Muon Detector – Baseline Design

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Muon Detector Requirement

Identify muons with high efficiency:

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

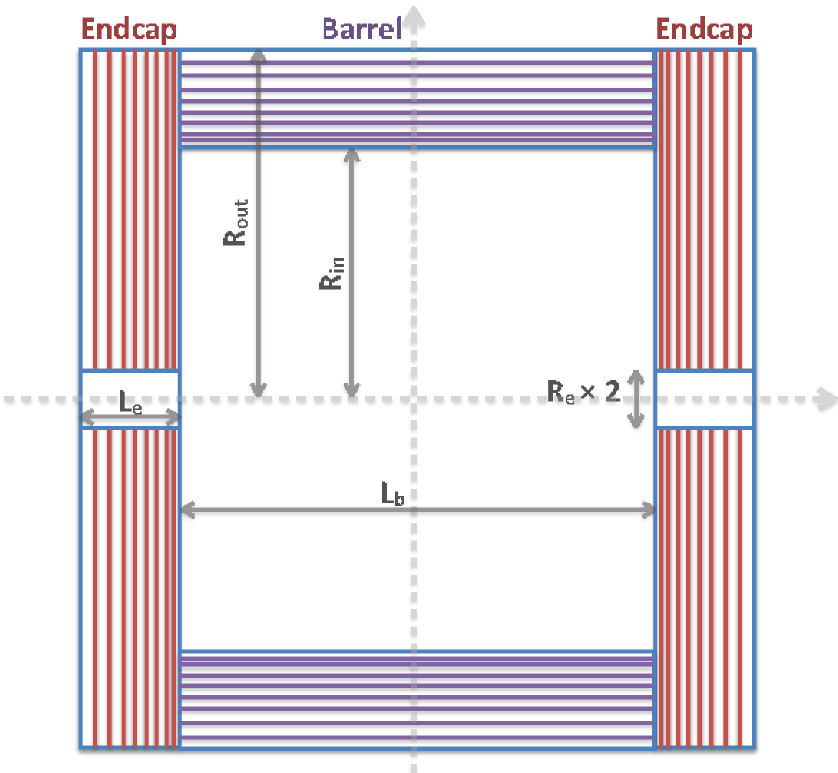
Standalone muon detector merits:

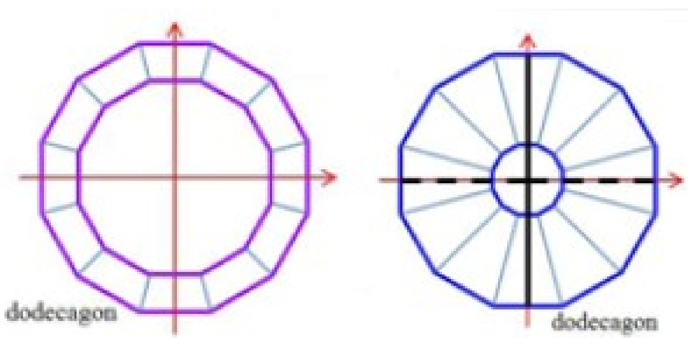
- Non-isolated muon identification, long-lived particle detection
- Provide complementary information together with calorimeter
- Robustness and redundancy

Technology:

- Bakelite/glass RPC [First talk]
- Many other options considered
  - μRWell [Second talk]
  - Micromegas, GEM
  - MDT, Scintillator Strip

Muon Detector Overview





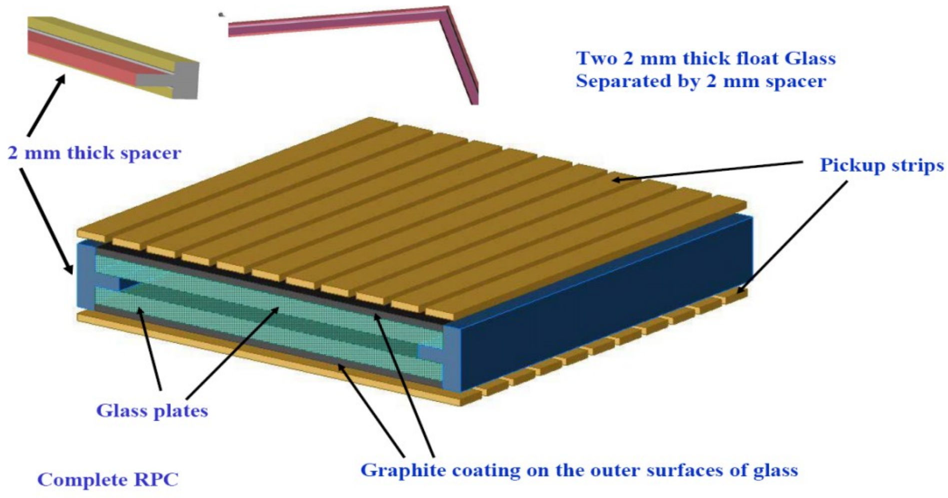
Structure:

