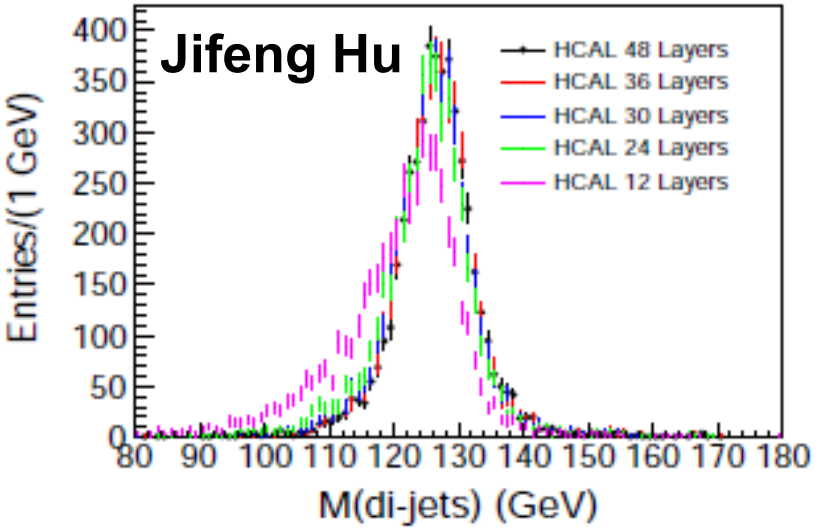
  - Detector R&D: study aging effects, improve long-term reliability and stability, improve massive and large area production procedures and readout technologies

Backup

Muon Detector Energy Compensation Study





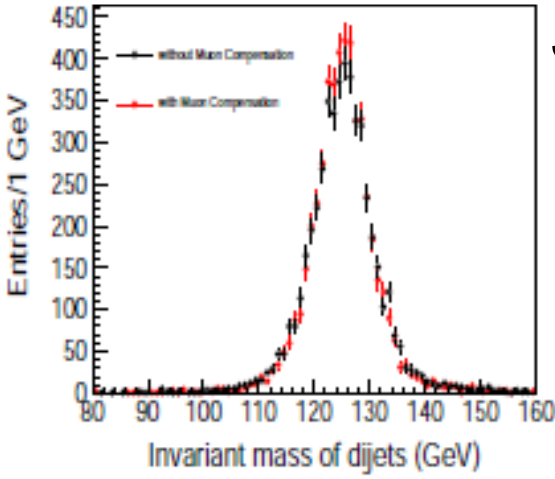
Example: simulation study using ZH->vvgg sample

HCAL outer layers unused

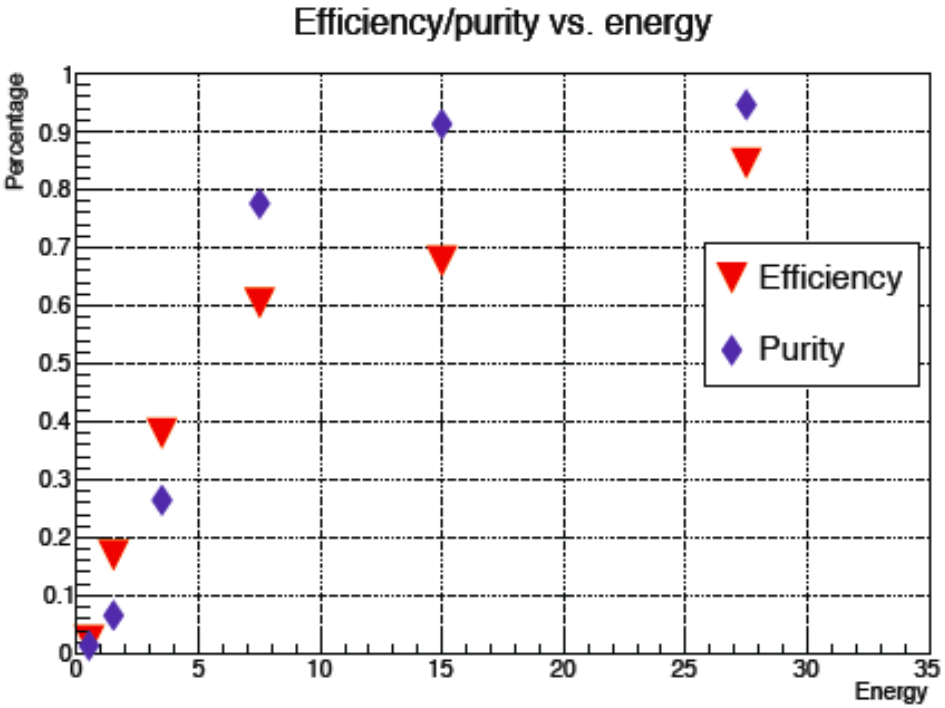
- **Optimized # of layer: 40**

Mass resolution effect small

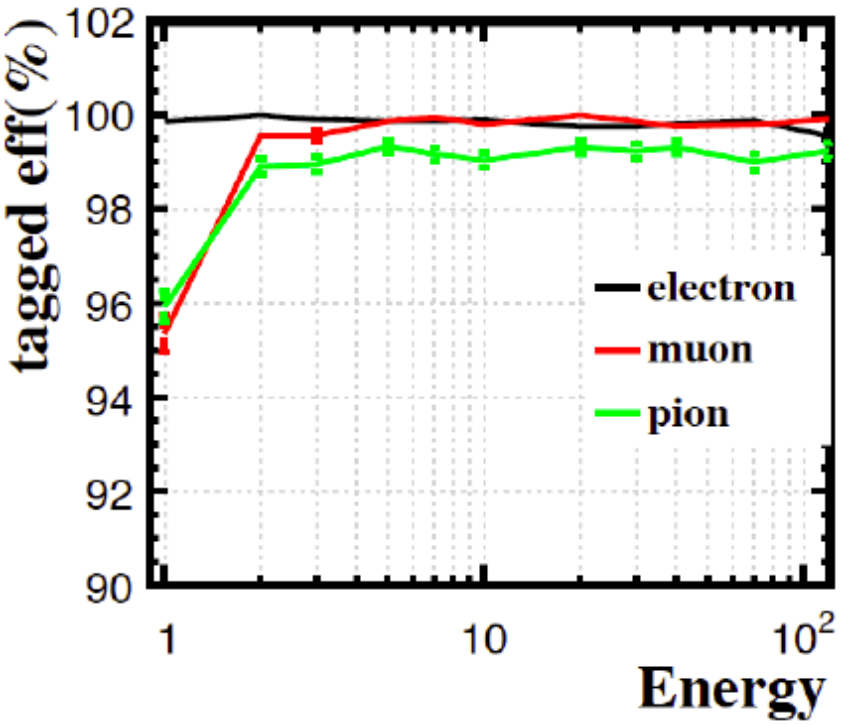
- **Energy compensation < 1GeV**



Non-isolated Muon ID Study



ZH->vvbb simulation study



Isolated simulation study