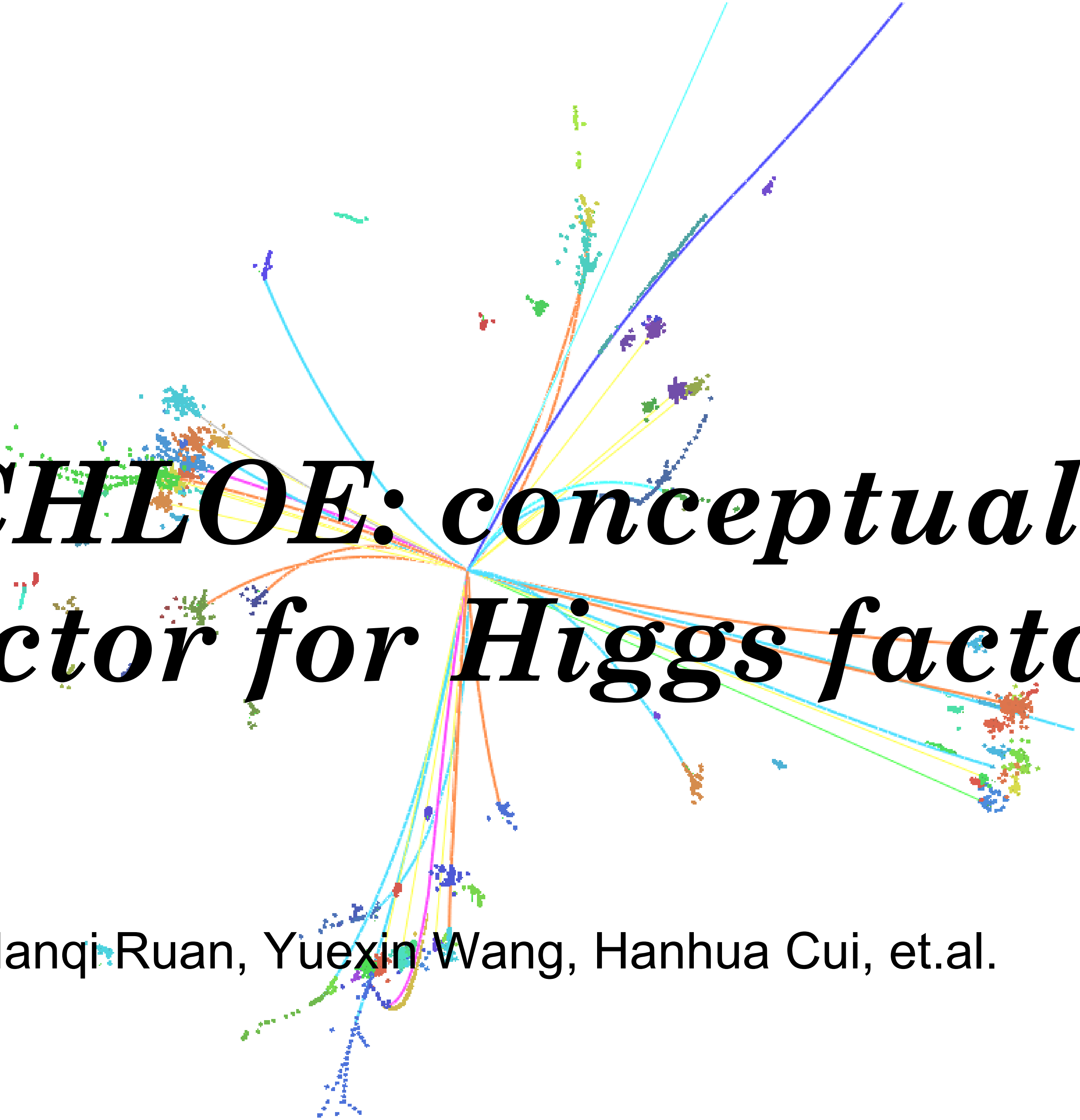
CHLOE: conceptual detector for Higgs factory



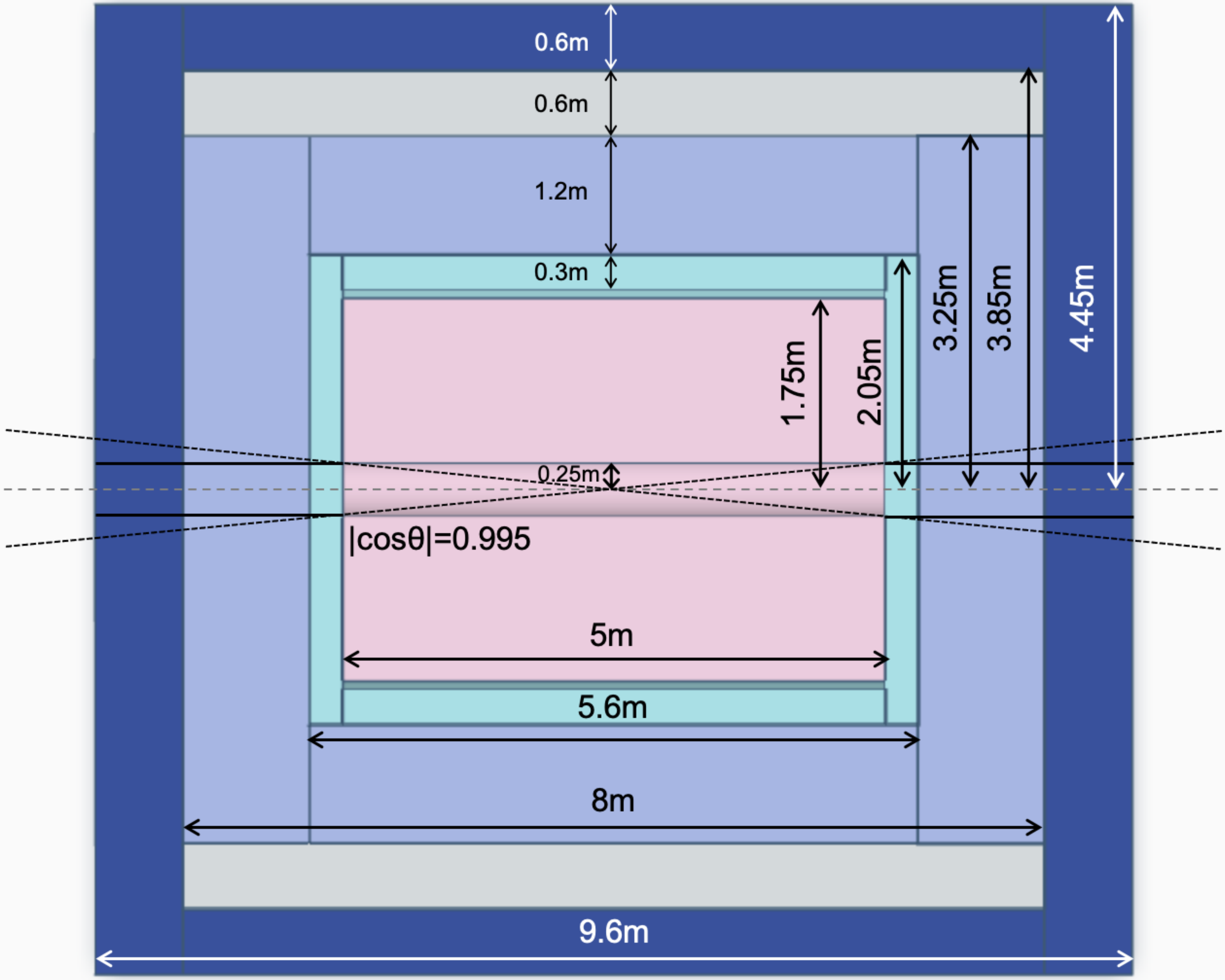
Manqi Ruan, Yuexin Wang, Hanhua Cui, et.al.

Outline

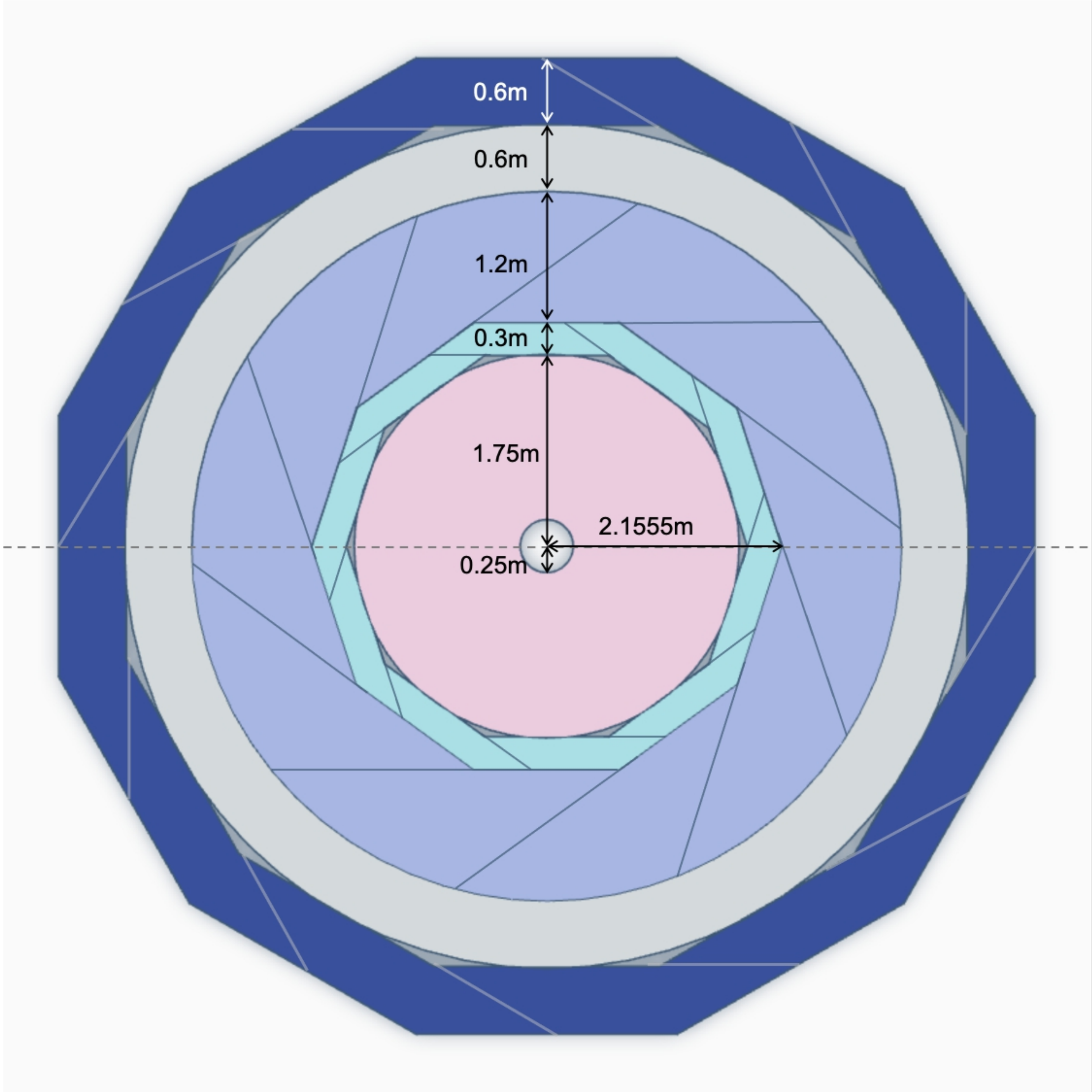
- Requirements
- CHLOE Concept
- Sub detector local geometry & technology
  - Calorimeter
  - Tracker
  - Vertex
- Global Geometry
  - R & Z of tracker
  - Polygon sides
- Challenges & Open questions
- Summary

Requirements

- Adequate to collision environment, especially the beam background
- Acceptance: |cos(theta)| > 0.99
- VTX:
  - Quantified by Migration Matrix (Eff*purity of b/c at Z pole: > 80% for b, > 50% for c)
  - delta(D0/Z0) ~ 5 micrometer, VTX inner radius ~ 10 mm
- Tracker:
  - dP/P ~ 0.1%;
  - Pt Threshold < 100 MeV;
  - Pid: charged Kaon reco. at eff/purity > 95% at inclusive hadronic events at Z pole;
    - 3% dE/dx or dN/dx
    - ToF 50 ps
- Calorimeter:
  - PFA compatible
  - EM: dE/E ~ 3%/sqrt(E), Photon Energy threshold ~ 100 MeV
  - BMR < 4% (to pursue **3%**), Neutral Hadron Energy threshold ~ 1 GeV



0.6m
0.6m
1.2m
0.3m
1.75m
2.05m
3.25m
3.85m
4.45m
0.25m
|cosθ|=0.995
5m
5.6m
8m
9.6m

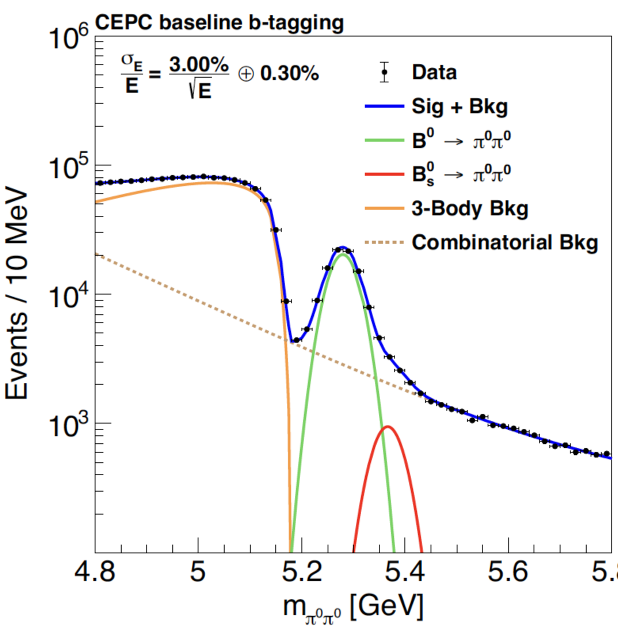

0.6m
0.6m
1.2m
0.3m
1.75m
2.1555m
0.25m

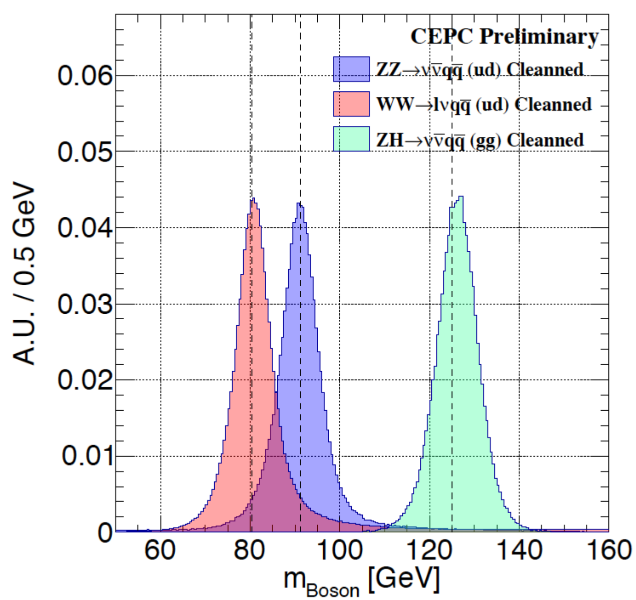
Characteristic designs

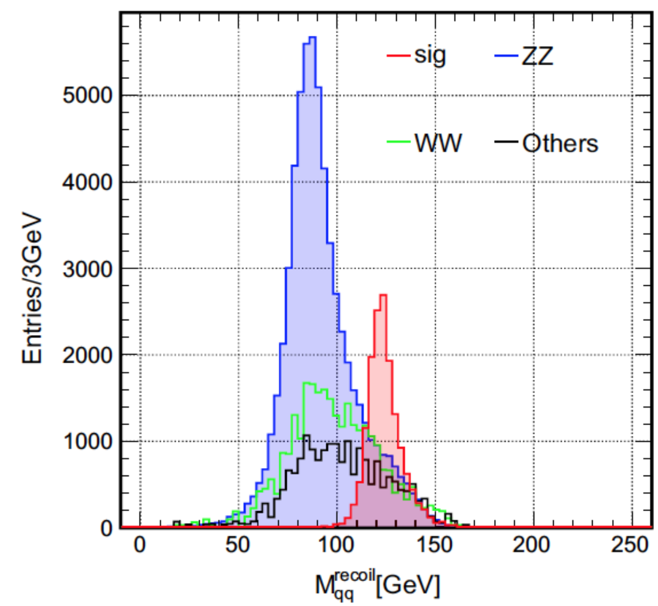
- Vin: vertex inside the beam pipe with inner radius ~ 10 mm
- Tracker:
  - Larger volume gaseous detector (inner/outer radius = 25/175 cm, Z = 500 cm) + Silicon External layer
- ECAL:
  - Xstal bar ECAL with 4 positioning-timing layers
  - Octagon configuration of inner boundary
- HCAL: High Density Scintillating Glass + Iron absorber
- Large volume Solenoid & Yoke to provide 2/3 T B-Field

Calorimeter requirements

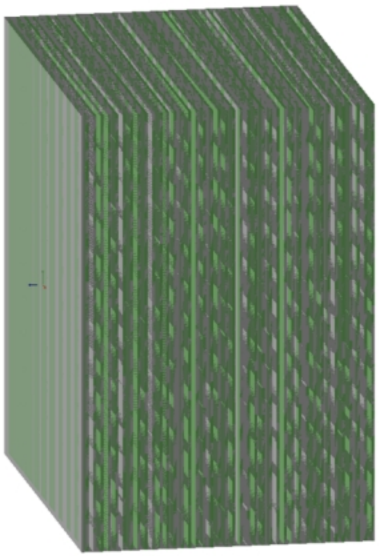
- Compatible with PFA: i.e., capable to reconstruct pi-0 inside jets.
- EM energy resolution: ~ 30 MeV @ B meson (Xstal)
- BMR: < 4% - pursue 3%

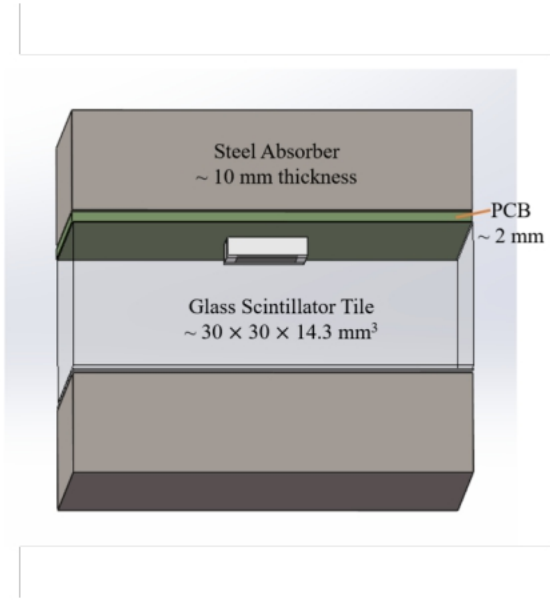


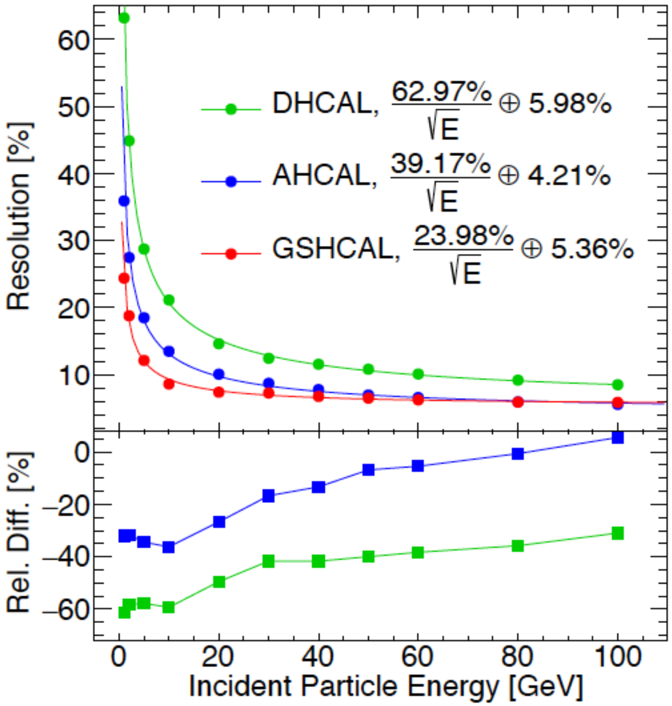




GSHCAL



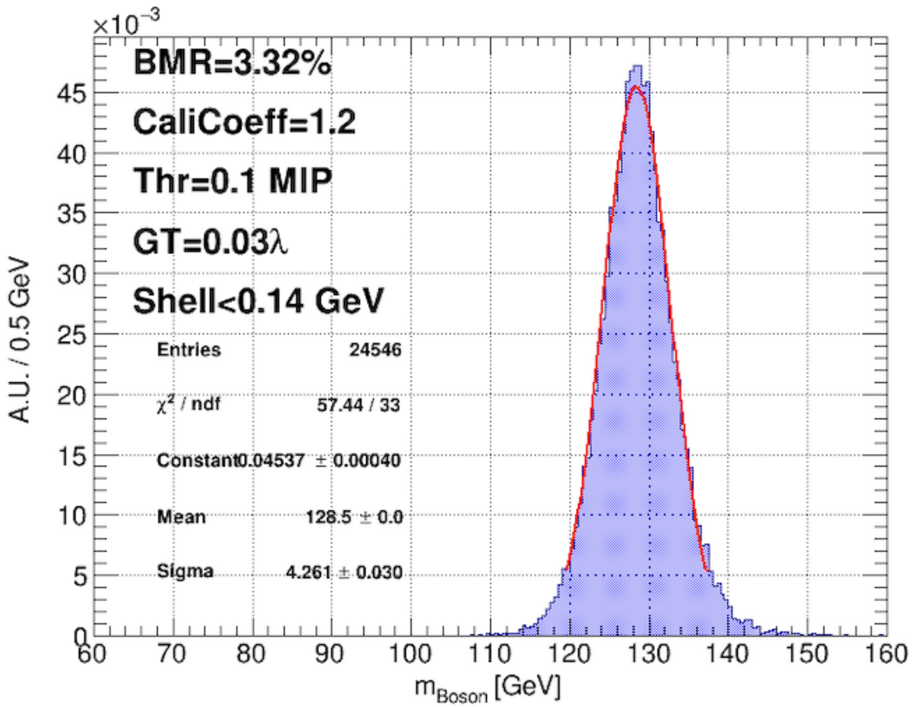


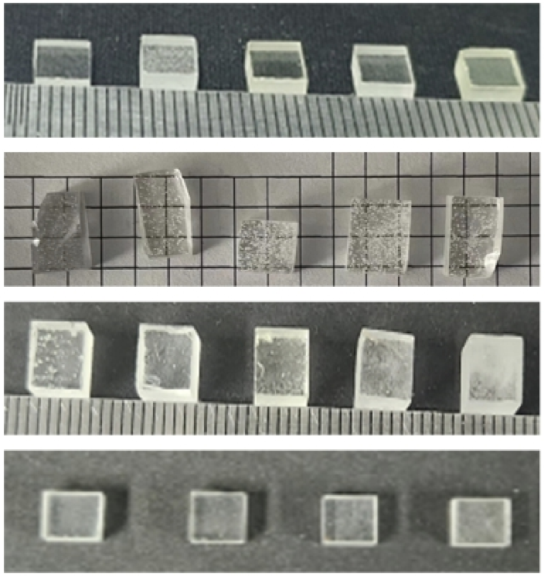


- Substantial improvement at Hadronic Energy resolution with relevant energy...