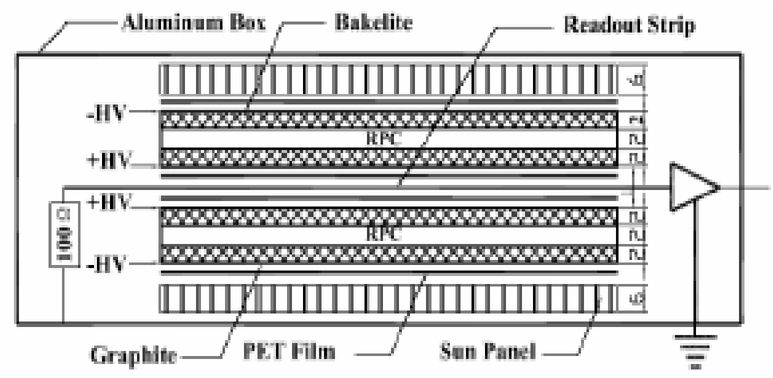
- **Between magnet iron yoke, outside HCAL**
- **Cylindrical barrel & two endcap system**
- **Solid angle coverage: 0.98 * 4π**

Two detector designs:

- **RPC as baseline**
- ***μ*RWell as alternative**

Baseline: RPC Option





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**

✓ **Low cost, easy construction**

✓ **Position resolution: 1-2 cm**

✓ **Time resolution: ~ 1 ns**

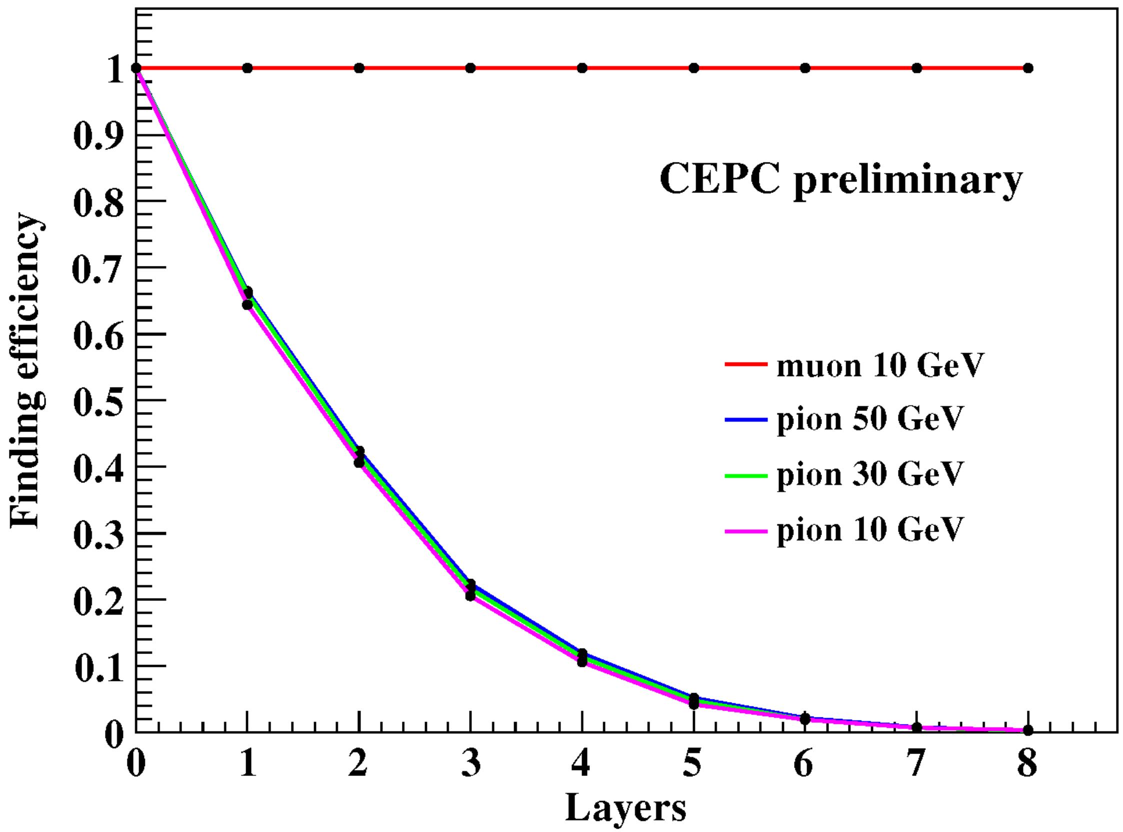
✓ **Rate capability: ~100 Hz**

Baseline: RPC Option

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: RPC Option



Full simulation sample not available yet

Preliminary study done with early simulations: simple geometry and simulation configuration setup

- **Pion fake rate depends on absorber length**
- **Muon efficiency high and stable**

Baseline Parameters

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 (λ = 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/cm²]	50 – 100	~60
Technology	RPC	RPC (super module, 1 layer readout, 2 layers of RPC)
	μRWell	
Total area [m²]	Barrel	~4450
	Endcap	~4150
	Total	~8600

More Simulation Studies

Muon system as an add-on

- Simulation study with built-in calorimeter / TCMT geometry, also integrated with yoke and magnet system
- Complementary to Calorimeter
  - Effect as a tail catcher / muon tracker (TCMT)
  - Simulation study suggest the level of improvement insignificant (depends on the energy deposited in the muon detector)

Non-isolated muon efficiency

- Simulation study using LICH (PFA) muon ID algorithm
- Check muons inside jets
  - Preliminary study using ZH->vvbb simulation samples sees lower efficiency than isolated case
    - For muon P_T > 10 GeV: 80% efficiency (95% purity)
  - Room for improvement
    - Tune PFA in harsh environment
    - Combine muon detector information

Conclusion and Future R&D

✓ CEPC muon detector conceptual design

- RPC chosen as the baseline design
- Baseline parameters meet physics requirements
- Mature and robust technique
- Low cost and easy construction

✓ Future R&D

- Combined identification study using both muon detector and calorimeter information
- Further layout and geometry optimization using full simulation samples
- Long-lived particles optimization
- Detector R&D: study aging effects, improve long-term reliability and stability, improve massive and large area production procedures and readout technologies