BMR wi GSHCAL

P. Hu & YX. Wang

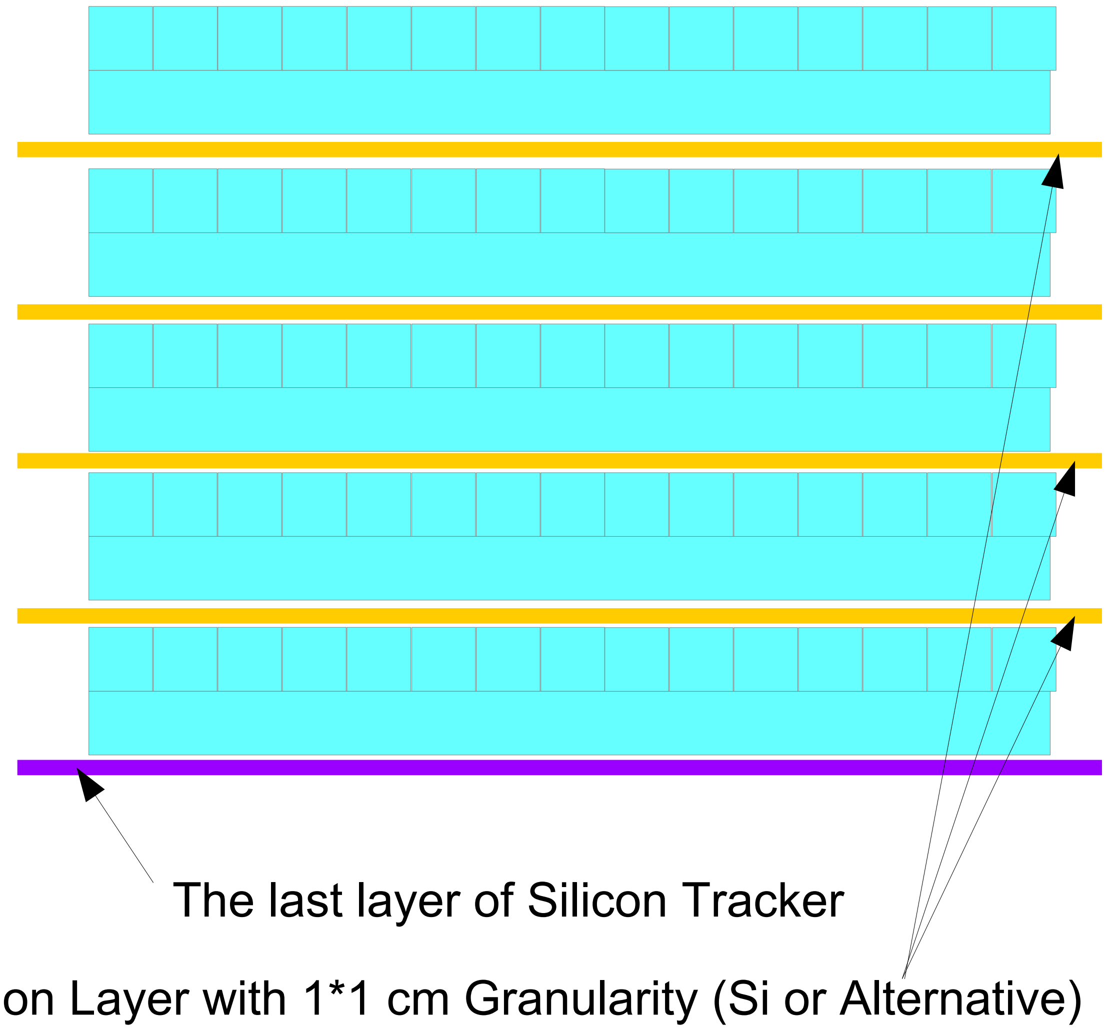




- Baseline + replace DHCAL to GSHCAL + Simple para. optimization
- ~ o(10)% improvement w.r.t. DHCAL

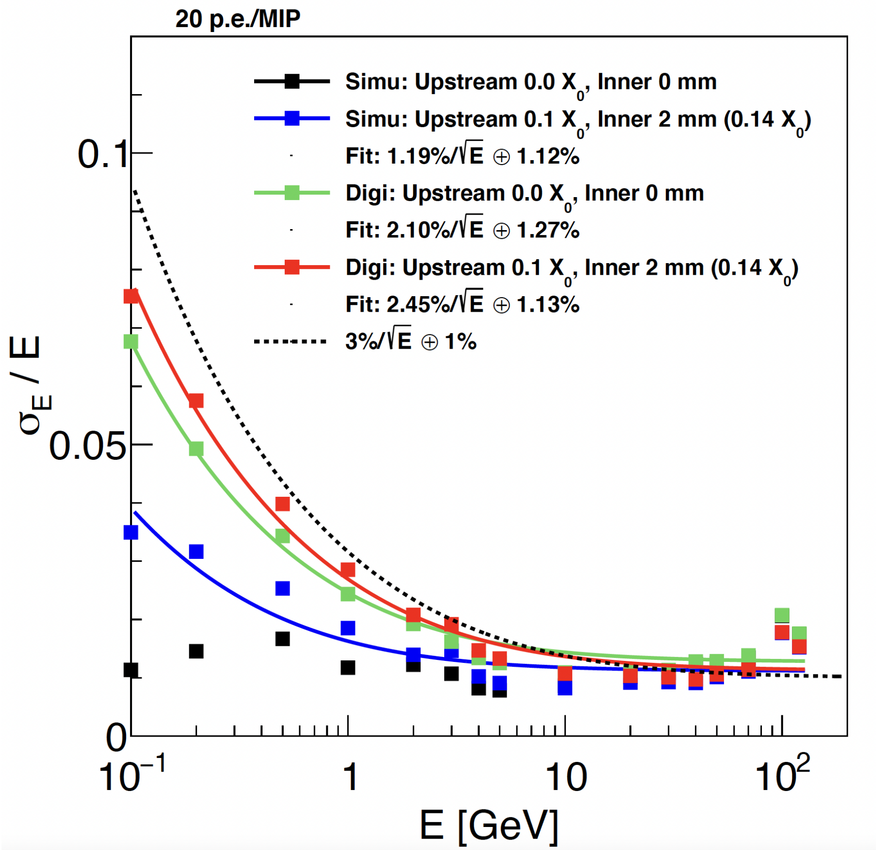
ECAL: Crystal + Position/timing layer

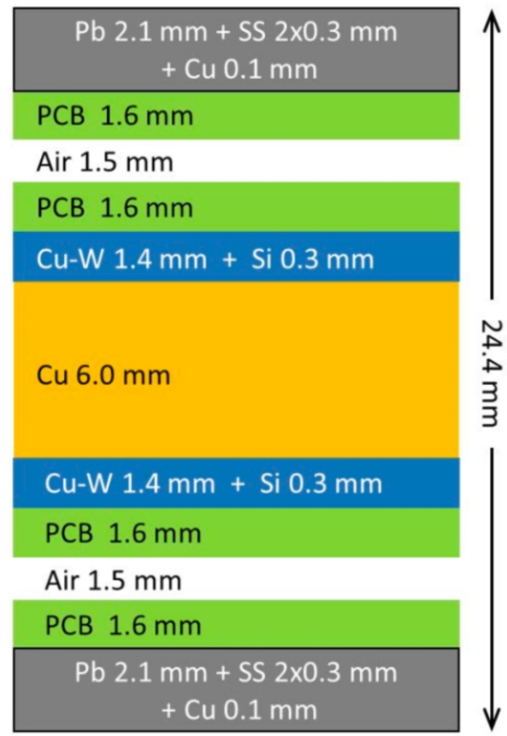
- Geometry
  - Total Crystal Volume: 23.3 m^3
  - Single Crystal Bar Dimension: 2.67cm * 2.67cm * 40cm = 291 cc, In total 80k bars
  - Inner Area: 80 m^2
  - Total Readout Channel:
    - 80000*2 = 160k (Crystal)
    - 800000*4 = 3.2 M (Si)
- Performance
  - EM resolution
  - Anticipated BMR
  - Timing



*Compared to 1*1*40 cm crystal bars*
With in total 570 k bars and 1.14 M readout

EM resolution





CMS HGC Project:

600 m^2 Si + 300 m^2 Sci

Total cost:
69 M CHF ~ 500 M CNY

~~

CEPC:

~ 300 m^2 Positioning Layer

~ o(100) M CNY

- Positioning layer: material budget of ~ 0.2 X0 (3 mm Cu), fraction < 3%
- Compatible with CMS HGC Silicon layer wi cooling; which has much higher data rate & requirement on energy reco. -> further optimization is possible

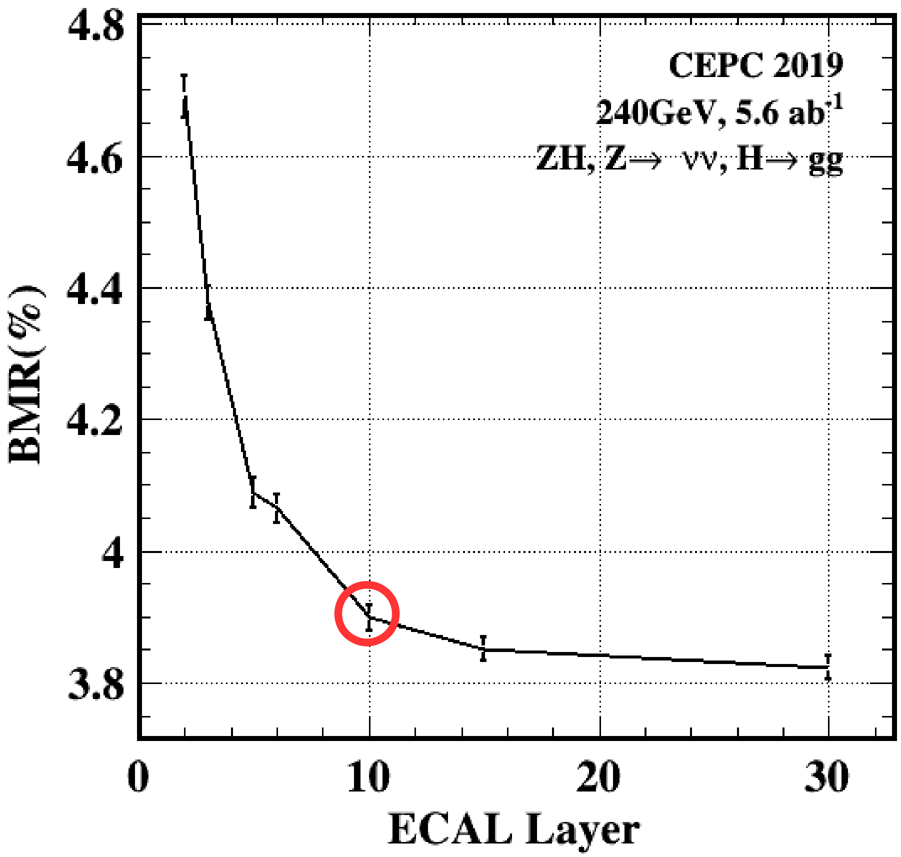
BMR

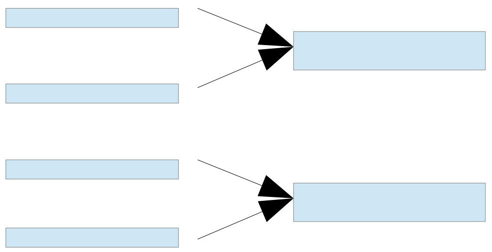
- Optimization study at Baseline – Merge Hits of neighboring layers in longitudinal direction. Compared to 30 Si-W layers, 10 layers has a relative degrading of 2% (3.82 → 3.9)

- 5 double-layers + 4 silicon sensors + advanced algorithm shall comparable to 10 layers... if not better

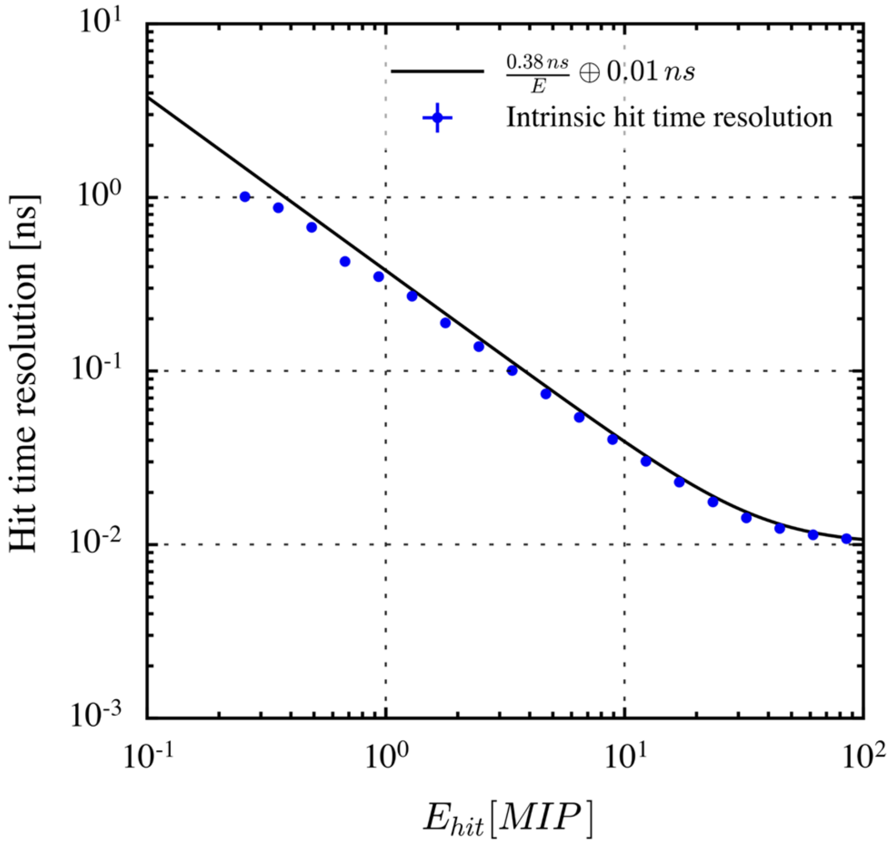
- Better EM resolution of Xstal ECAL has positive impact on BMR

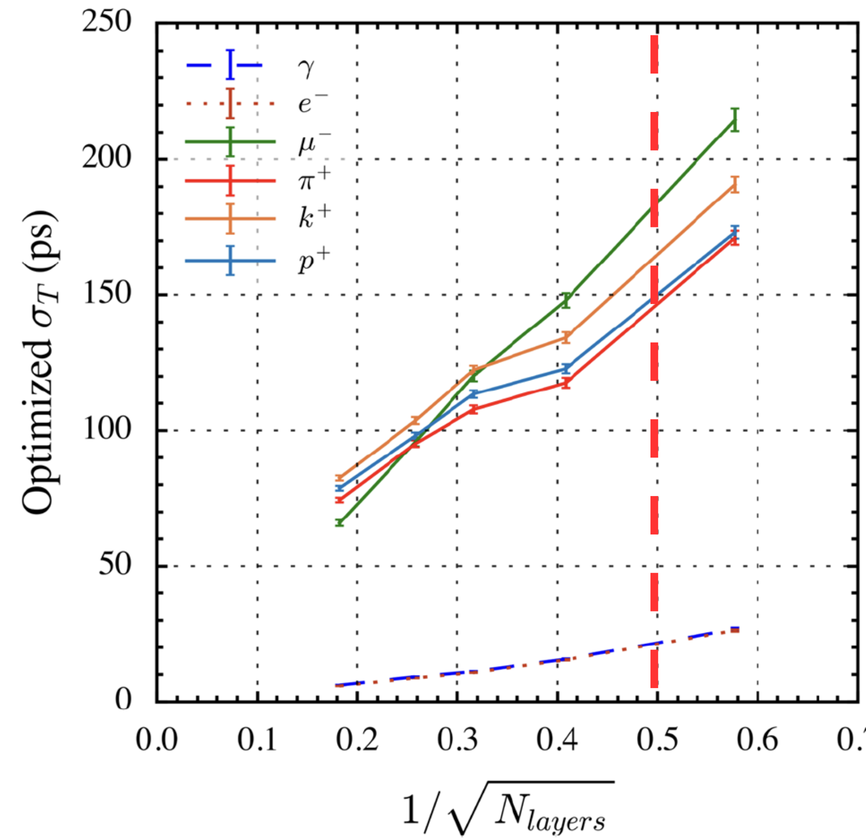
- BMR shall be comparable to baseline





Timing

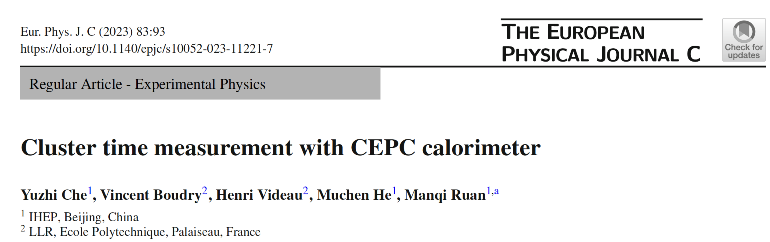




4 CMS HGC layers: time resolution for 10-15 GeV particles:

150-160 ps for hadron shower

20 ps for EM shower



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THE EUROPEAN PHYSICAL JOURNAL C
Regular Article - Experimental Physics

Cluster time measurement with CEPC calorimeter

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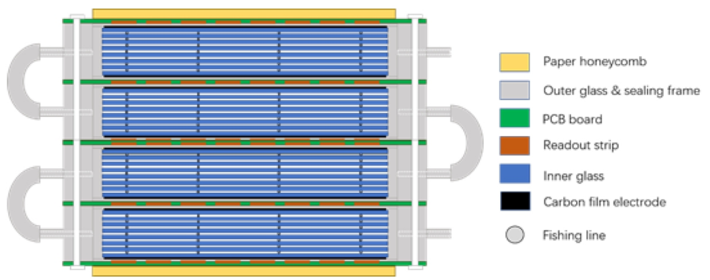
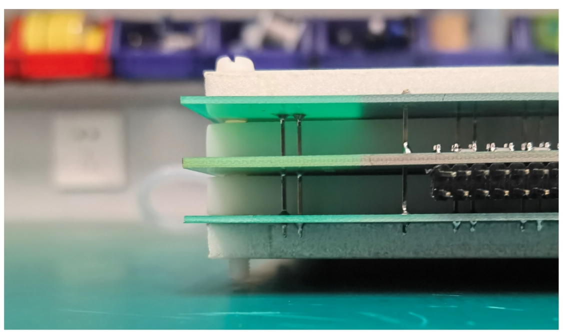
Precision Cluster timing is critical to dealing with in time leakage & Off time pileup effects

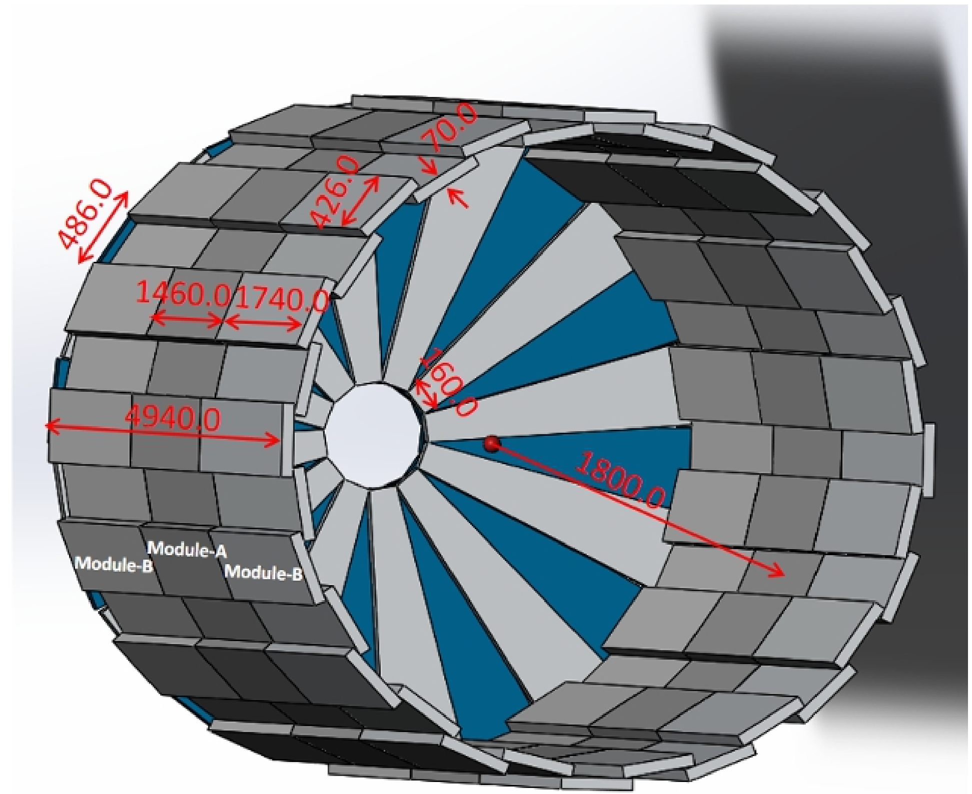
Alternative choice of positioning layer



(a) Structure of sealed MRPC.



(b) Sealed MRPC in kind.

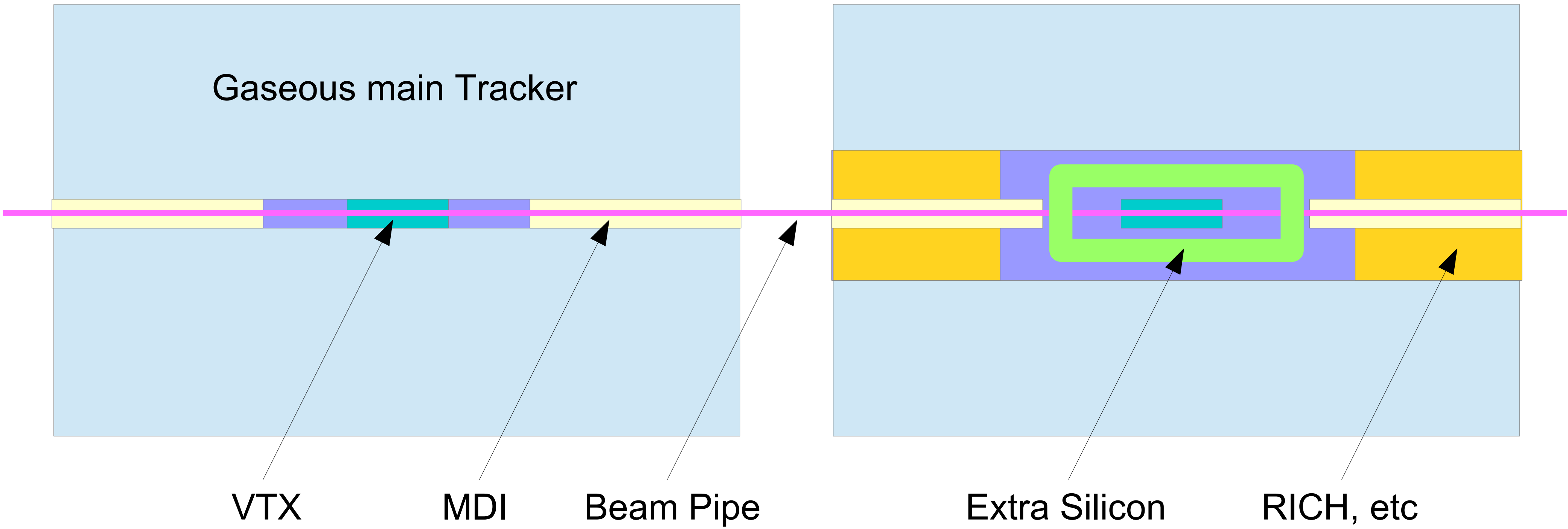


- MRPC: 35 M CNY for 1 layer, with 35 ps time resolution & area ~ 80 m^2
- Geo. & Readout need to be optimized, to integrate with ECAL.