Backup

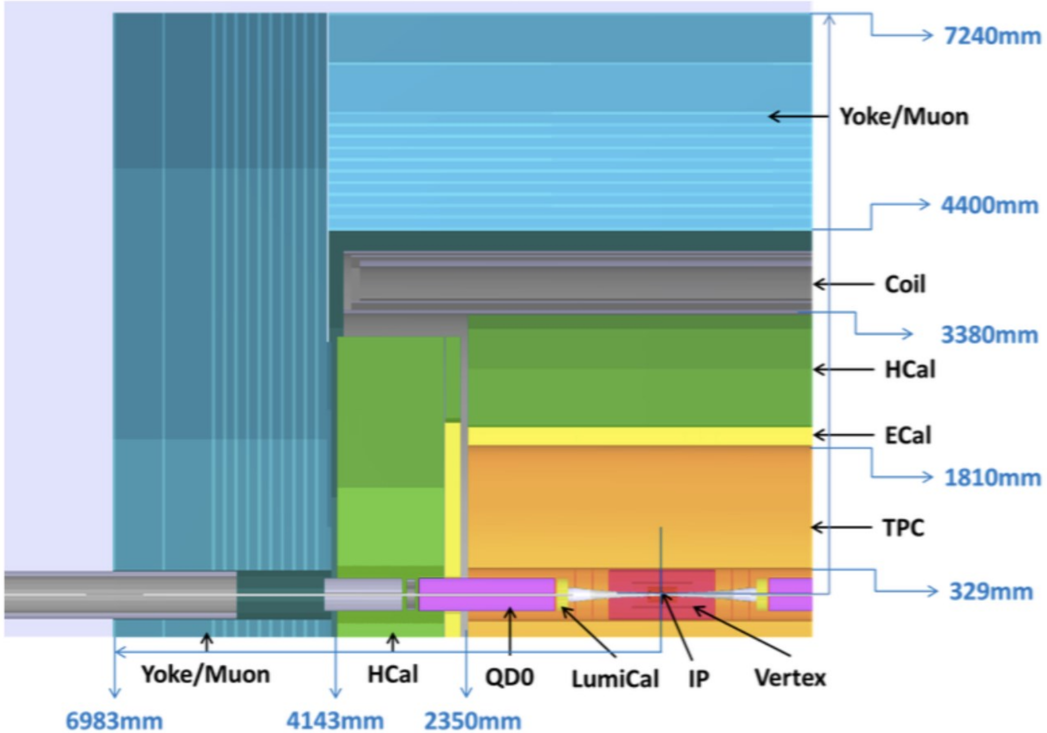
CEPC Detector Overview

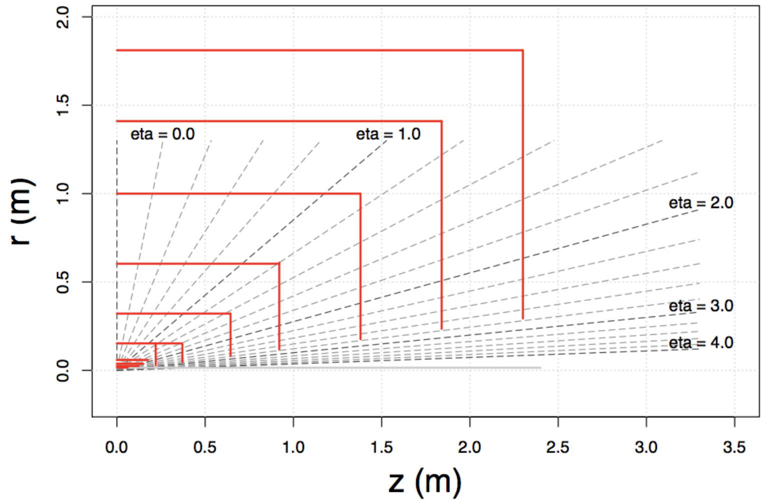
Baseline: ILD-like

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

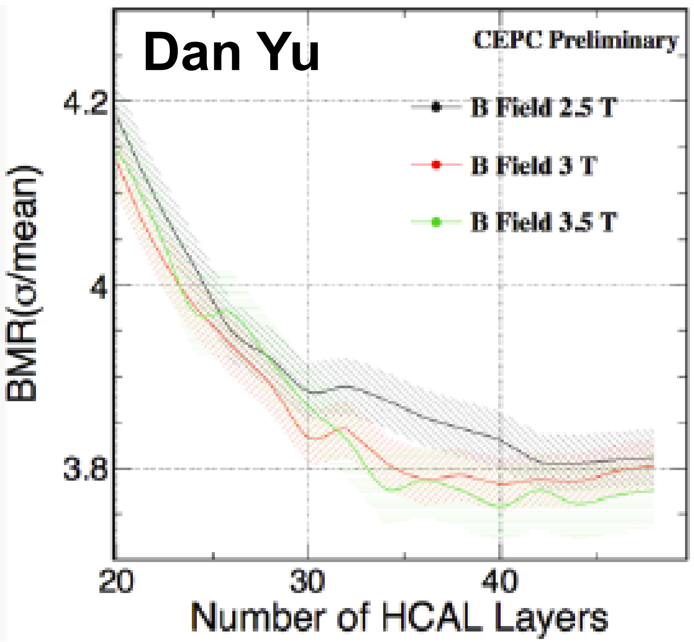
Alternatives

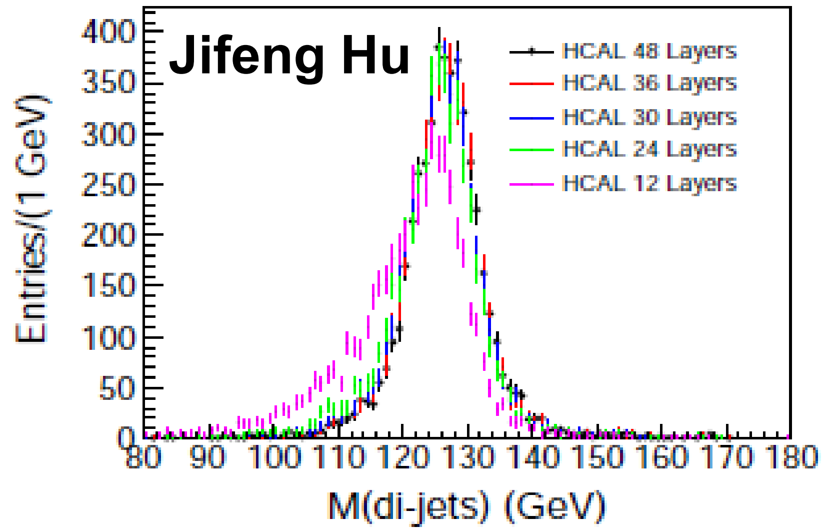
- Low-field concept
- Full-silicon concept





Energy Compensation





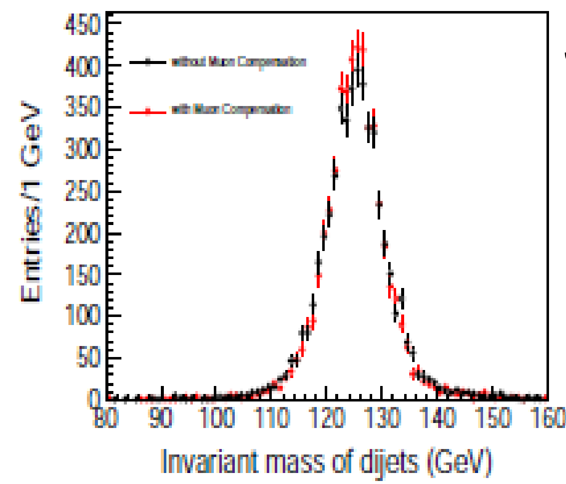
Example: simulation study using ZH->vvgg sample

HCAL outer layers unused

- **Optimized # of layer: 40**

Mass resolution effect small

- **Energy compensation < 1GeV**



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