Tracker & Vertex

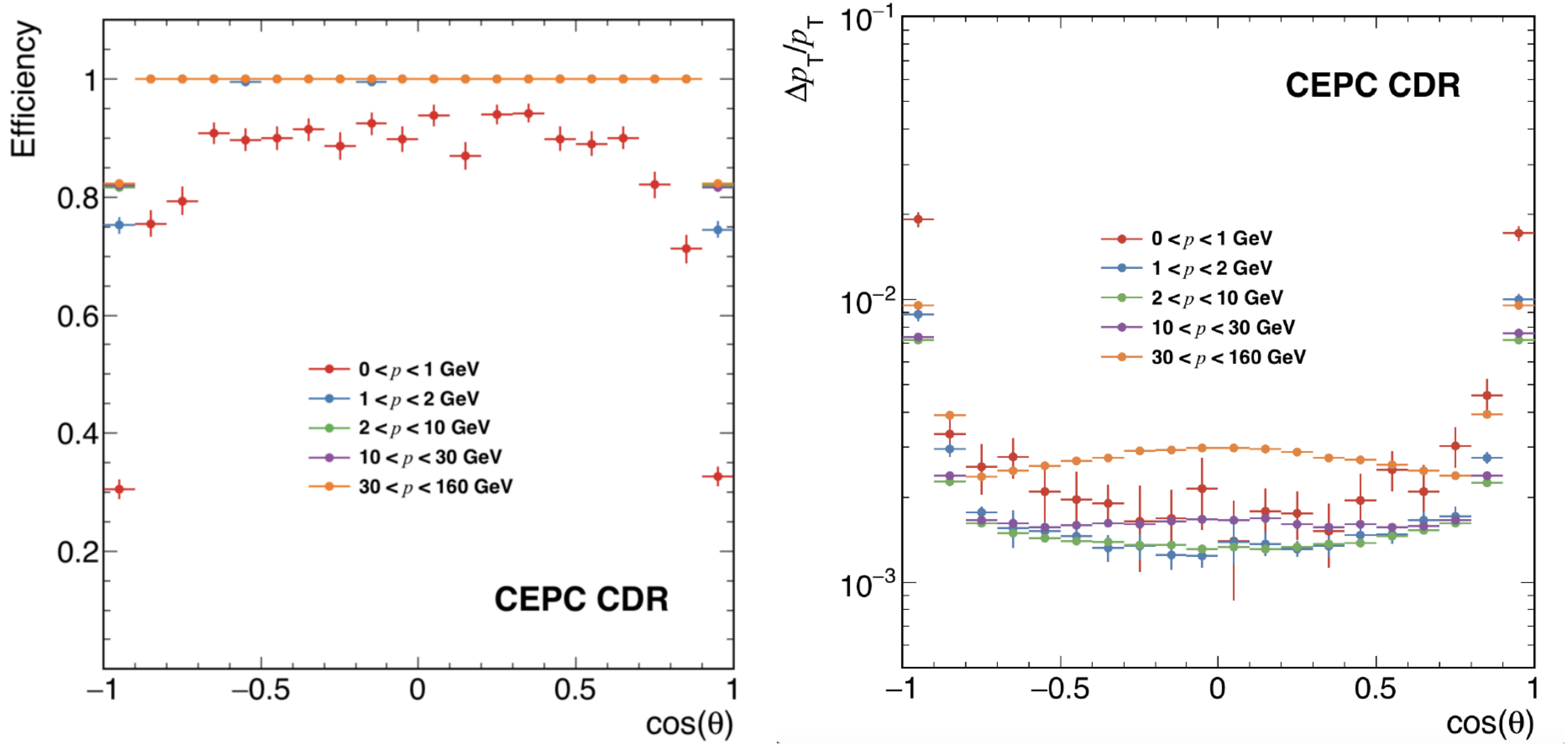
- Performance always requires:
  - Smaller R_{in} : limited by Beam background/Beamstrahlung & MDI
    - Large acceptance
    - VTX: ~ better 2nd Vertex & Flavor tagging
    - Tracker: better differential Pid (especially fwd), lower Pt threshold
  - Large R_{out} : limited by cost
    - Better momentum resolution,
    - Better Pid,
    - Better separation, better BMR

2.5 Tracker Scenarios



- Our understanding to Beam background & MDI design not fully converged
  - Beamstrahlung background seems to be very challenge to gaseous tracker
- I will discuss mainly the 1st scenario (Left)：
  - Tracker inner radius of 25 cm to have good Pid in fwd region
- The 2.5 scenario: Silicon Tracker with Pid (like AMS, with much better precision...): *impossible??*

Tracker: tracking

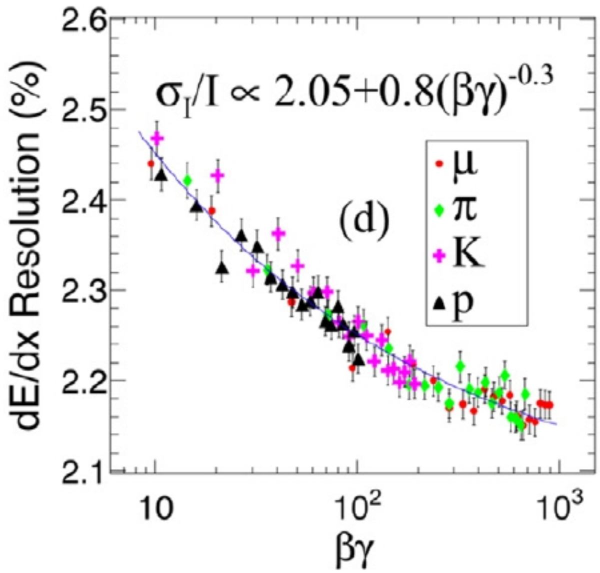


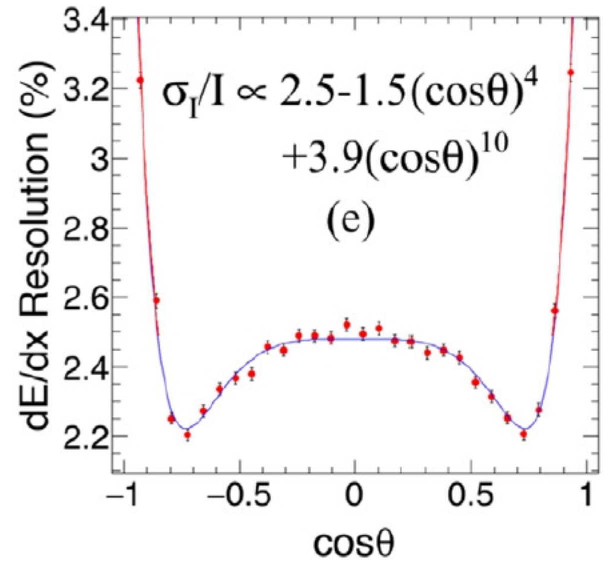
(a) (b)

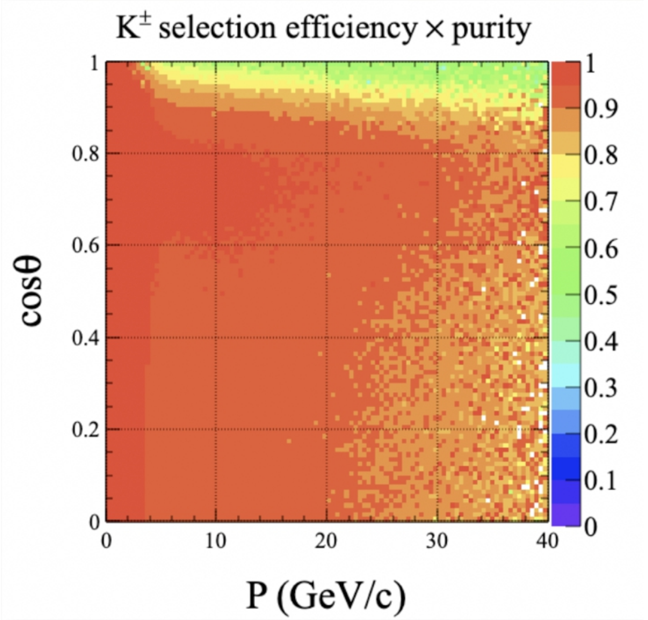
Figure 10.3: Single track reconstruction: (a) efficiency and (b) momentum resolution as a function of the cosine of the polar angle in different momentum bins.

...Scaled as BR^2...

Tracker: Pid







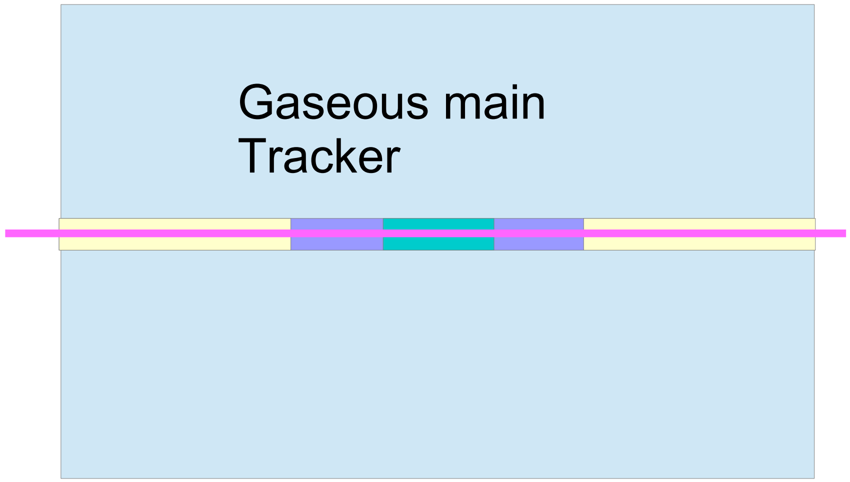


Table 3
The $K^{\pm}$ identification performance with different factors, $\sigma_{actual} = factor \cdot \sigma_{intrinsic}$, with/without combination of TOF information at the Z-pole.

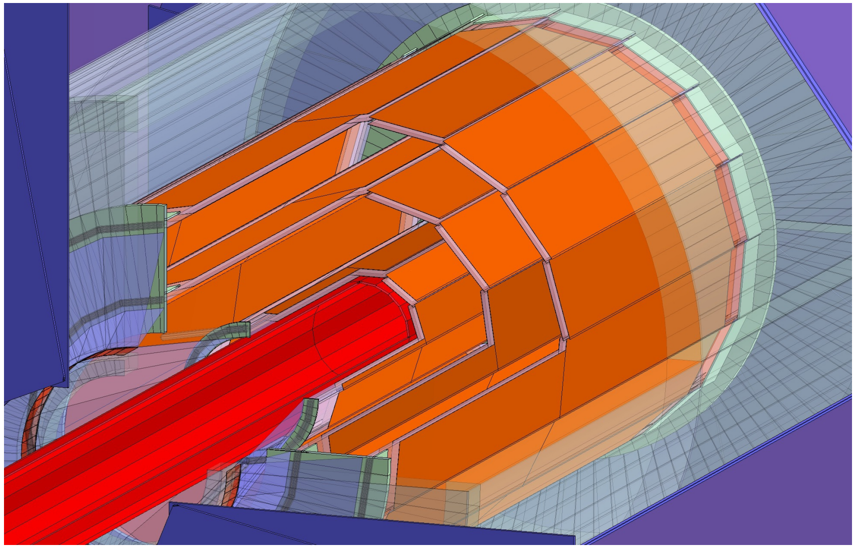
	Factor	1.	1.2	1.5	2.
dE/dx	ε_K (%)	95.97	94.09	91.19	87.09
	$purity_K$ (%)	81.56	78.17	71.85	61.28
dE/dx & TOF	ε_K (%)	98.43	97.41	95.52	92.3
	$purity_K$ (%)	97.89	96.31	93.25	87.33

- Pid via dEdx or dNdx: better than 3% in barrel region for GeV level hadron
- Inner radius of TPC in baseline: 30 cm
- Reducing inner radius is strongly favored in fwd region

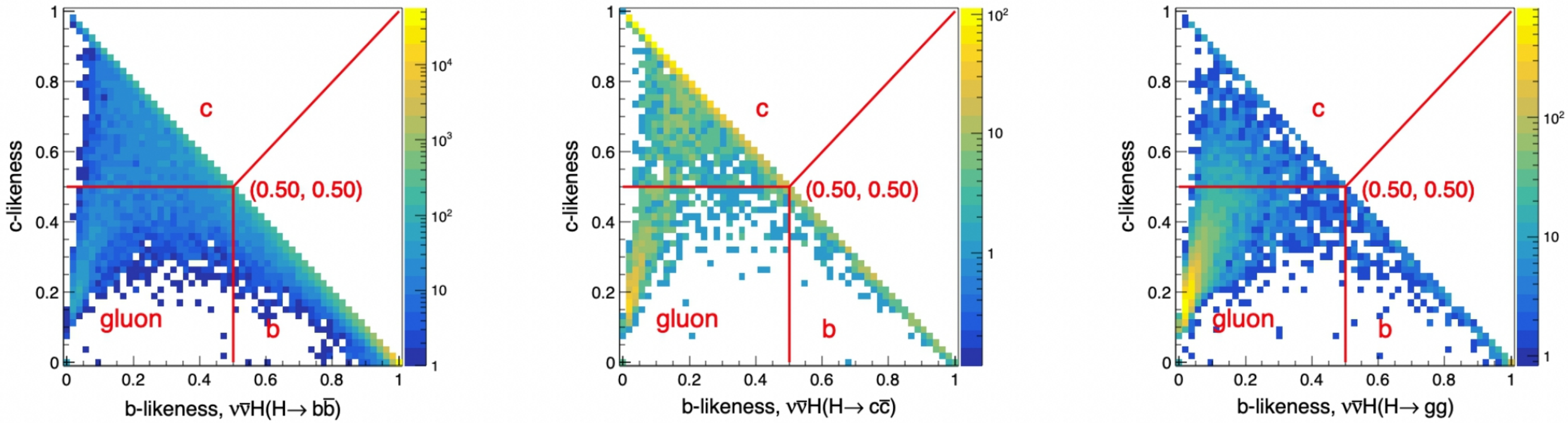
Vertex

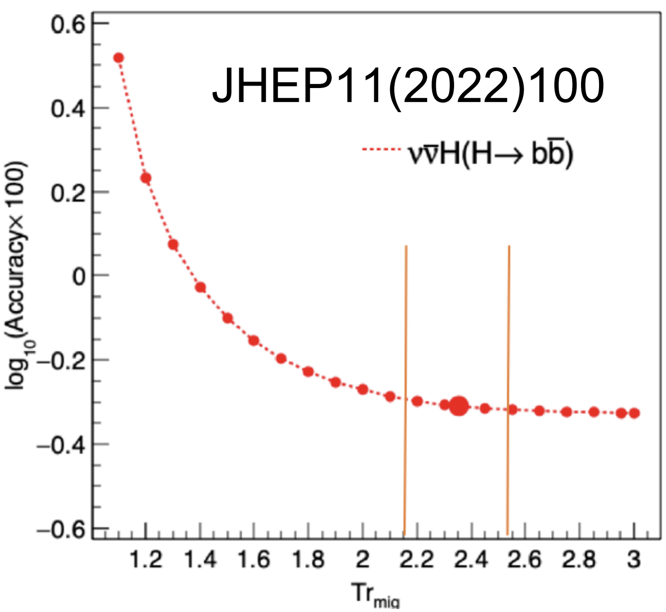
- Closer, Thinner, Preciser w.r.t. Baseline
- 3 Scenarios
  - Smaller radius: 10 mm inner radius
  - **Vin (Vertex inside): innermost layer inside Beam pipe**
  - Vin portable: Movable innermost layers inside beam pipe

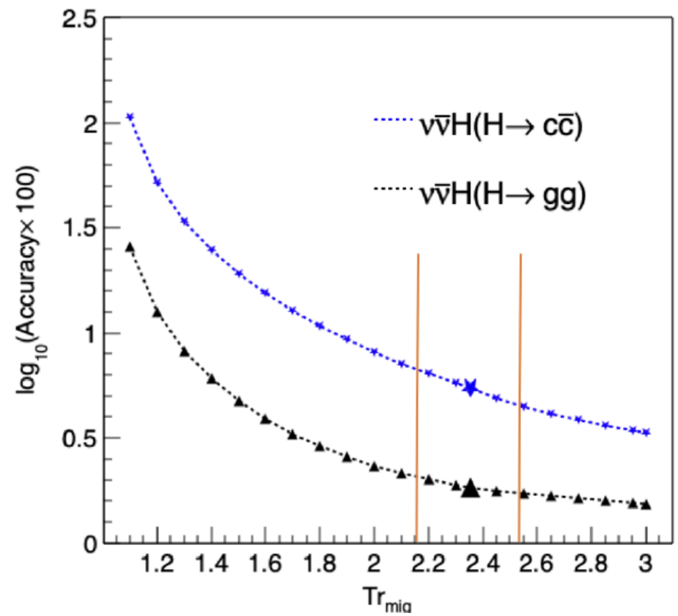
	R(mm)	Z(mm)	single-point resolution(μm)	material budget
Layer 1	16	62.5	2.8	$0.15\%/X_0$
Layer 2	18	62.5	6	$0.15\%/X_0$
Layer 3	37	125.0	4	$0.15\%/X_0$
Layer 4	39	125.0	4	$0.15\%/X_0$
Layer 5	58	125.0	4	$0.15\%/X_0$
Layer 6	60	125.0	4	$0.15\%/X_0$



Vertex performance & Impact on benchmark



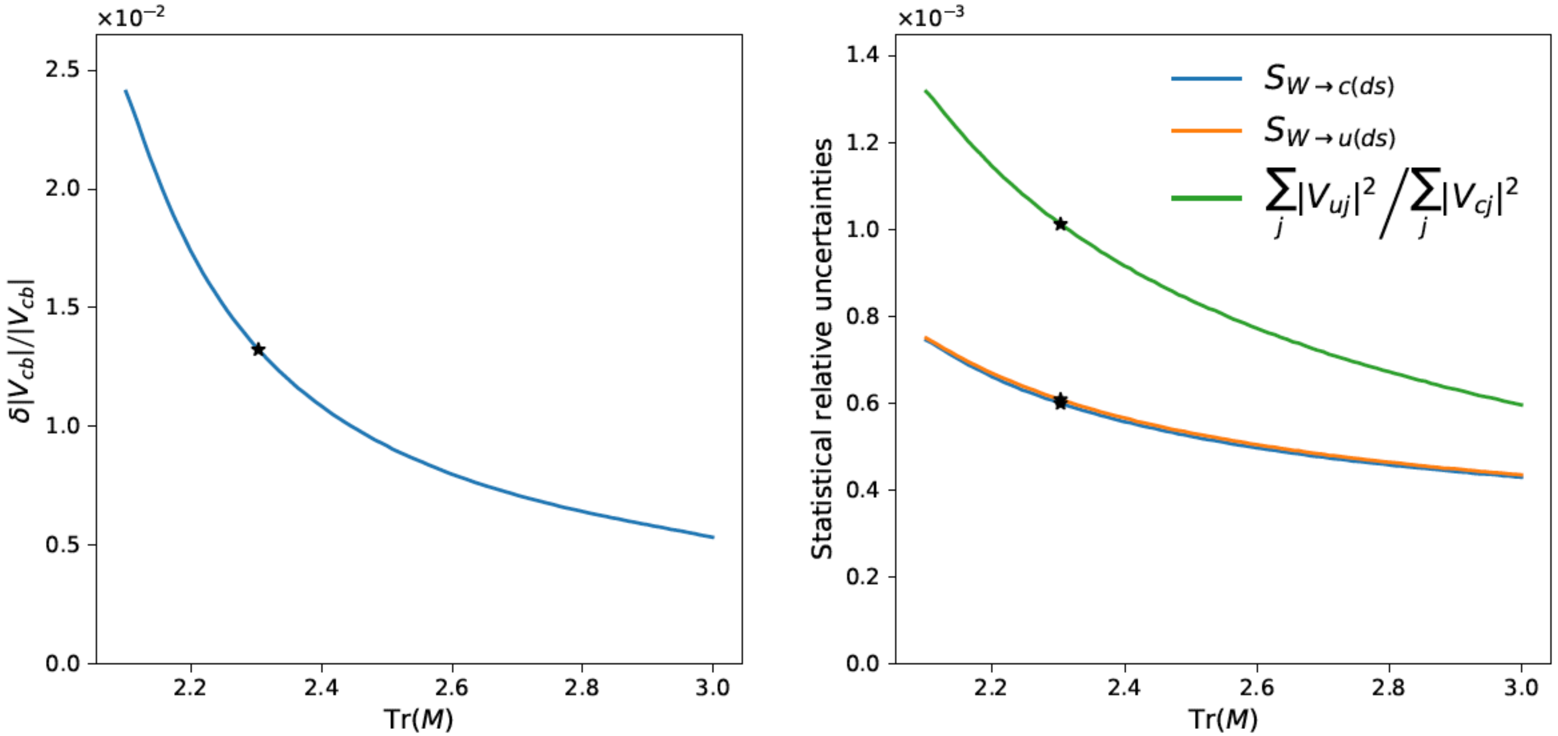




true \ identified as	b	c	g
b	0.8675	0.0887	0.0437
c	0.1136	0.6263	0.2601
g	0.0411	0.1007	0.8582

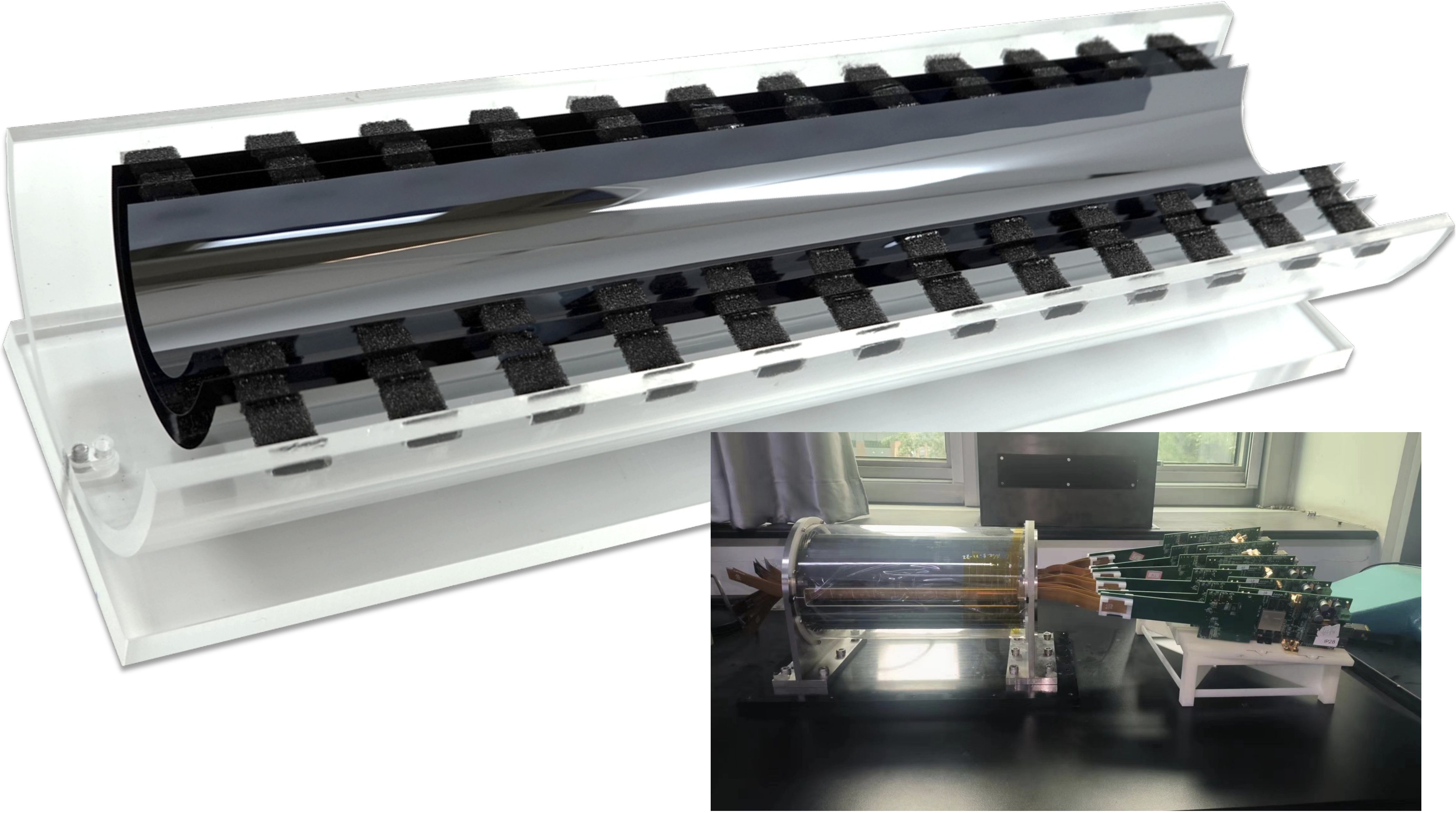
$$Tr_{\text{mig}} = 2.35 + 0.05 \cdot log_2 \frac{R^0_{\text{material}}}{R_{\text{material}}} + 0.04 \cdot log_2 \frac{R^0_{\text{resolution}}}{R_{\text{resolution}}} + 0.10 \cdot log_2 \frac{R^0_{\text{radius}}}{R_{\text{radius}}}.$$

Vertex

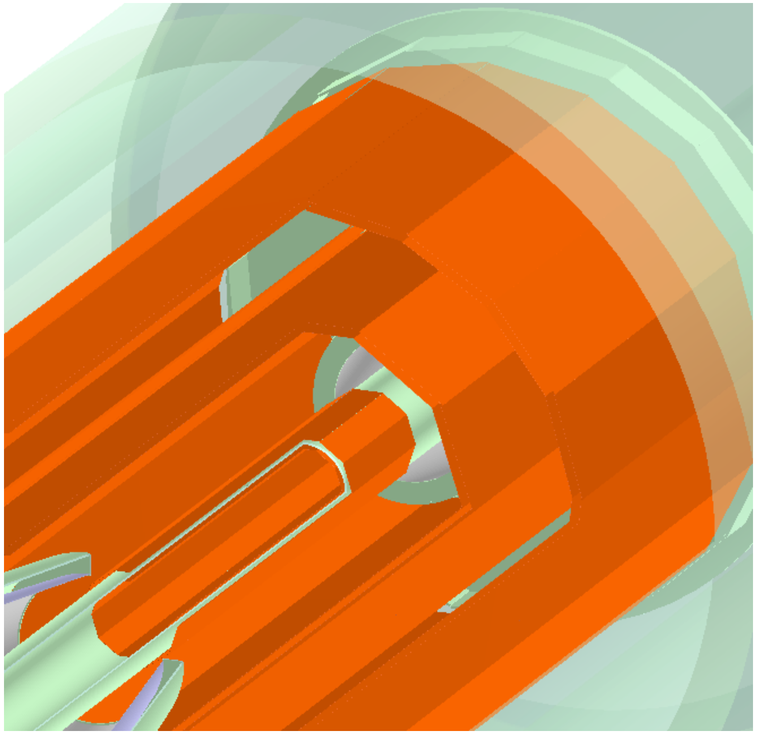


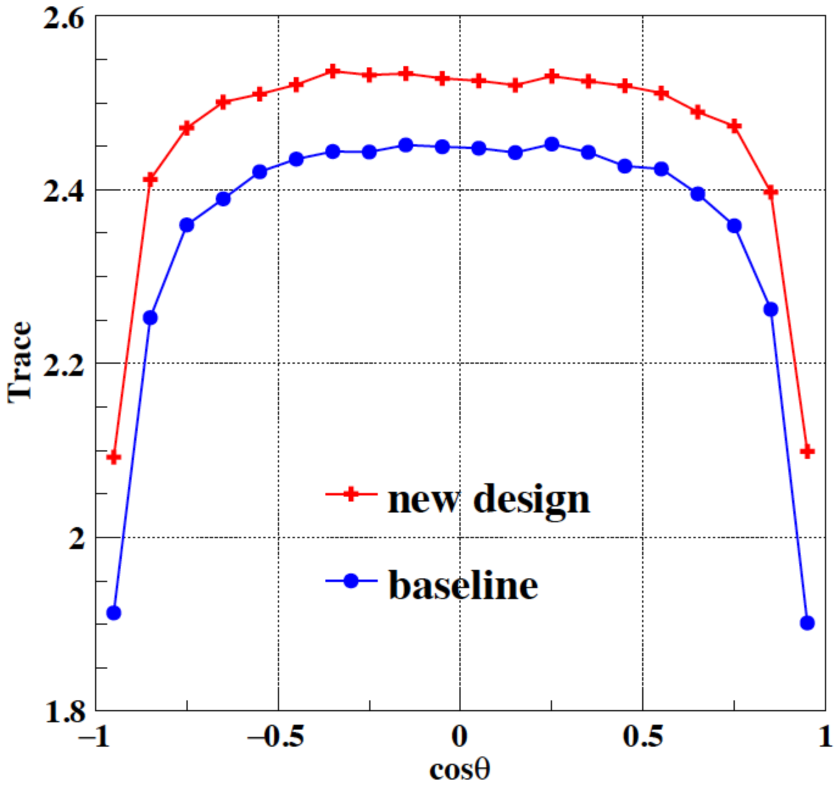
Similar performance dependence on CKM measurements at 240 GeV using semi-leptonic WW events

...ALICE ITS3...



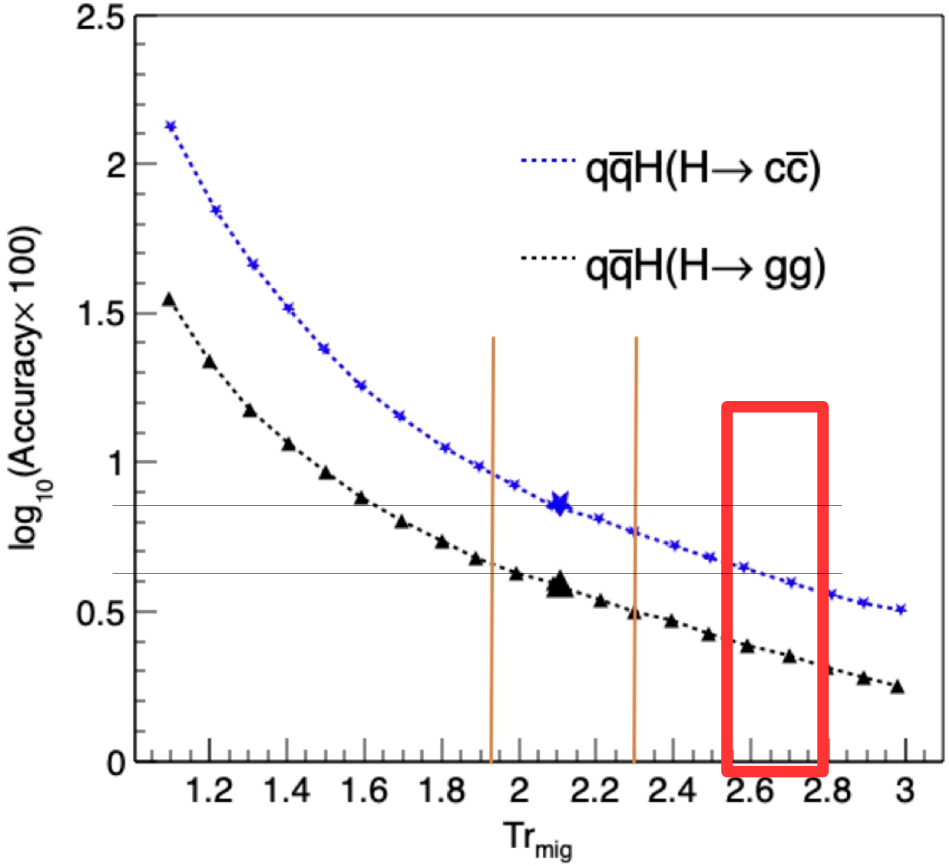
Vin

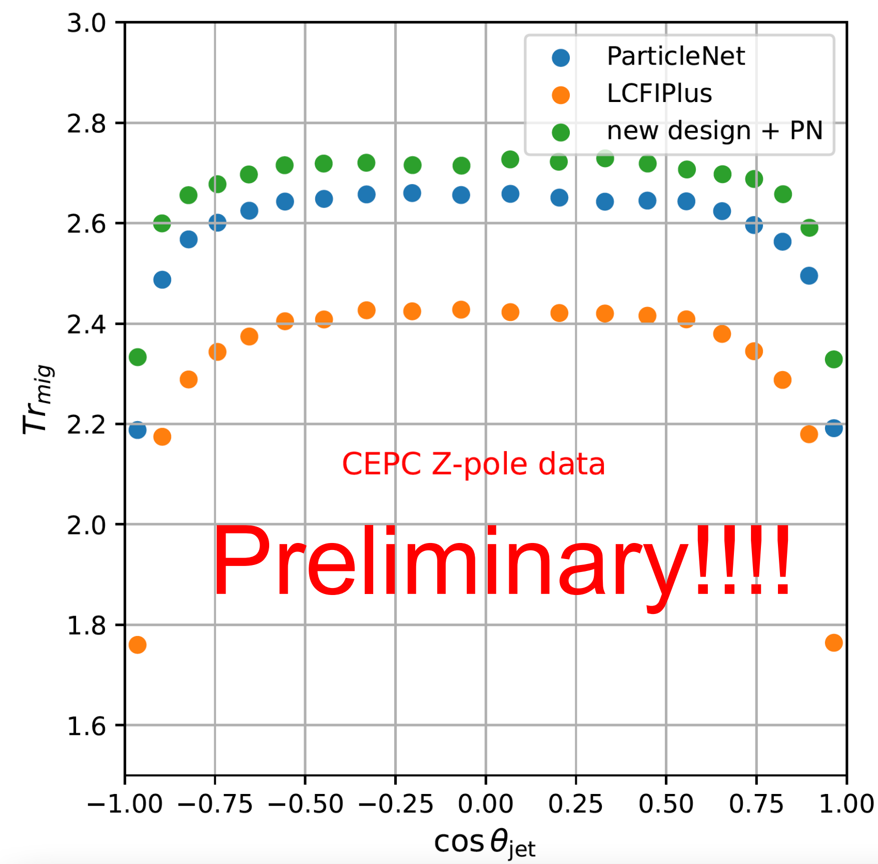




- Vin: Pro
  - Closer to the IP with same beam pipe radius
  - No multiple scattering to the 1st layer
  - Loose the material constrain of beam pipe: more efficient cooling, etc
- Tr(MM) in the barrel
  - Baseline: 2.45, Vin ~ 2.55
  - Compared to Baseline: improves the accuracy of g(Hcc) and Vcb by ~20%

Perspective to future



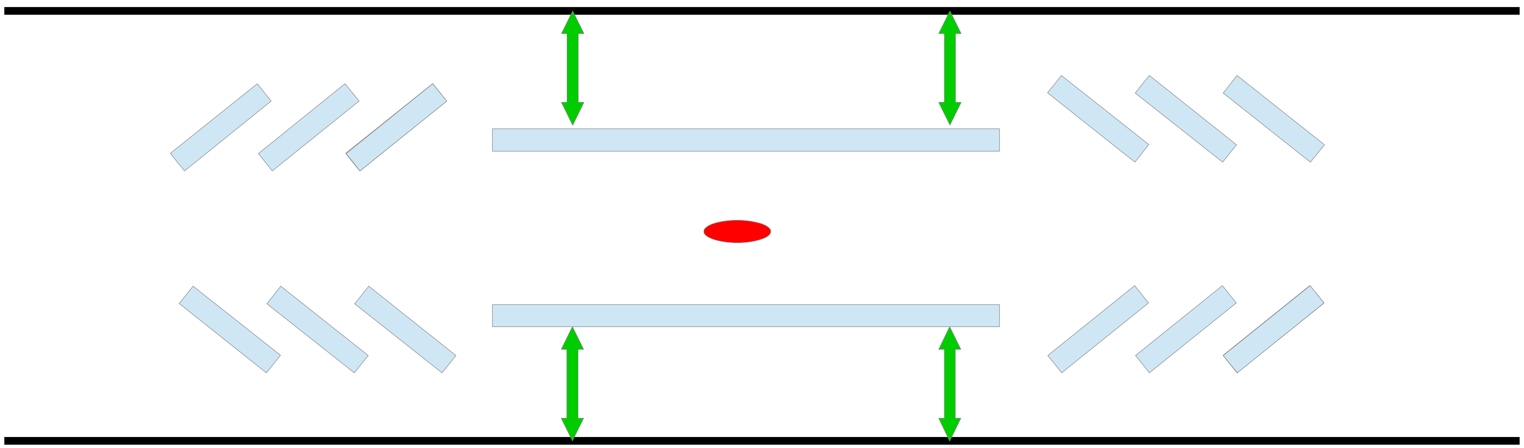


- Much intelligent algorithm (Particle Net) ...: improves from 7% ~ 4%
- Vin + Particle Net V.S. Baseline + LCFIPlus : **Doubles** the accuracy...

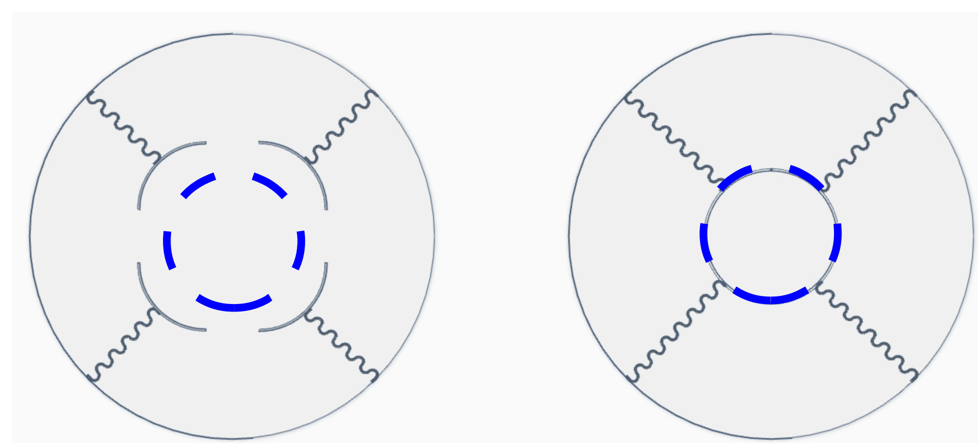
Vin

- Challenges
  - Vacuum of 1E-7 – 1E-8 Pascal;
    - OK if silicon only (Preliminary Dis. With Yongsheng)
  - Power & Signal
    - Integrated design with beam pipe
    - 6G antenna
  - HOM
    - Not a problem if inner surface is smooth enough -> Integrated design with beam pipe
  - RF protection
    - Micro-meter thick gold coating
  - Cooling
    - Using beam pipe
  - Protection & Beam monitoring...

Vin portable



- Challenge, but attractive
  - Pursue minimal inner radius
  - Tuning with feedback to beam background monitoring (BPM, Lumi-CAL, etc)
  - No multiple scattering from beam pipe, critical for pp collider experiments
  - Very challenge for the mechanics & HOM...

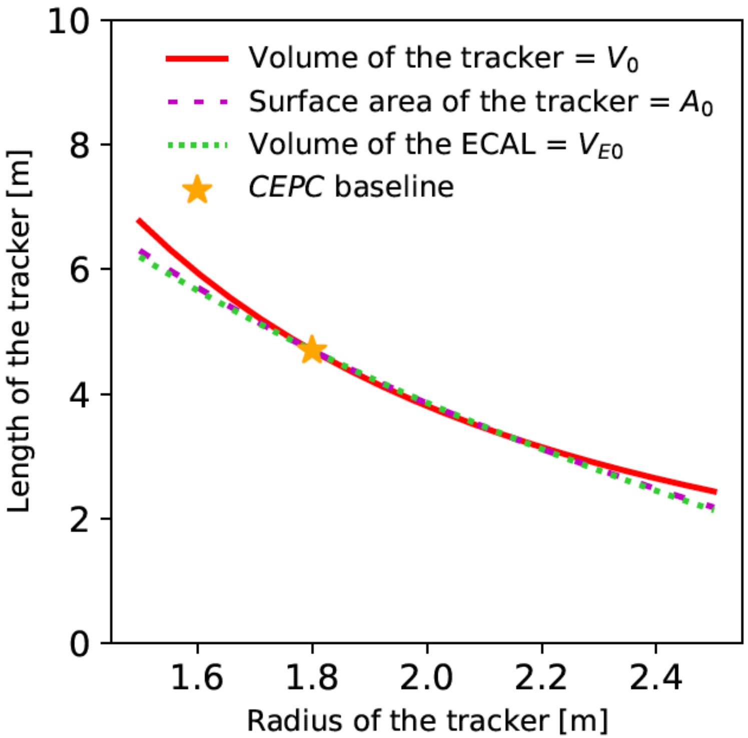


Global Geometry

- Tracker: R&Z

- Calorimeter:
  - ECAL: Polygon sides?
  - Mechanic: Patel or Vortex?

Tracker: R/Z ratio



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Optimization of tracker configuration for the CEPC

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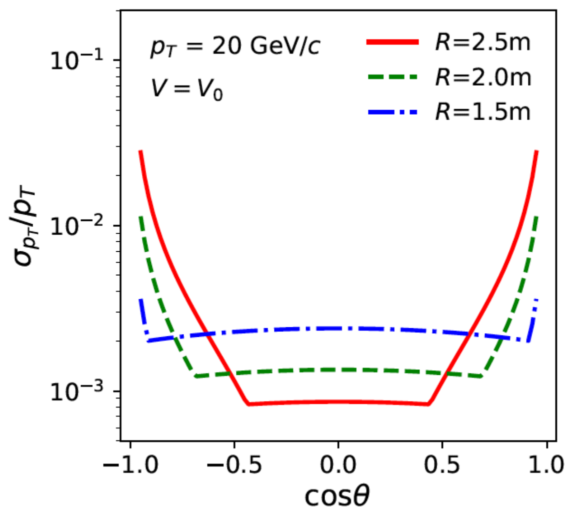
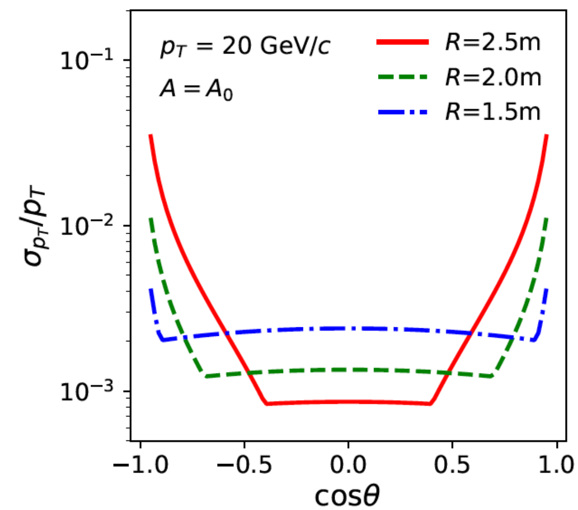
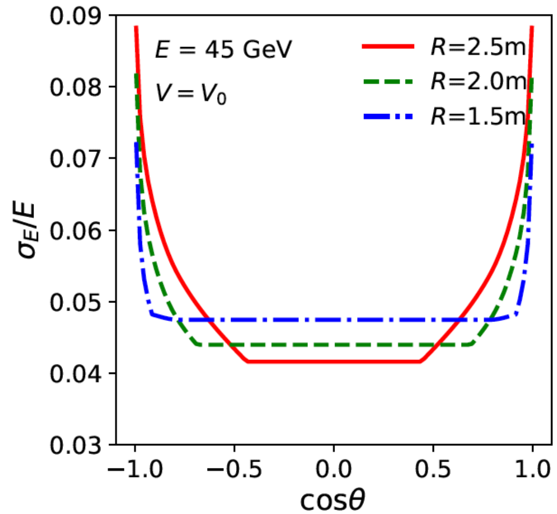


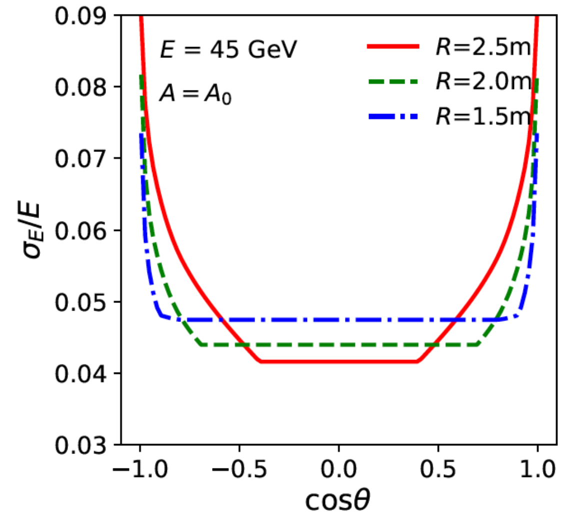
(a)



(b)



(c)



(d)

Tracker: R/Z ratio

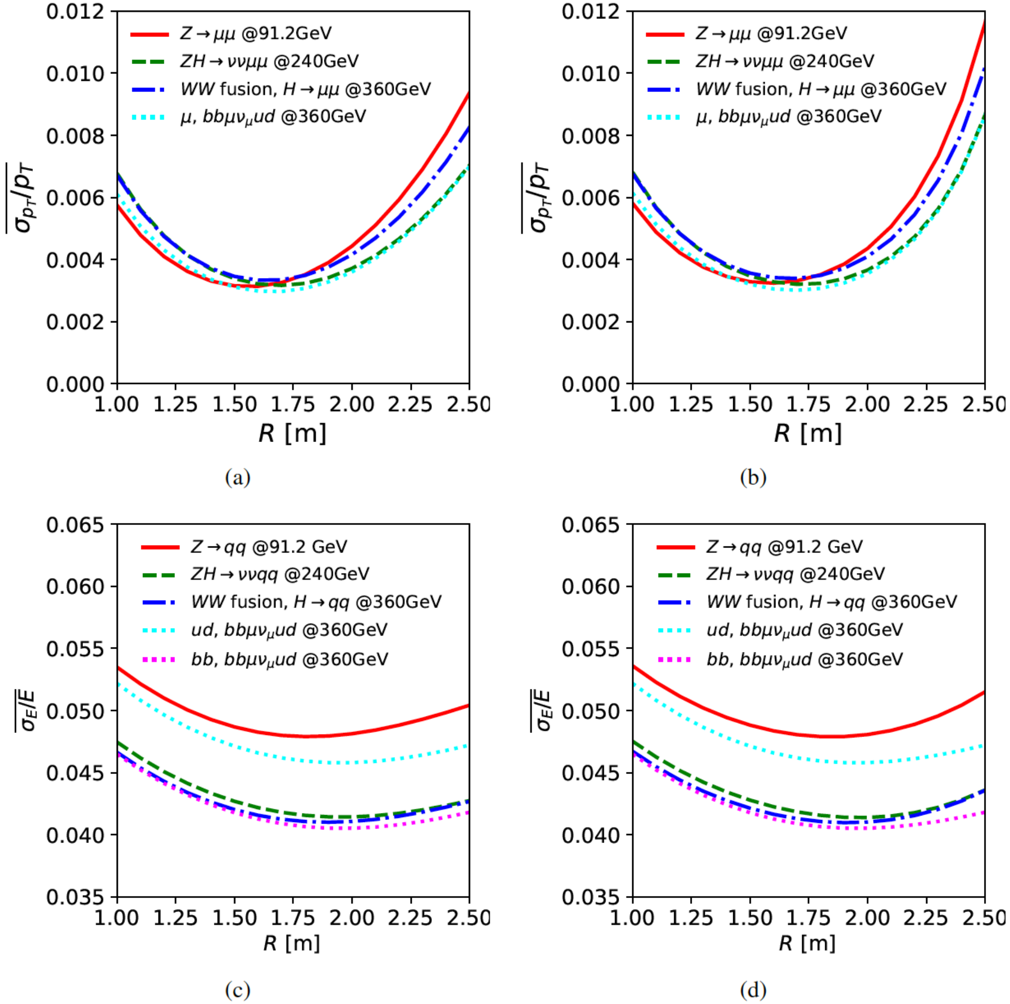
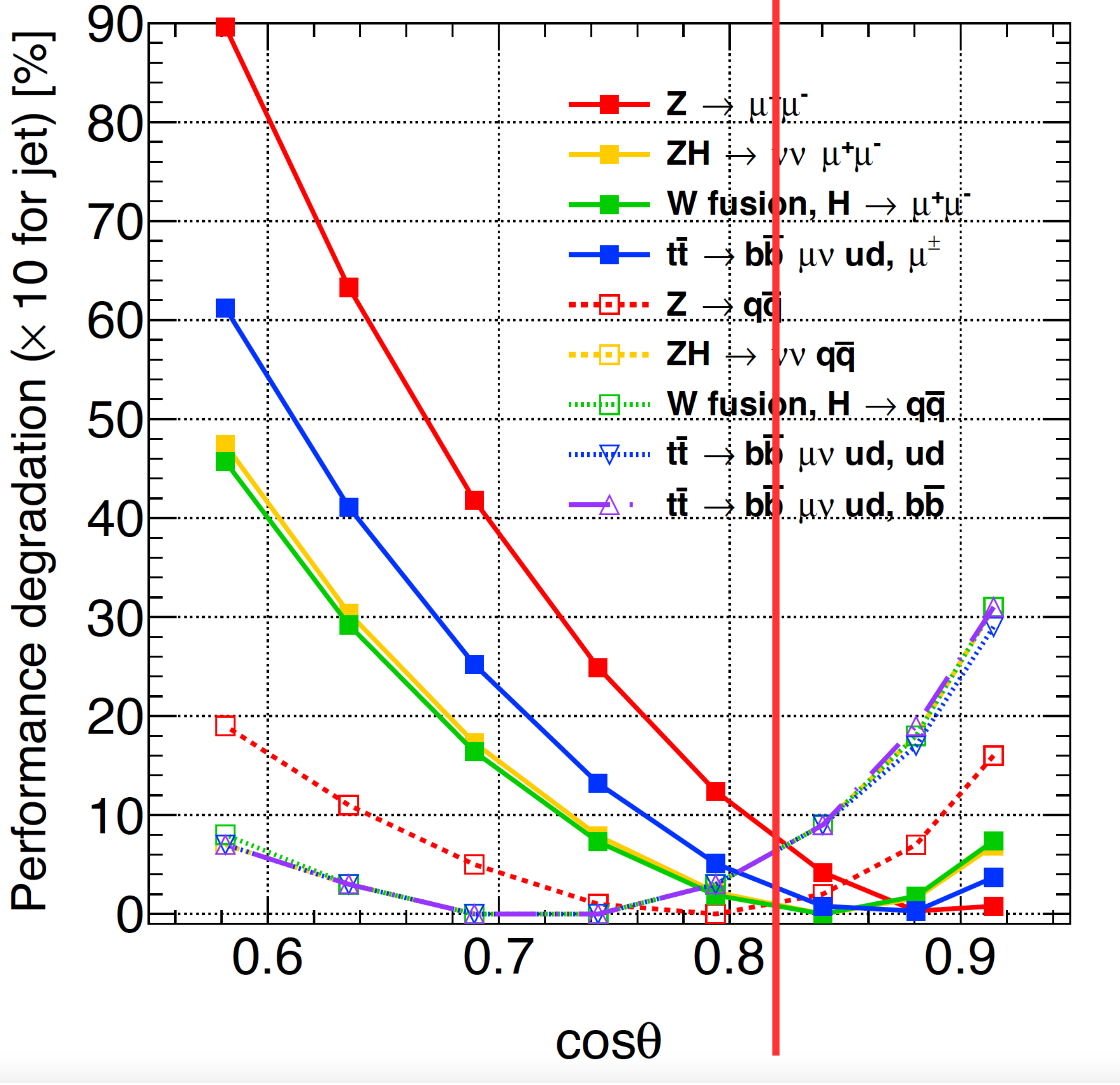


Table 3. The performance degradations for different tracker radii compared to the optimal resolution of each benchmark channel. The box shows the minimum number of each row.

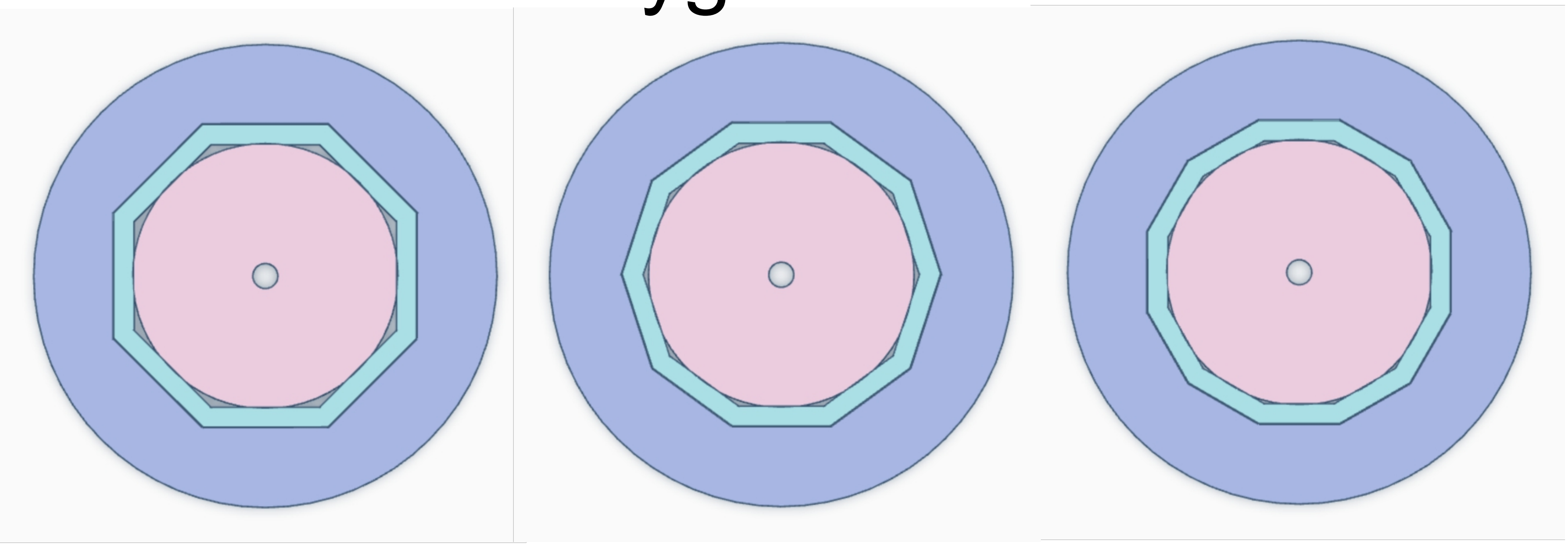
Benchmark	Cost estimator	Degradations (%) vs. radii (m) 1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2
$Z \to \mu^-\mu^+$ $\sqrt{s}$ = 91.2 GeV	volume	0.8	**0.3**	4.2	12.4	24.9	41.8	63.3	89.6
	surface area	1.4	**0.0**	2.3	8.5	19.0	34.6	56.3	86.1
$Z \to q\bar{q}$ $\sqrt{s}$ = 91.2 GeV	volume	1.6	0.7	0.2	**0.0**	0.1	0.5	1.1	1.9
	surface area	2.0	1.0	0.4	**0.0**	0.0	0.4	1.1	2.1
$ZH \to \nu\nu\mu^-\mu^+$ $\sqrt{s}$ = 240 GeV	volume	6.9	1.6	**0.0**	2.2	7.9	17.3	30.4	47.4
	surface area	8.5	2.5	**0.1**	1.1	5.7	14.4	28.0	47.9
$ZH \to \nu\nu q\bar{q}$ $\sqrt{s}$ = 240 GeV	volume	3.1	1.8	0.9	0.3	0.0	**0.0**	0.3	0.7
	surface area	3.4	2.1	1.1	0.4	0.1	**0.0**	0.3	1.0
W fusion, $H \to \mu^-\mu^+$ $\sqrt{s}$ = 360 GeV	volume	7.4	1.8	**0.0**	1.9	7.3	16.4	29.2	45.7
	surface area	9.0	2.9	**0.1**	0.9	5.2	13.6	27.0	46.4
W fusion, $H \to q\bar{q}$ $\sqrt{s}$ = 360 GeV	volume	3.1	1.8	0.9	0.3	**0.0**	0.0	0.3	0.8
	surface area	3.4	2.1	1.1	0.4	0.1	**0.0**	0.3	1.0
$\mu^\pm$, $b\bar{b}\mu\nu_\mu ud$ $\sqrt{s}$ = 360 GeV	volume	3.7	**0.3**	0.8	5.1	13.2	25.2	41.1	61.2
	surface area	5.0	0.8	**0.2**	3.1	9.8	20.9	37.3	60.5
ud, $b\bar{b}\mu\nu_\mu ud$ $\sqrt{s}$ = 360 GeV	volume	2.9	1.7	0.9	0.3	0.0	**0.0**	0.3	0.7
	surface area	3.2	2.0	1.1	0.4	0.1	**0.0**	0.3	0.9
$b\bar{b}$, $b\bar{b}\mu\nu_\mu ud$ $\sqrt{s}$ = 360 GeV	volume	3.1	1.9	0.9	0.3	0.0	**0.0**	0.3	0.7
	surface area	3.4	2.1	1.1	0.4	0.1	**0.0**	0.3	1.0

Track (radii 1.6–1.7) | Jet (radii 1.8–2.0)

R/Z: 1.75/5 meter

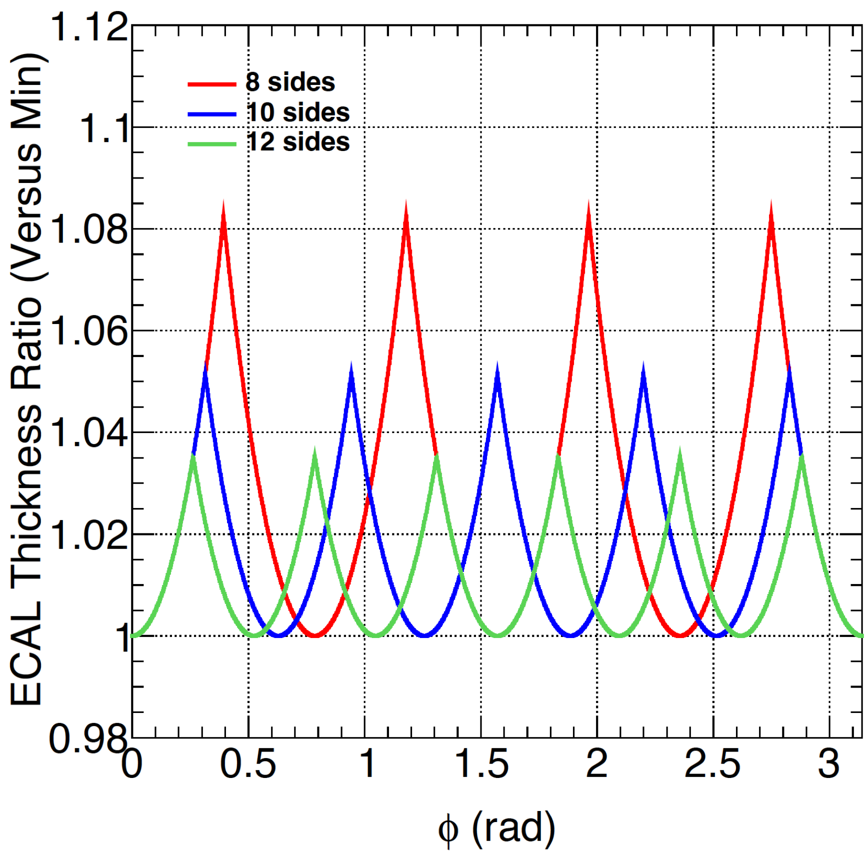


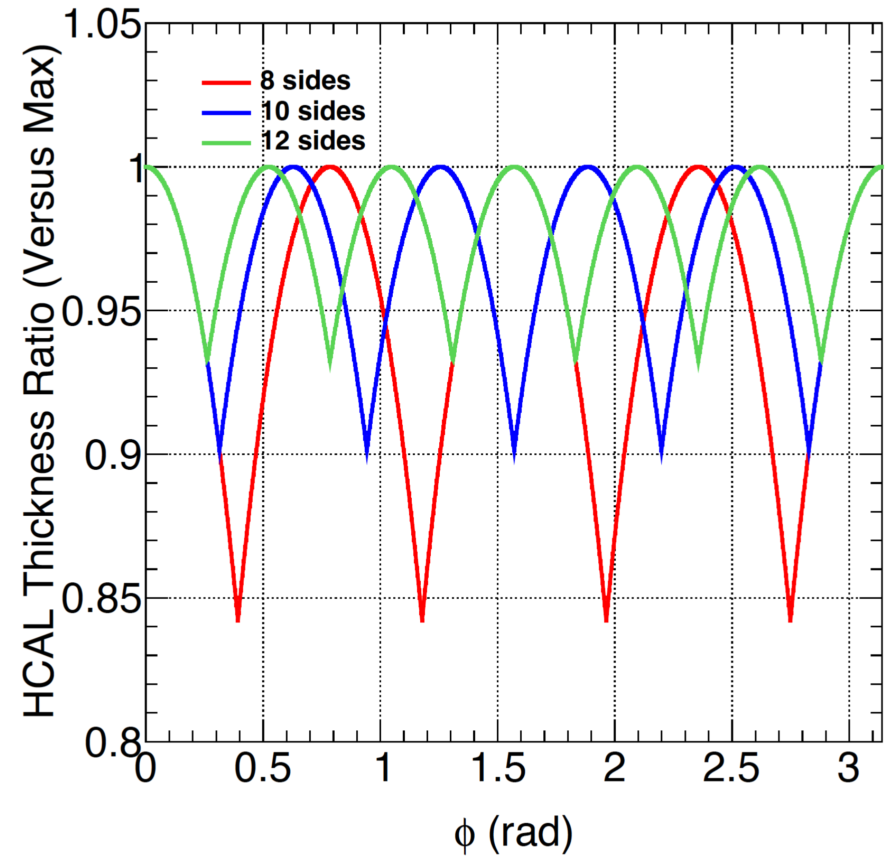
Polygon sides



ECAL		HCAL (45 layers)					
Polygon	V (m^3)	Sampling Fraction	Thickness Endcap (mm)	Thickness Barrel (mm)	Glass thickness ratio	Total V (m^3)	Glass V (m^3)
8	31.8911	1:1	1161	1200	0.604651	206.709	124.987
10	31.2703					208.62	126.142
12	30.9449					209.622	126.748
8	31.8911	1:6	987.498	1000	0.203314	160.99	32.7315
10	31.2703					162.901	33.1201
12	30.9449					163.903	33.3237

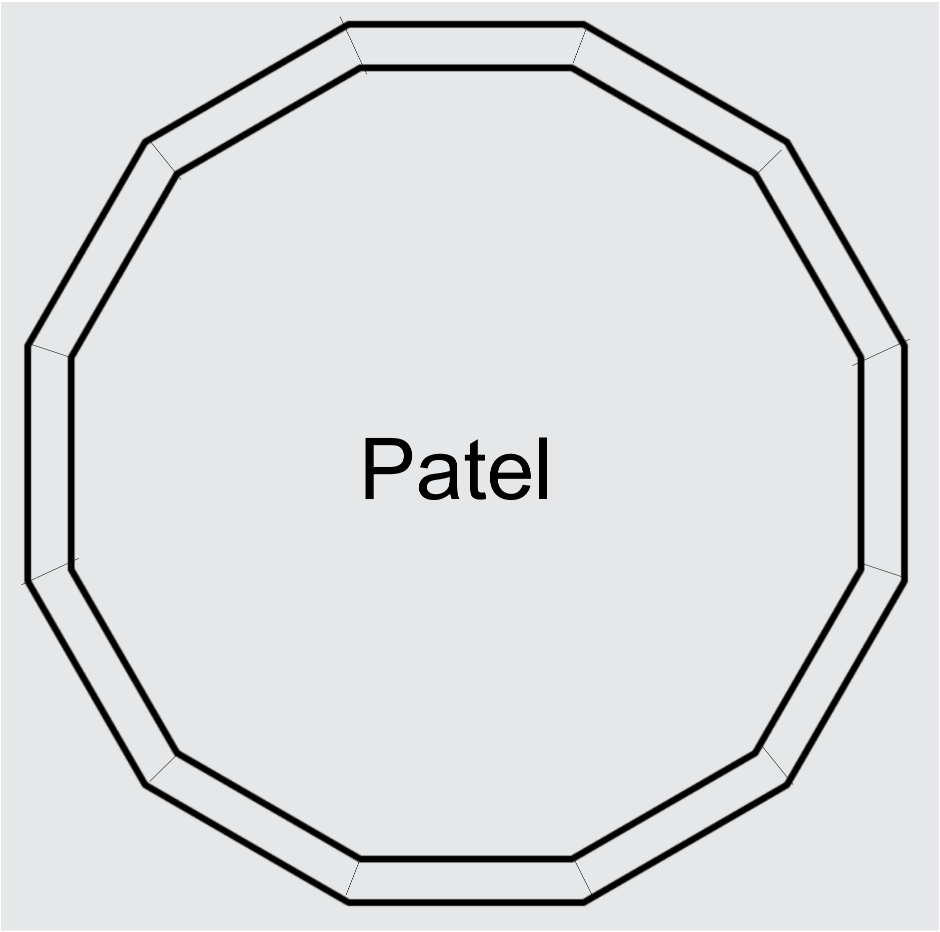
...Inhomogeneity in Φ...

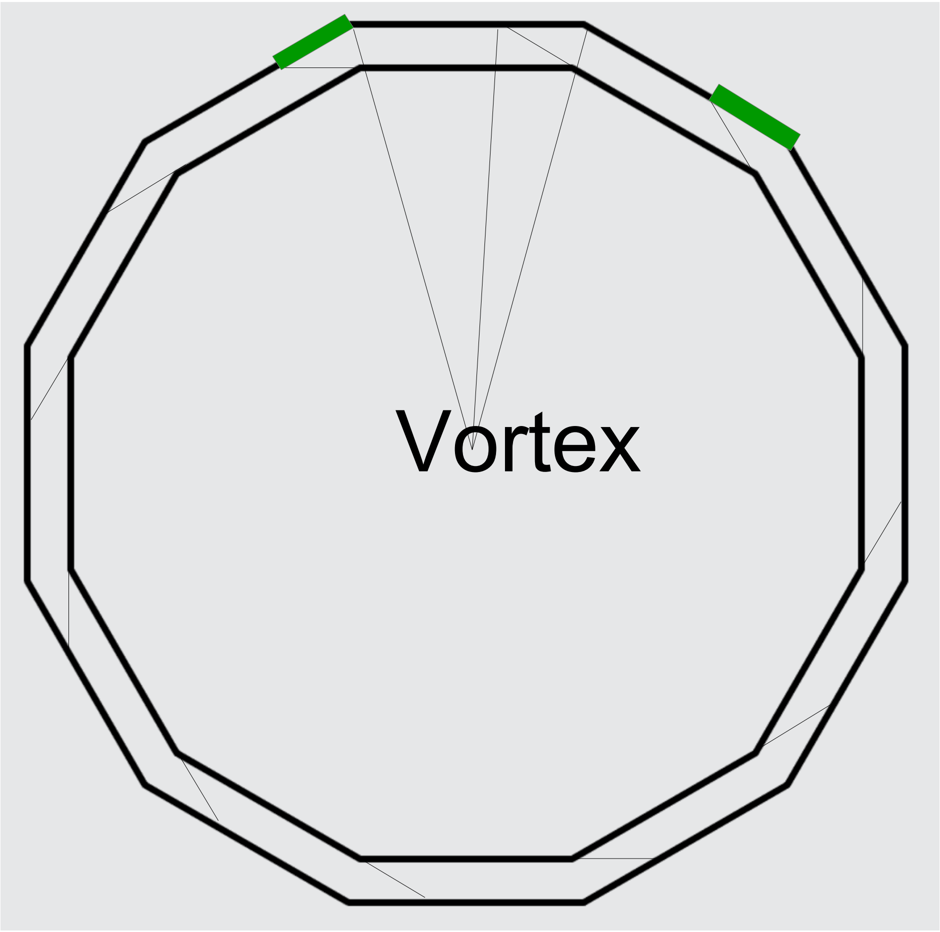




Material budget variation smaller than 10% → Polygon sides >= 10

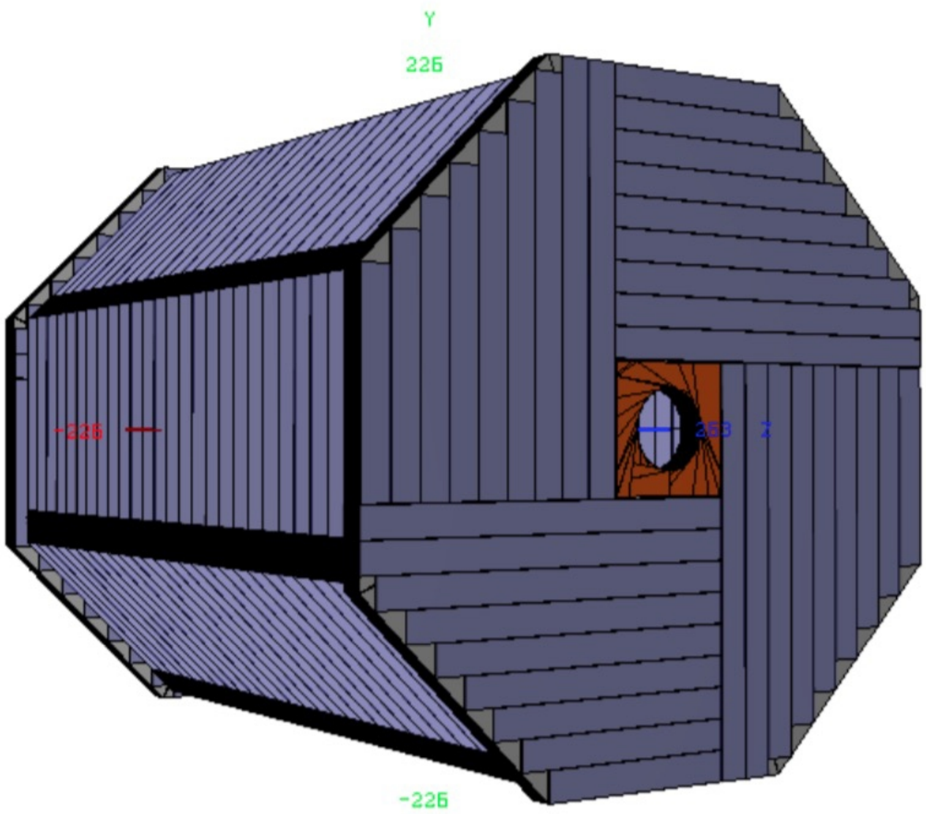
Polygon mechanic

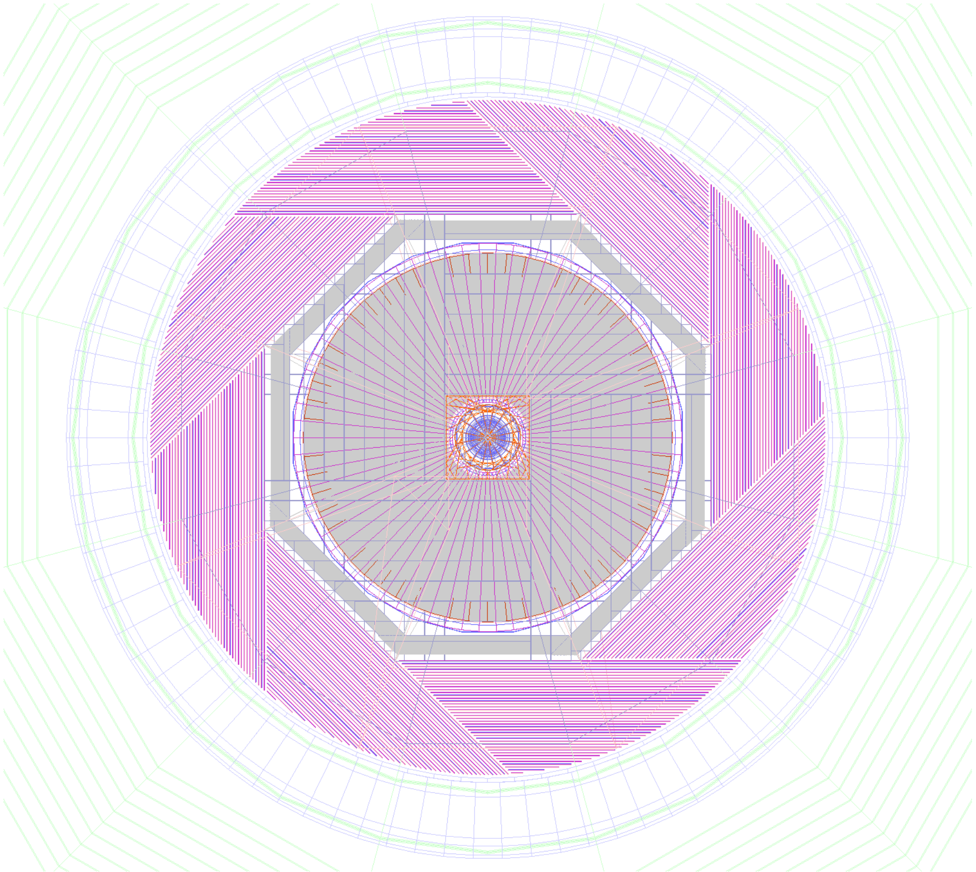




Vortex: Pro: Dead zone not aligned with IP;
Self-supporting structure;
Easier Access to PCB/electronics from external;
Con: Large fraction of overlapping region: need dedicated correction
Need to cut Xstal to fit the obtuse shape.

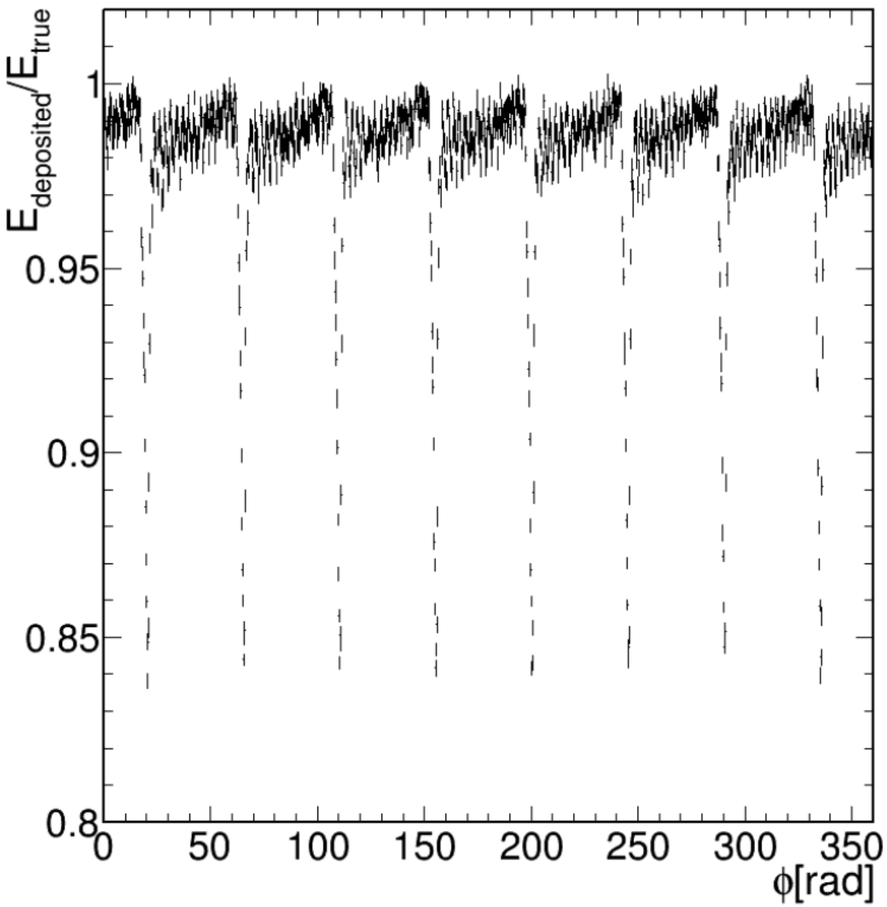
Baseline geometry



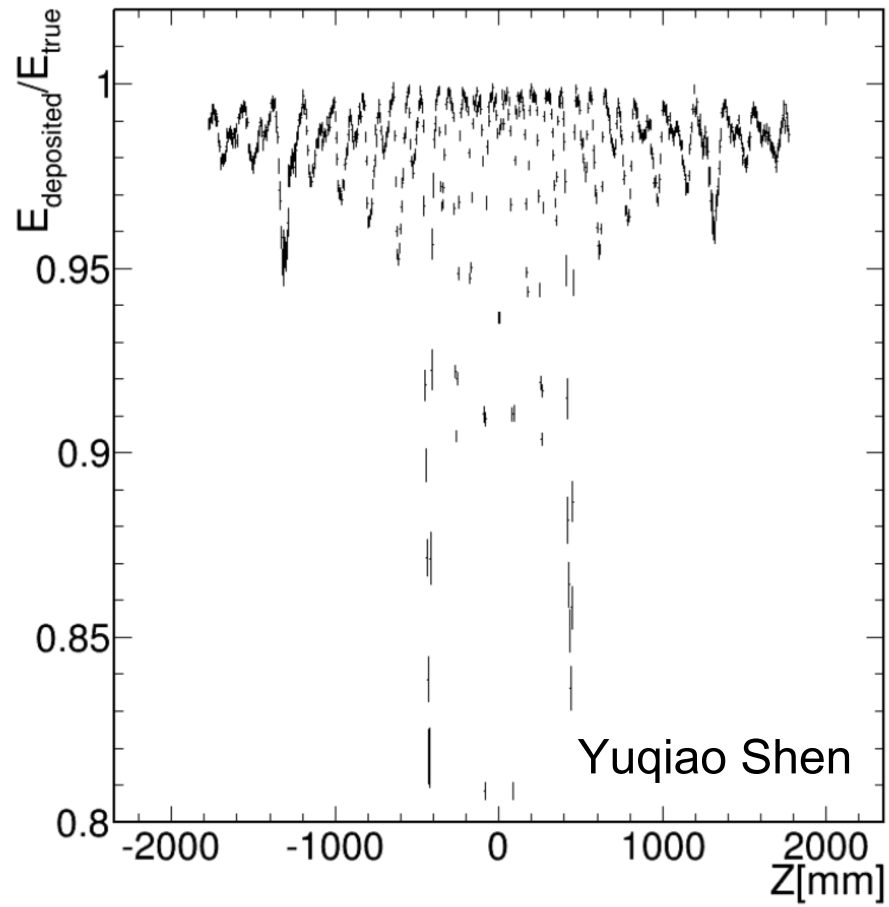


Baseline ECAL

Photon recon. at baseline

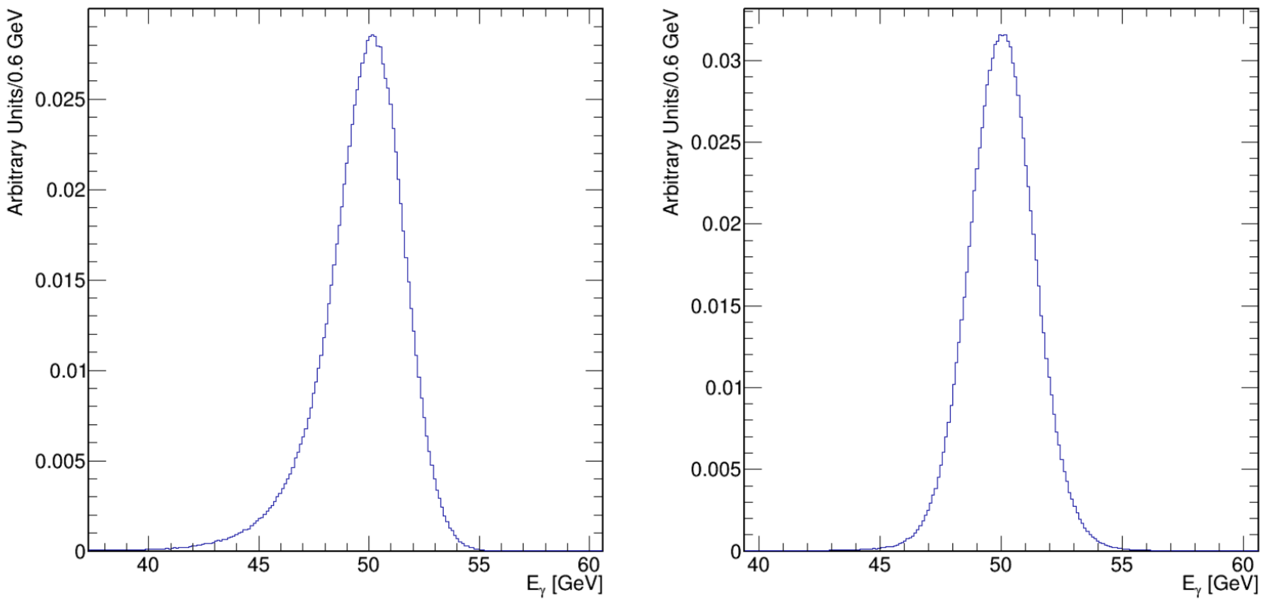


(a)



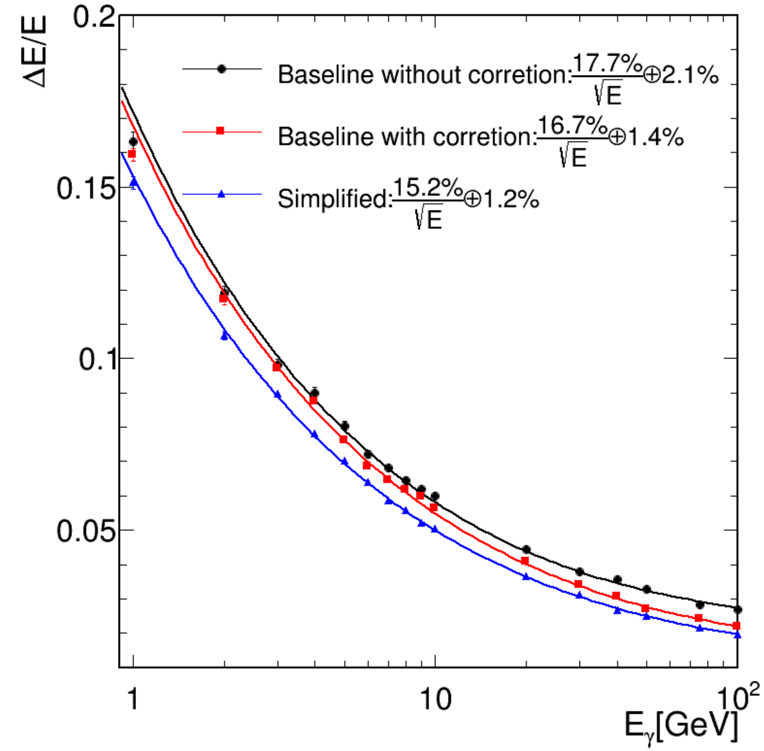
(b)

Photon energy reco at baseline



(a) (b)

Fig. 9: The energy distributions of 50 GeV photon before (a) and after (b) applying the energy correction algorithm. Roughly 1.5 million events, normalized to unit area.



- For flat sample over theta/phi in barrel.
  - ~20% degrading compared to ideal geometry (no dead zone)
  - Half could be correct back using shower angular information
- Not really significant at baseline – and can be better controlled using advanced tools

Geometry

- Tracker:
  - Inner/outer radius 25/175 cm, Z = 500 cm
  - Barrel/Endcap Joint, cos(θ) = 0.82
  - Acceptance: |cos(θ)| ~ 0.995

- Calorimeter
  - Polygon sides > 8: 10, or 12.
  - Vortex mechanic structure
  - Need to quantify the angular dependence between energy/position response of crystal ECAL, and to develop corresponding correction algorithm

Summary

- We propose CHLOE, using
  - GSHCAL
  - Xbar ECAL + Position/timing layer of
    - **Silicon**
    - MGPRC
  - 2.5 Tracker Scenarios:
    - **Gas Tracker $R_{in/out}$ ~ 25/175 cm, Z ~ 500 cm**
    - Improved 4^{th}: Fwd RHIC
    - Full Silicon with Pid (dE/dx ~ 3%...)
  - 3 VTX Scenarios
    - Rin ~ 10 mm
    - **Vin**
    - Vin Portable
- Anticipated Performance
  - Acceptance: cos(θ)~0.995
  - **BMR ~ 3%**
  - **EM resolution 3%/sqrt(E), const. term < 1%**
  - Timing resolution ~ o(50) ps
  - dP/P ~ 0.1% in the barrel
  - Pid: **eff/purity > 96%** for charged Kaon at hadronic Z event
  - Jet Flavor Tagging:
    - Tr(Mig): from ~2.4 to ~2.7
    - Enhance the g(Hcc) and |Vcb| measurements by 60% - 100%...
  - Fulfill the requirements of not only Higgs, but also Flavor & New Physics

Summary

- Critical Challenges
  - Boundary conditions to determine sub-detector technology & configuration...
    - Impact of beam background on sub detectors, especially gaseous one
    - MDI design, installation & integration
  - Vin
    - Power & Signal
    - Integration - Hom heat & radiation bkgrd, coating...
    - Vacuum level - material requirements
    - Large curvature stitch tech...
  - ECAL
    - Xstal:
      - Homogeneity, light yield – SiPM coupling, saturation;
      - Non cuboid Xstal manufactory & response
      - Energy/Position reconstruction & correction algorithm

Summary

- Critical Challenges
  - ECAL
    - Position layer optimization:
      - specification (time, position, and potentially energy),
      - cooling requirement – material budget
  - HCAL
    - Requirement on homogeneity light yield & coupling to SiPM
    - Mass production of glass
  - **Need to understand the in-time leakage & off-time pile up**
- Action items
  - Optimization of geometry parameters via Detailed simulation + algorithm development... with machine learning, etc
  - R&D to address challenges...
  - Integration study

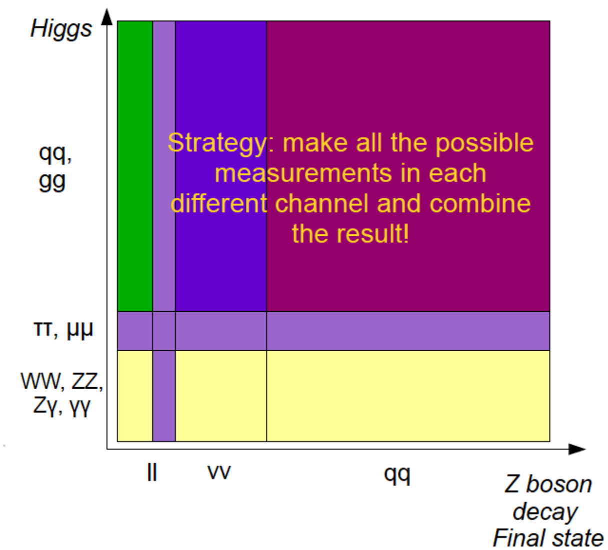
Back up

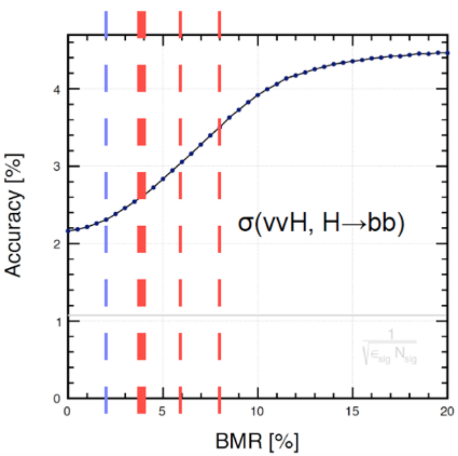
Tentative Para. table

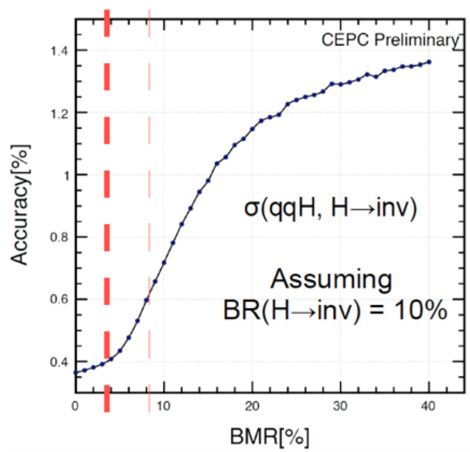
	CHOLE	CHOLE*1.2	4th	Baseline
Tracker R				
Tracker Z				
ECAL Volume/Weight				
HCAL Volume/Weight				
Solenoid Volume/Weight				
Yoke Volume/Weight				
BMR		3		3.8
EM resolution				
Pid				
dP/P				
FT: Tr(Mig)	2.5	2.5		2.4

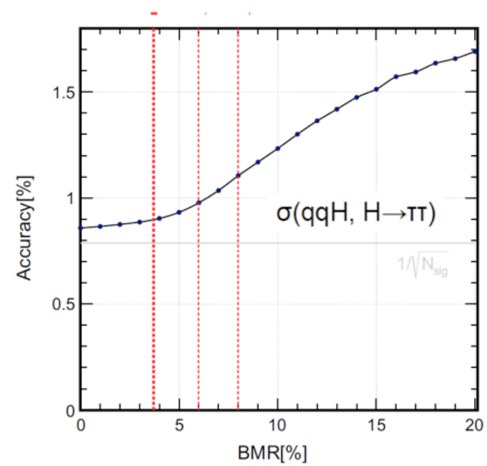
Hadronic event & BMR

- Core of e+e- Higgs factory Physics measurements
  - 97% of CEPC Higgs events are hadronic/semi-leptonic
- Higgs measurement require BMR < 4%;
- Flavor & NP: much more demanding



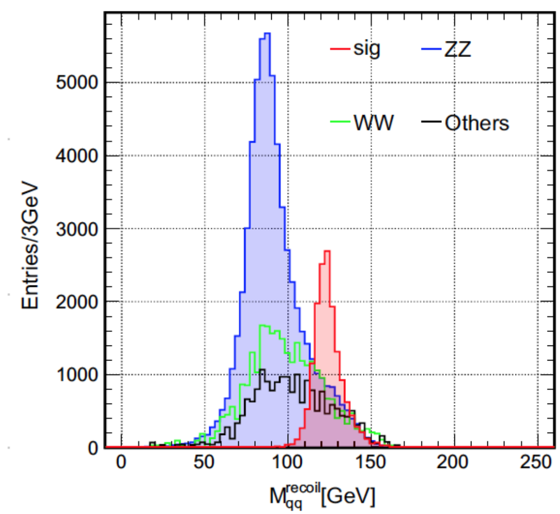




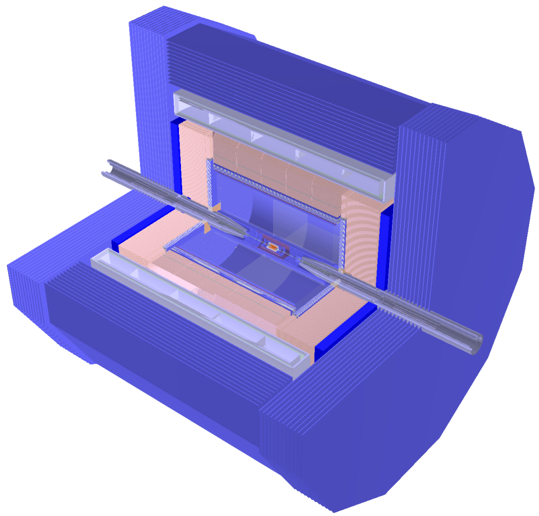


- Boson Mass Resolution: relative mass resolution of ννH, H→gg events
  - Free of Jet Clustering
  - Be applied directly to the Higgs analyses
- The CEPC baseline reaches 3.8%

	BMR = 2%	4%	6%	8%
σ(ννH, H→bb)	2.3%	2.6%	3.0%	3.4%
σ(ννH, H→inv)	0.38%	0.4%	0.5%	0.6%
σ(qqH, H→ττ)	0.85%	0.9%	1.0%	1.1%



@ Baseline



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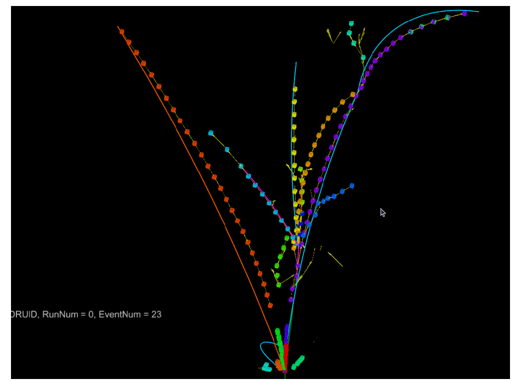

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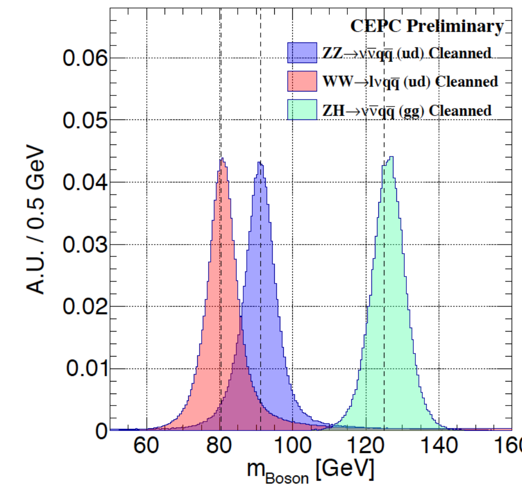


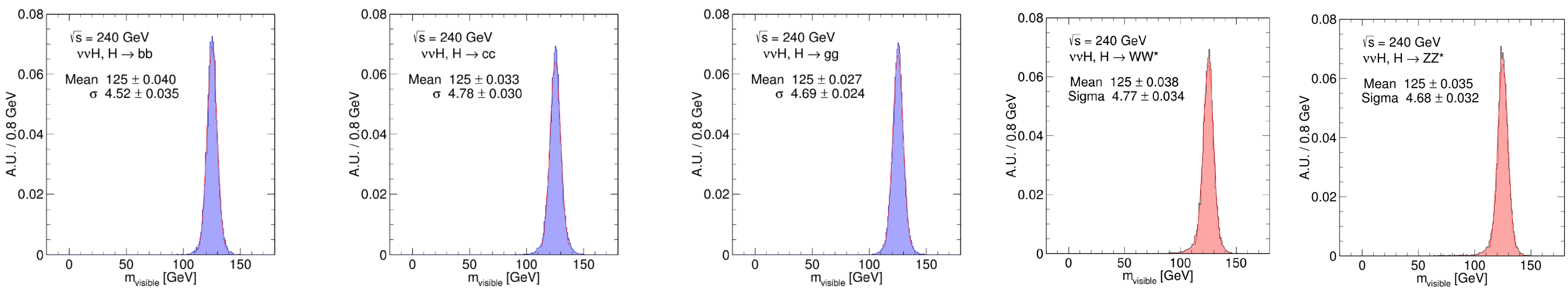
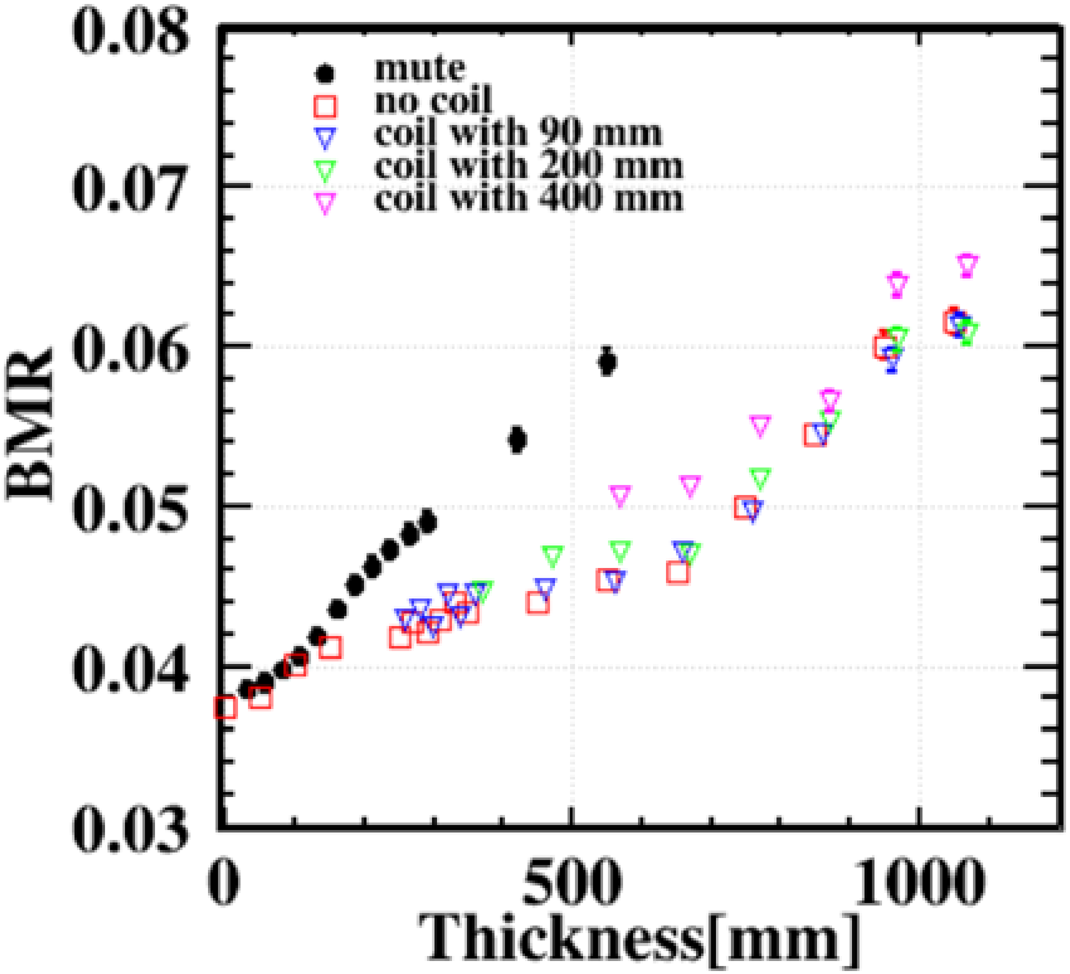


Table 3. Higgs boson mass resolution ($\sigma/Mean$) at different decay modes with jets as final state particles, after the event cleaning.

Higgs→bb	Higgs→cc	Higgs→gg	Higgs→ WW*	Higgs→ ZZ*
3.63%	3.82%	3.75%	3.81%	3.74%

Impact on BMR

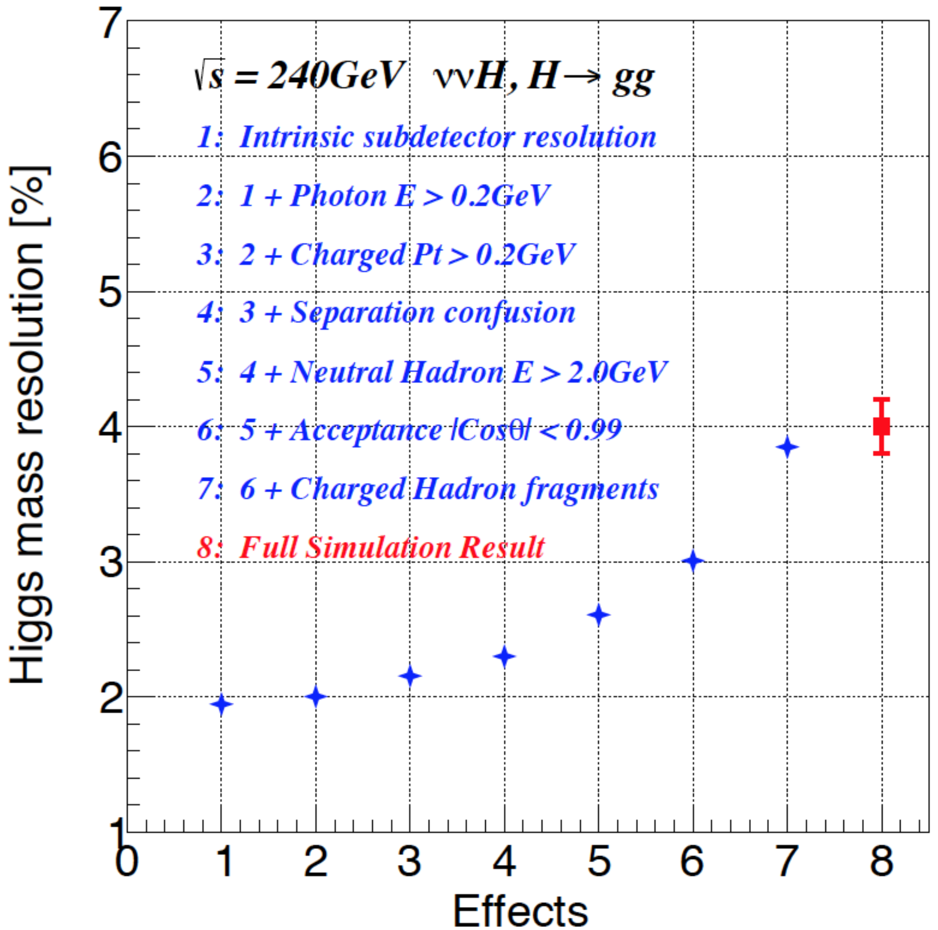


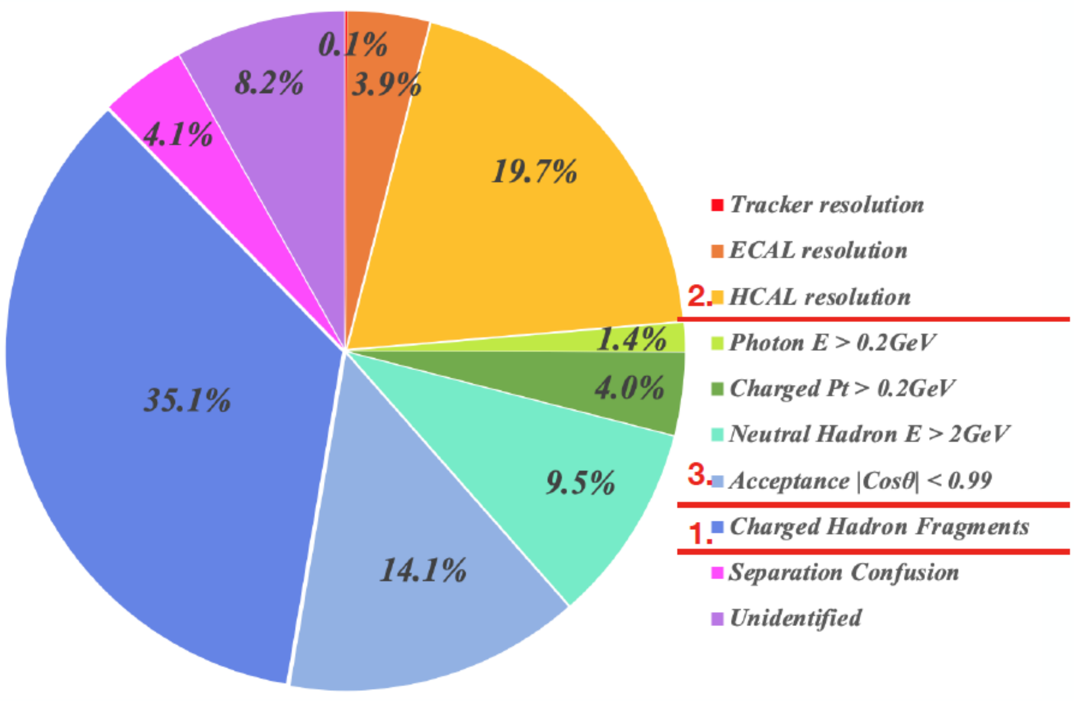
- BMR is sensitive to Both space & material
- A minimal space of

  R*(1(cos(pi/n)) – 1)

  is required to put a 0-thickness circle between parallel polygons. A 169 mm gap is required at baseline octagon structure, leads to a BMR degrading of 8% (3.8% -> 4.1%), whose gap is 30 mm.
- Solenoid material, BMR degrades for
  - 1X0 (of Al) & 260 mm Gap: 10%
  - 2.2X0 & 370 mm Gap: 15%.
  - 4.4X0 & 570 mm Gap: 32%.

PFA Fast simulation



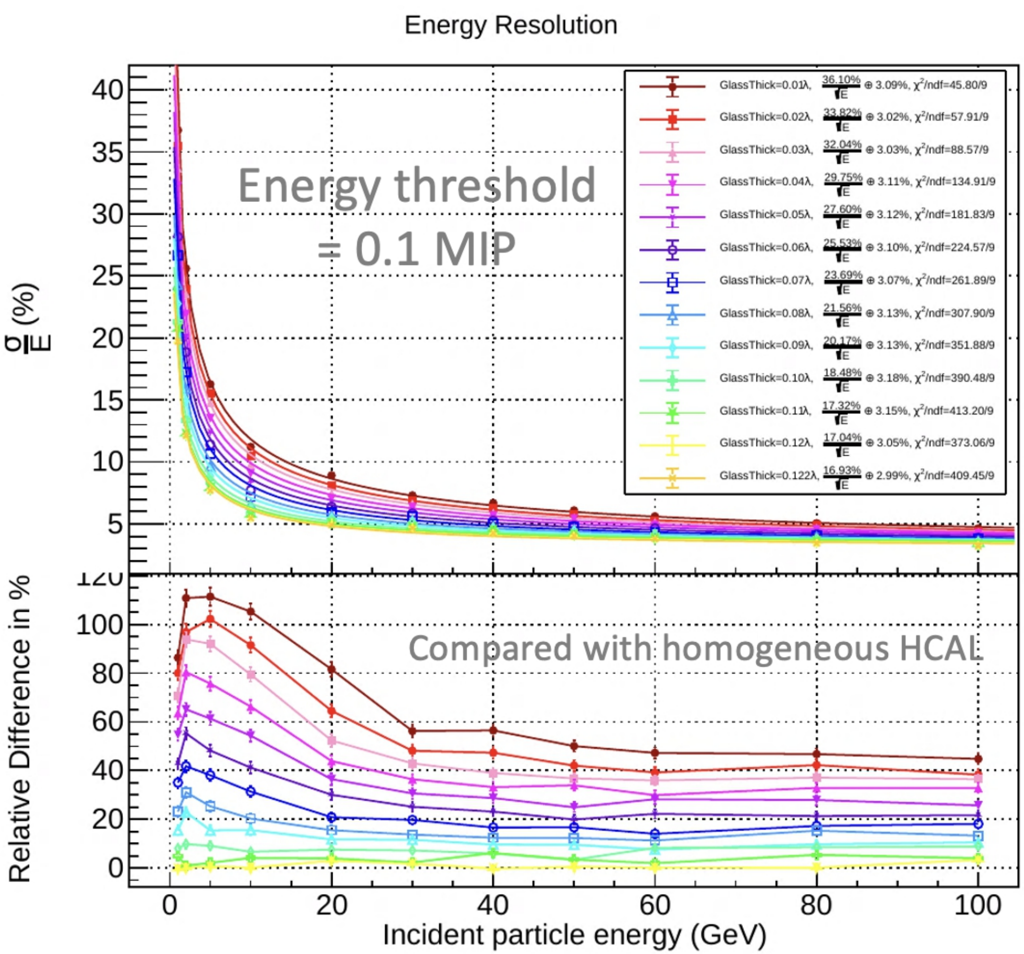


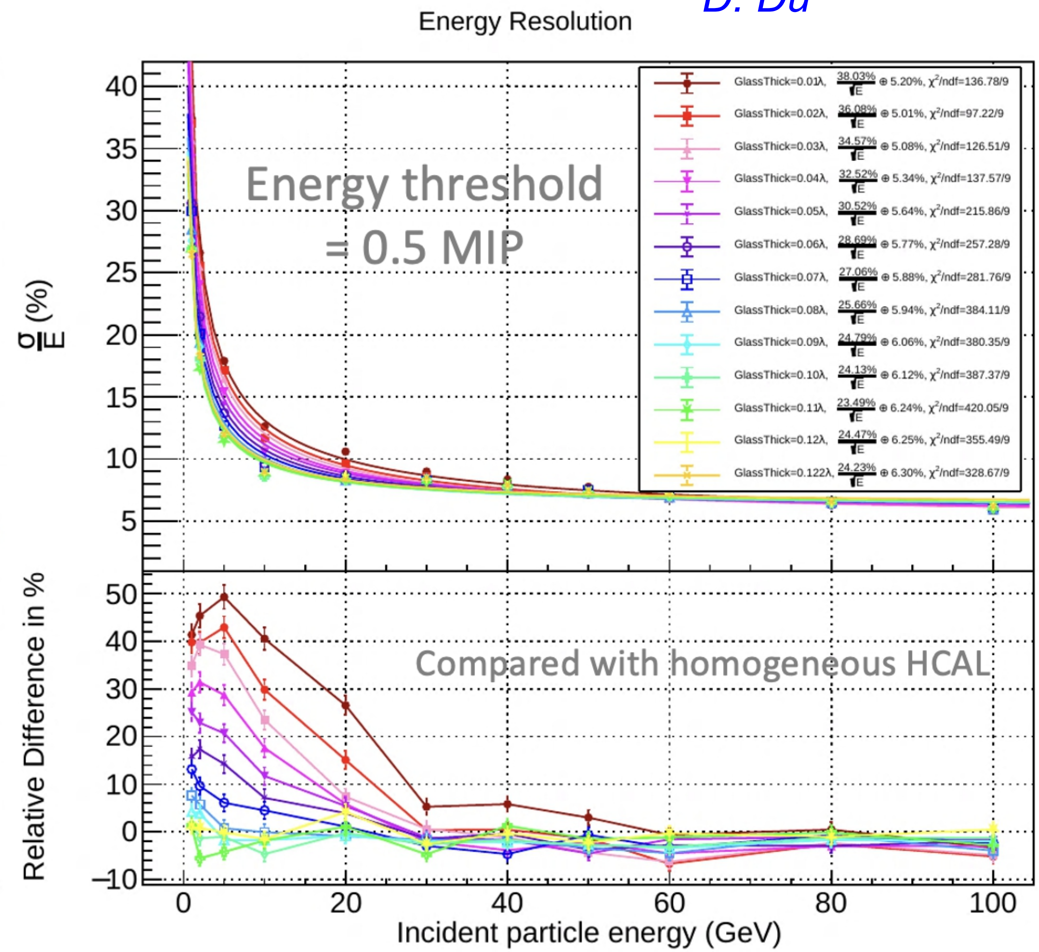
YX. Wang

Fast simulation reproduces the full simulation results, factorize/quantifies different impacts

HCAL

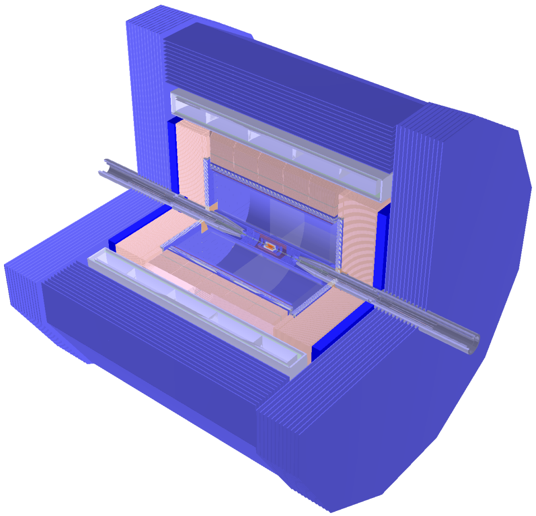
D. Du



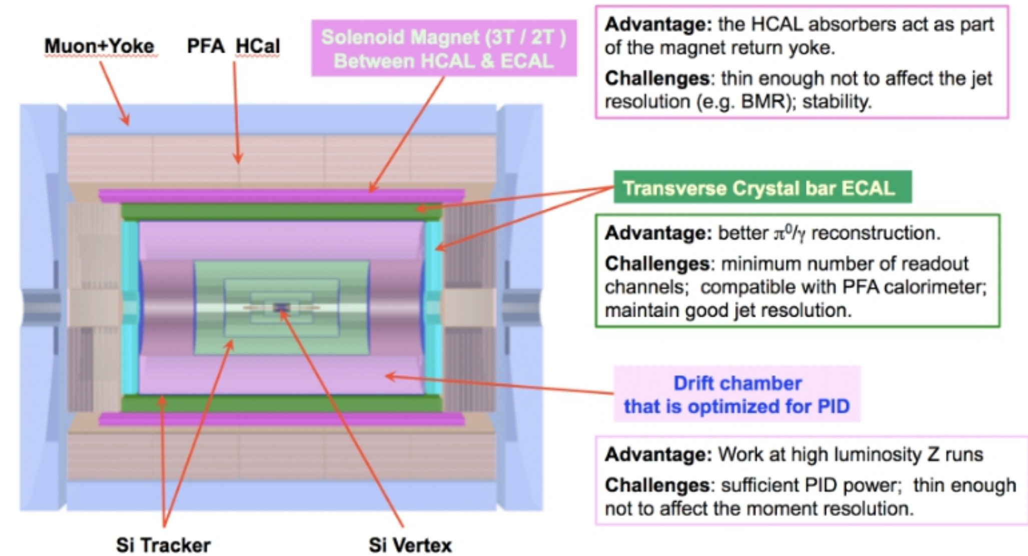


- In an ideal case - ideal Geometry ~ semi infinite...
- HCAL resolution significantly w.r.t. Baseline, at single particle level

From Baseline to 4th



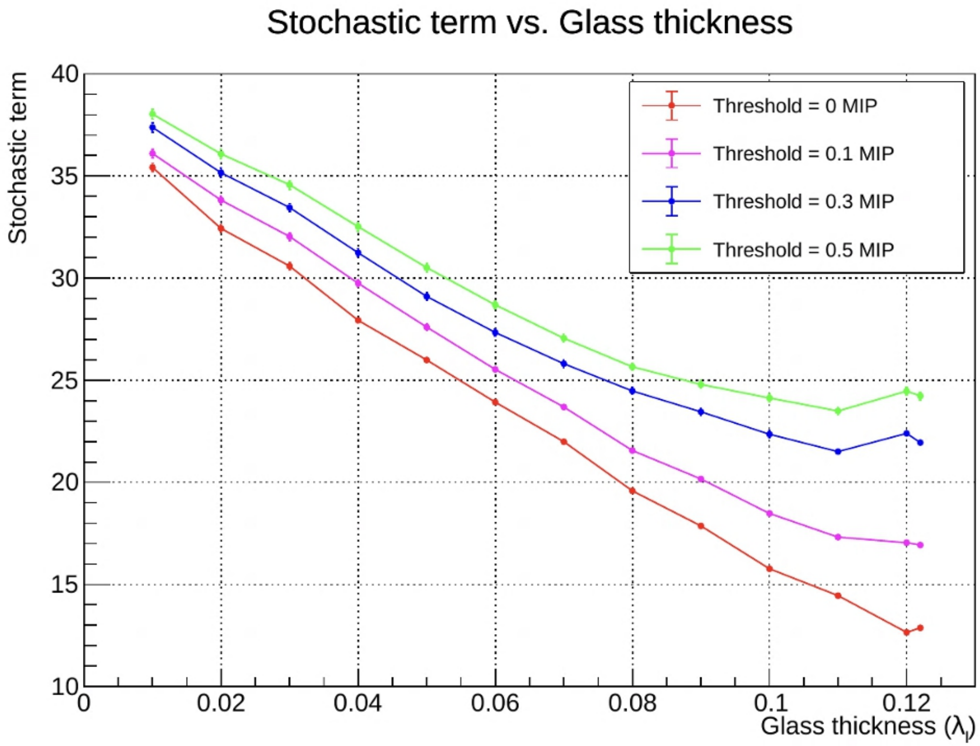
→

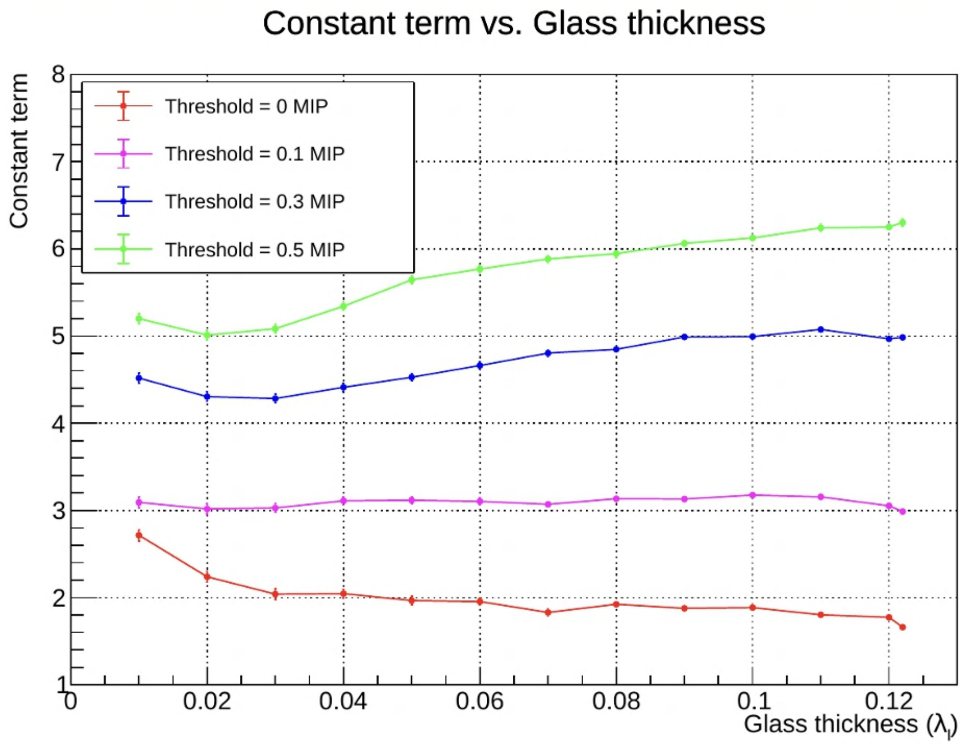


- Tracker: TPC + Silicon → Drift Chamber + Silicon
- ECAL: Si+W → Xstal
- HCAL: GRPC + Iron → Glass + Iron
- Solenoid: Outside HCAL → Between ECAL & HCAL

Single Particle @ GS HCAL

D. Du

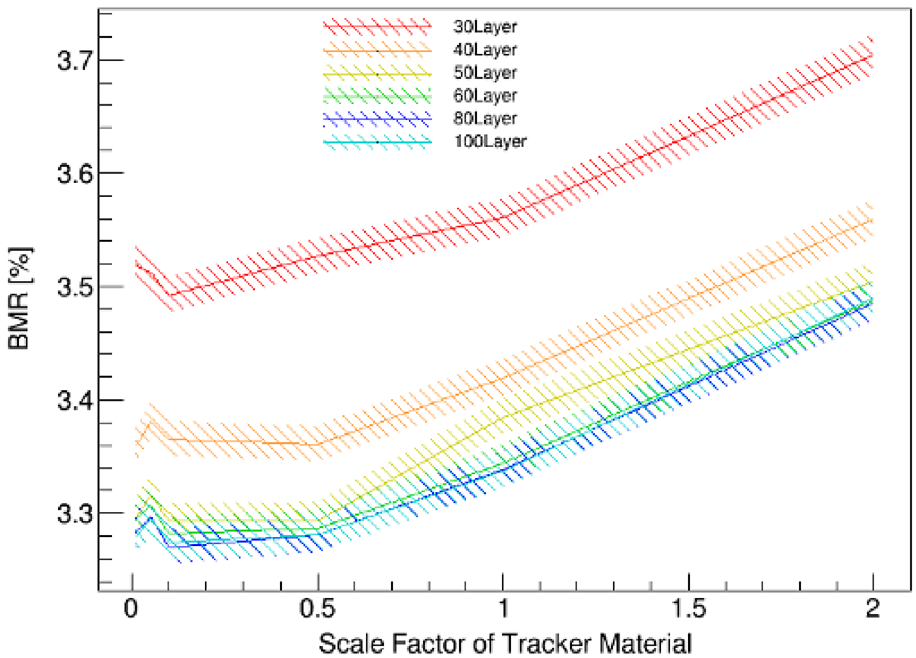


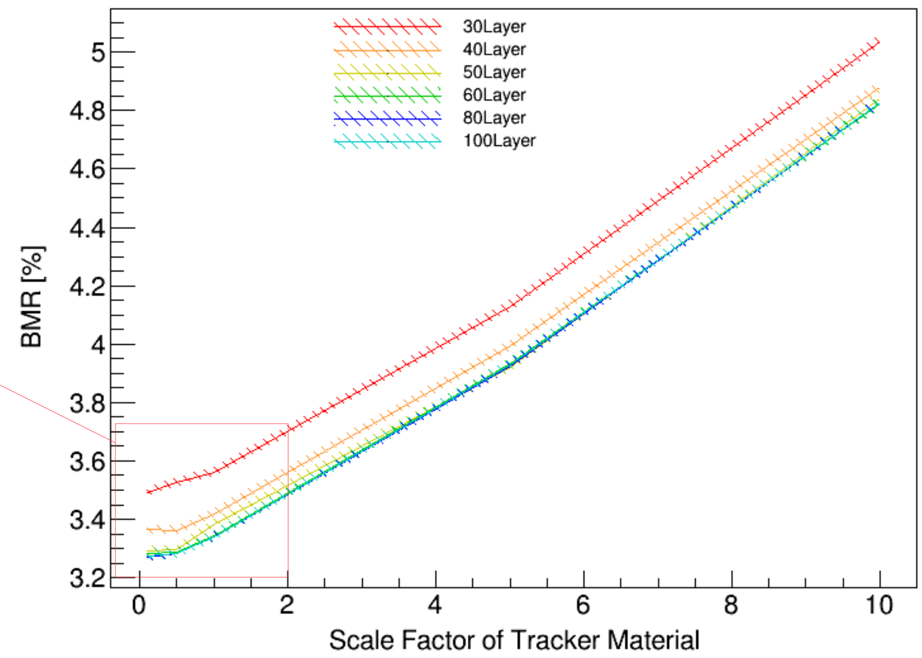


- Performance improves almost linearly at lower energy threshold, and larger sampling fraction

BMR VS upstream material

P. Hu, Preliminary

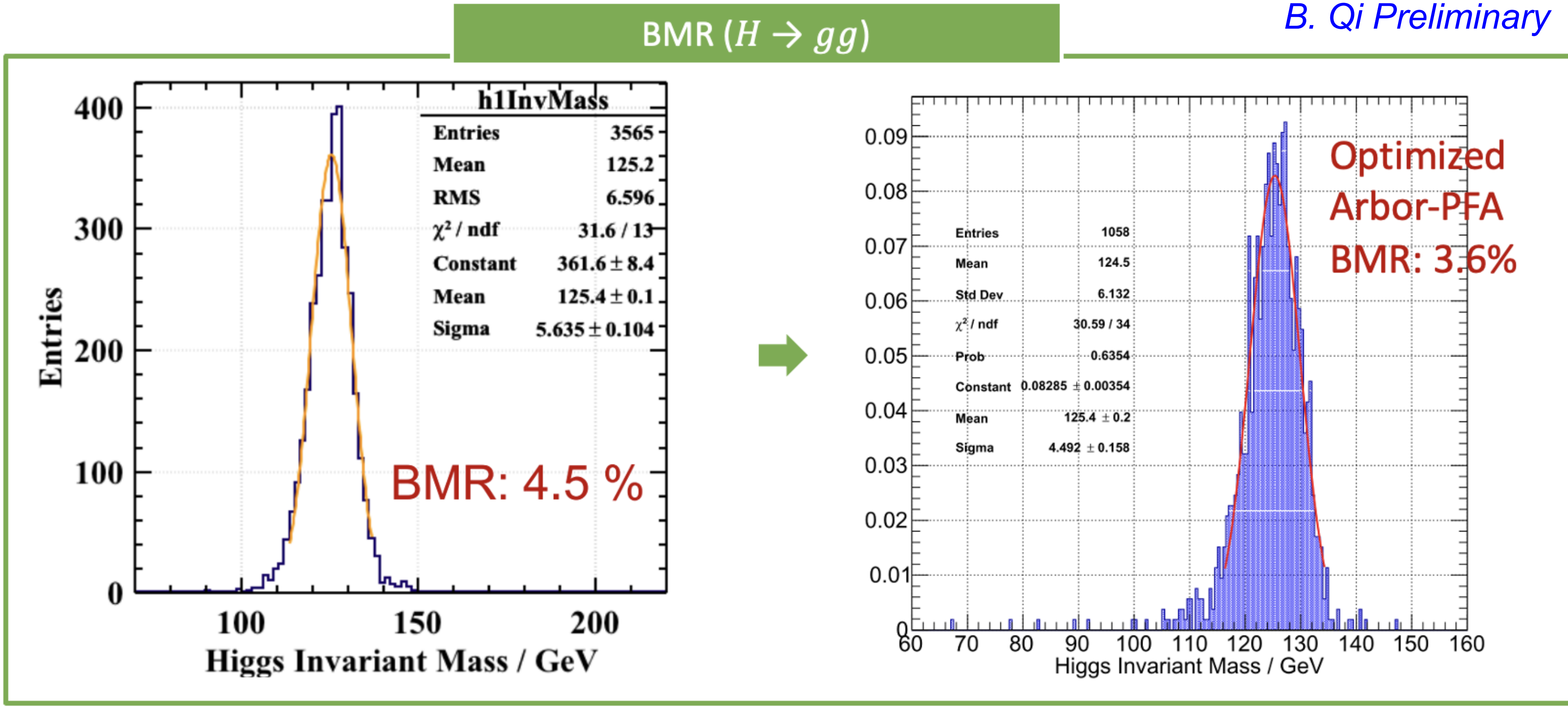




- Baseline: 10% X0 material in the barrel region.
- Would be great to half the upstream material.

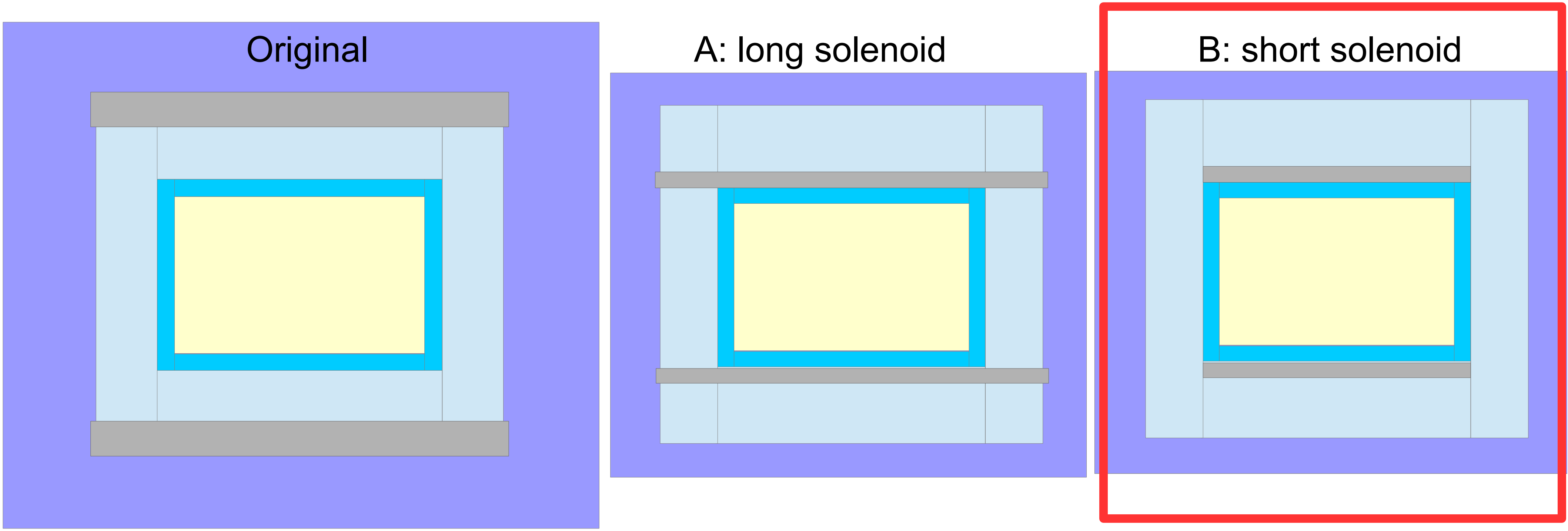
BMR @ Crystal ECAL Cell

B. Qi Preliminary



- A two-staged Arbor has been developed, which seems capable to overcome the difficulties of massive #Nhits in ECAL
- No significant improvement in BMR observed. 2% improvement anticipated from Fast simulation.

Solenoid between E&HCAL

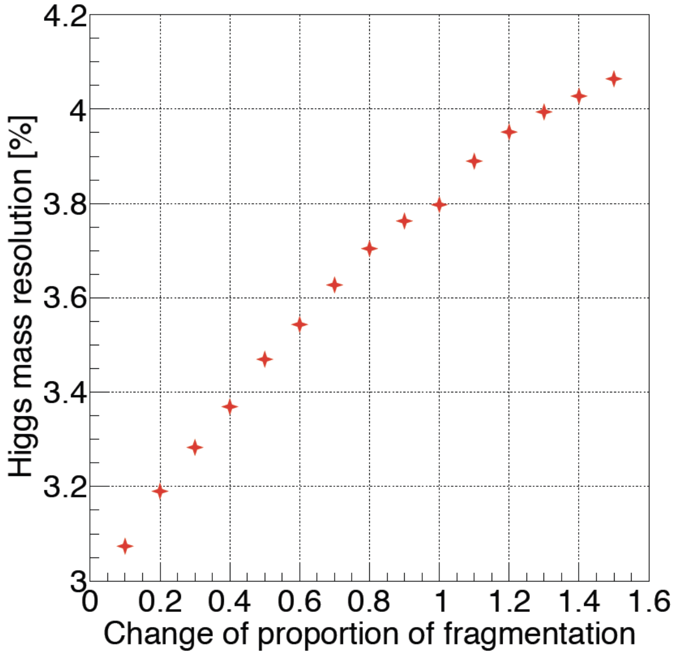


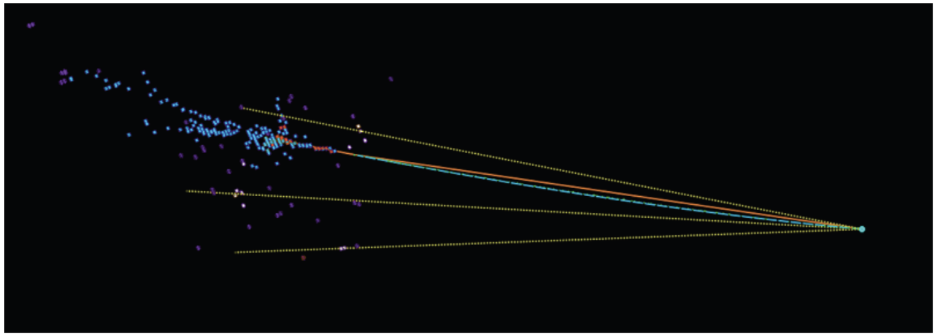
- Long/short solenoid between E/HCAL: saving cost on reduced solenoid & Yoke, while the HCAL cost increases (once ECAL/Tracker fixed)
- Performance comparison between long/short solenoid
  - Short solenoid has less dead materials & worse B-Field homogeneity
  - Assume B-Field difficulties can be solved, short solenoid has better performance, and implemented in Full sim (Thanks to ChengDong!)

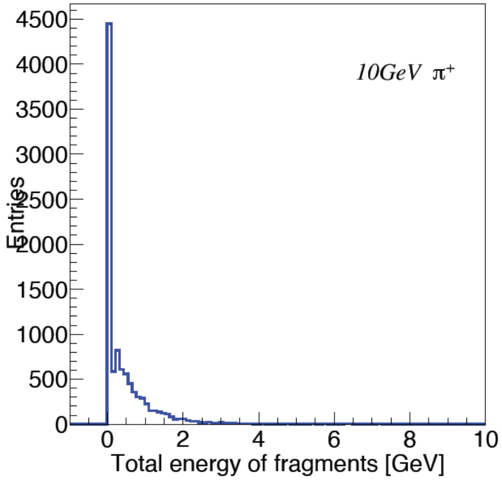
二、粒子流重建算法中误差源的拆解分析与模型构建

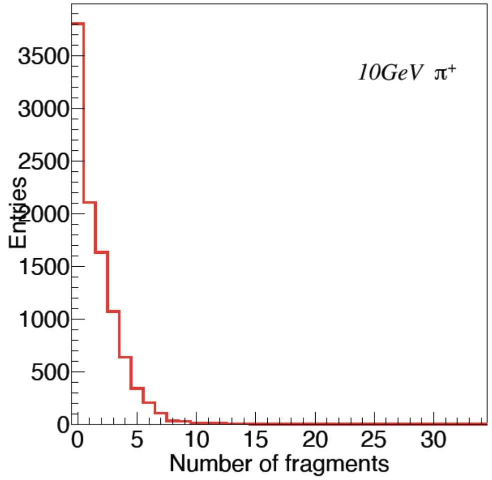
➢ 依赖关系分析——带电强子碎裂簇团

- ➢对 BMR 的影响最显著
- ➢若能完全消除：BMR ~3.8% → 3%
- ➢消除一半：BMR ~3.8% → 3.5%

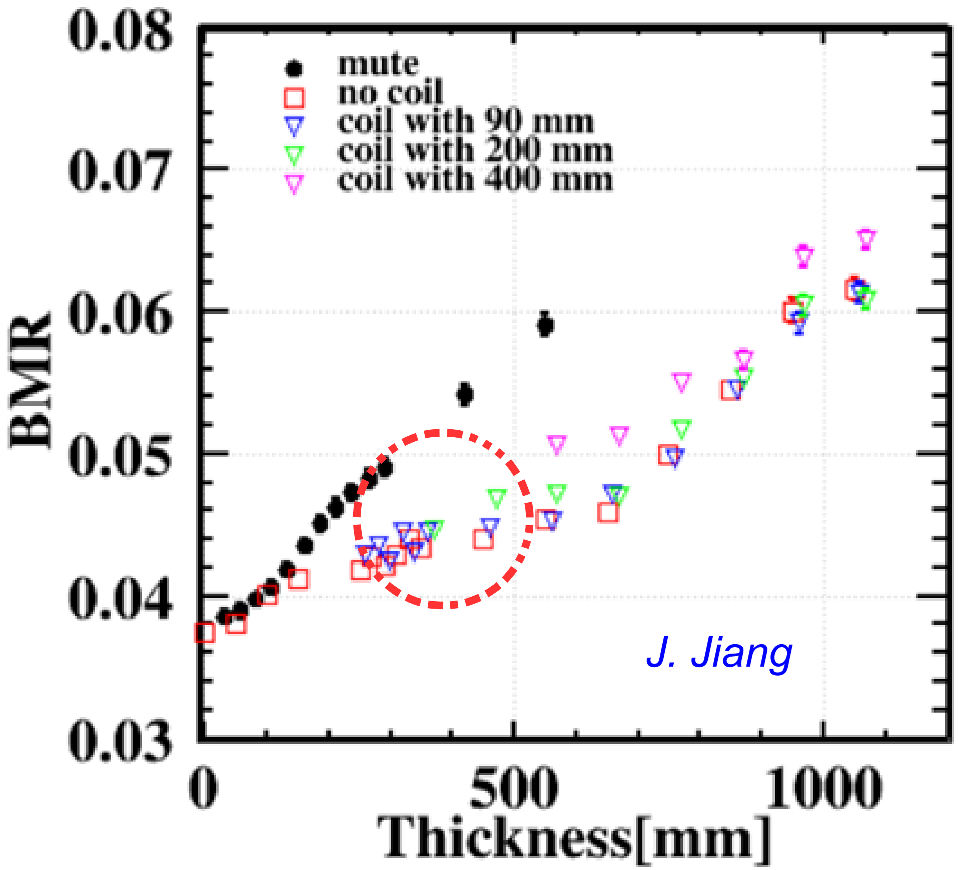


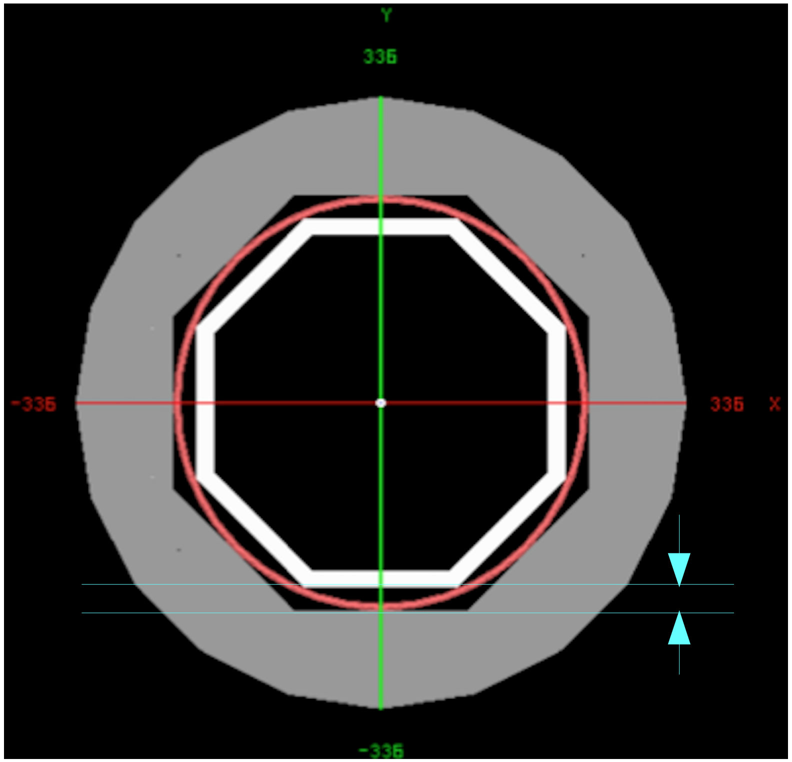






Smaller Solenoid Impact on BMR



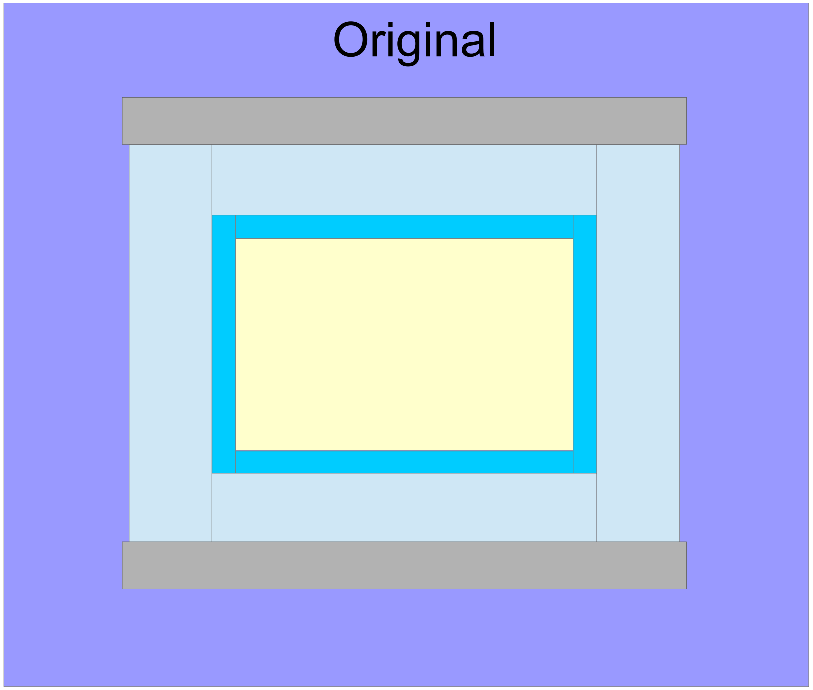


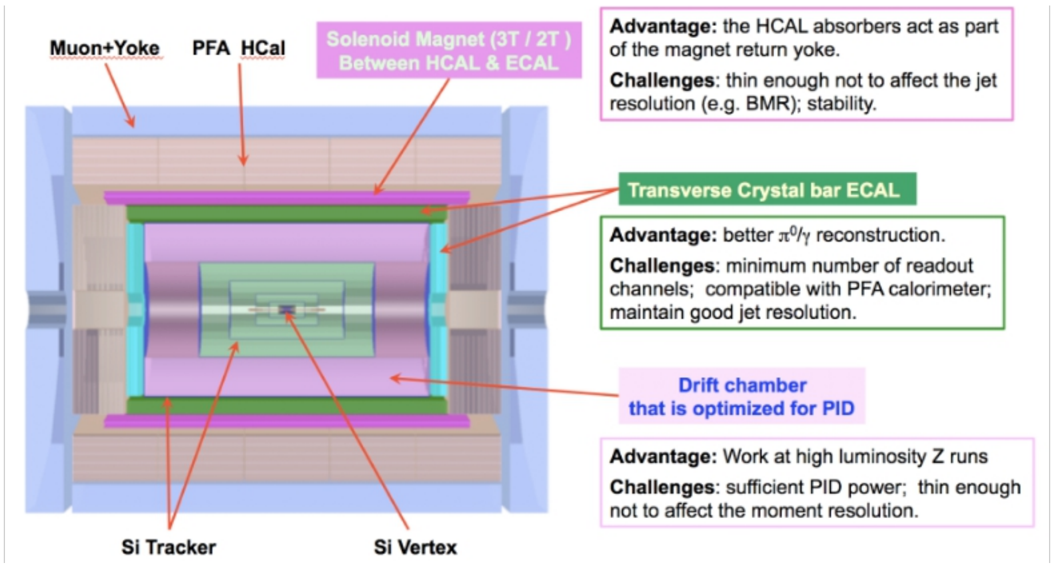
150 mm thick Cylinder Solenoid require at least 300 mm distances between ECAL/HCAL, Solenoid has Material Budget of at least 1 - 2 X_0

BMR Degrades from 3.8% to ~4.4%.

Valve, Dead-zone, etc, will induce further inhomogeneity and degrades the performances.

Difference in cost



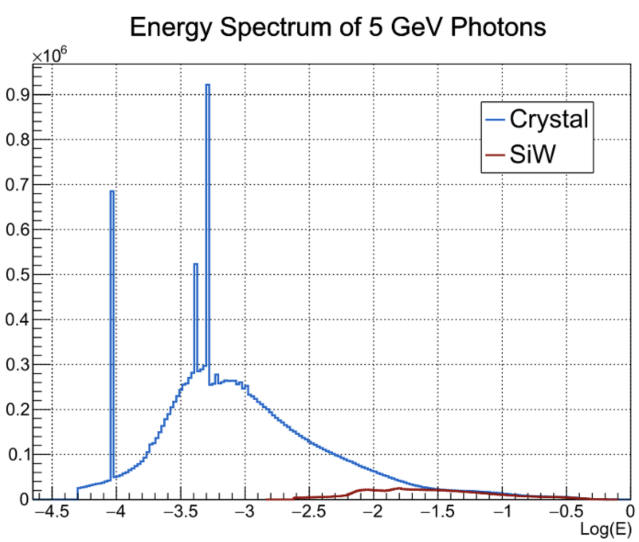


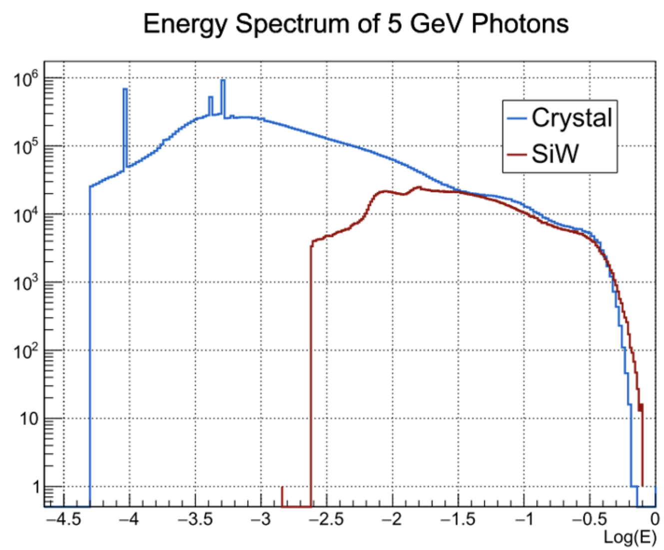
	Inside	Outside
Solenoid (LTS)	10900 w	14706 w
Yoke	? (~ 1000 w)	~ 6000 w
Solenoid (HTS)	14500 – 15400 w	22000 – 23800 w

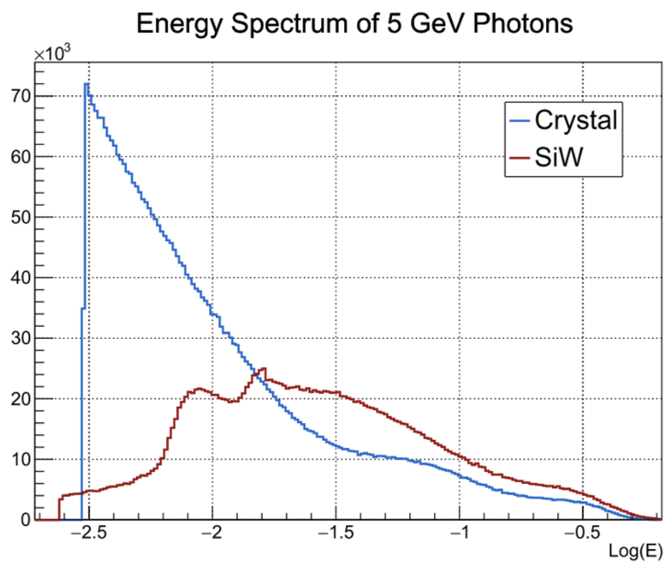
LTS (NiTi): Cost difference ~ 100 M.
HTS(YBCO): Cost difference < 150 M.

Summary

- Tracker: TPC + Silicon → Drift Chamber + Silicon:
  - Almost irrelevant if the Tracker is good enough;
  - BMR: Small margin from Pid, require upstream material in the barrel < 10%, if possible, 5%.
- ECAL: Si+W → Xstal
  - Crystal improves EM resolution, and induces much more hits
  - Small impact on BMR if separation power is ensured.
- HCAL: GRPC + Iron → Glass + Iron
  - Promising
    - Single Particle level improved up to 2 times
    - 10% improvement on BMR (3.3%)
- Solenoid: Outside HCAL → Between ECAL & HCAL
  - BMR degrading to at least 4.4! Strongly disfavor
- Vertex, or VTX + MDI: Lots of margin & need intensive effort



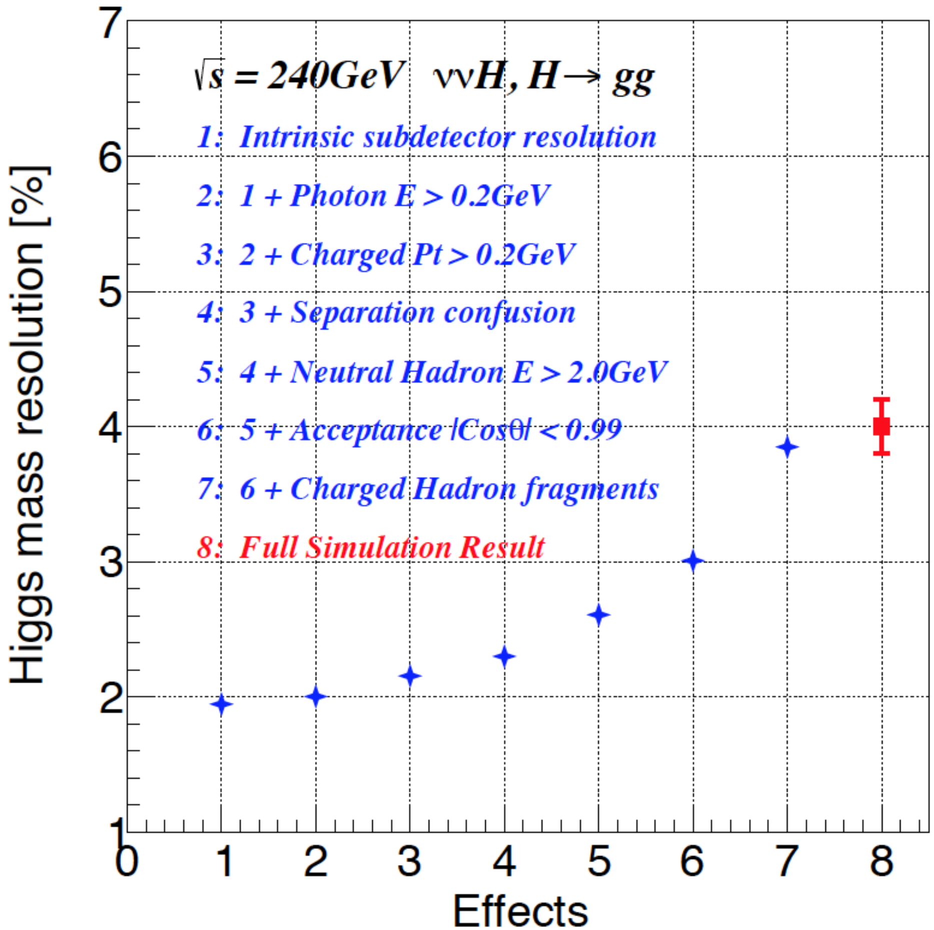


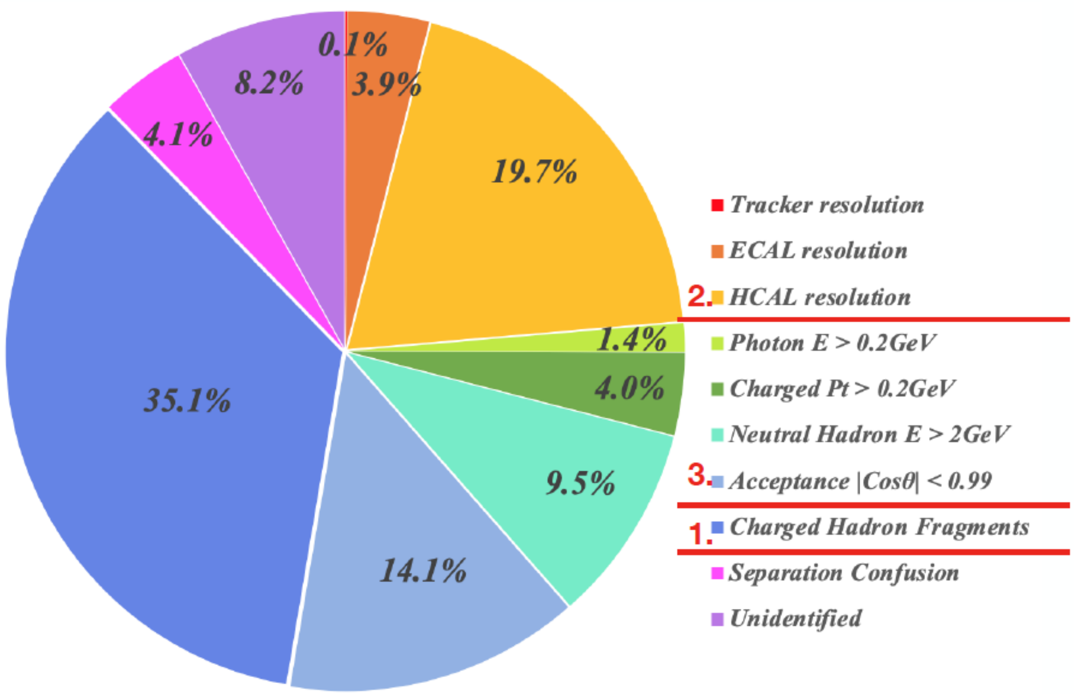


- Original energy spectrum, 10k events, threshold 50 keV
- A large number of low energy hits in crystal ECAL

- Threshold (0.3 MIP): SiW 50 keV, crystal 3 MeV

PFA Fast simulation





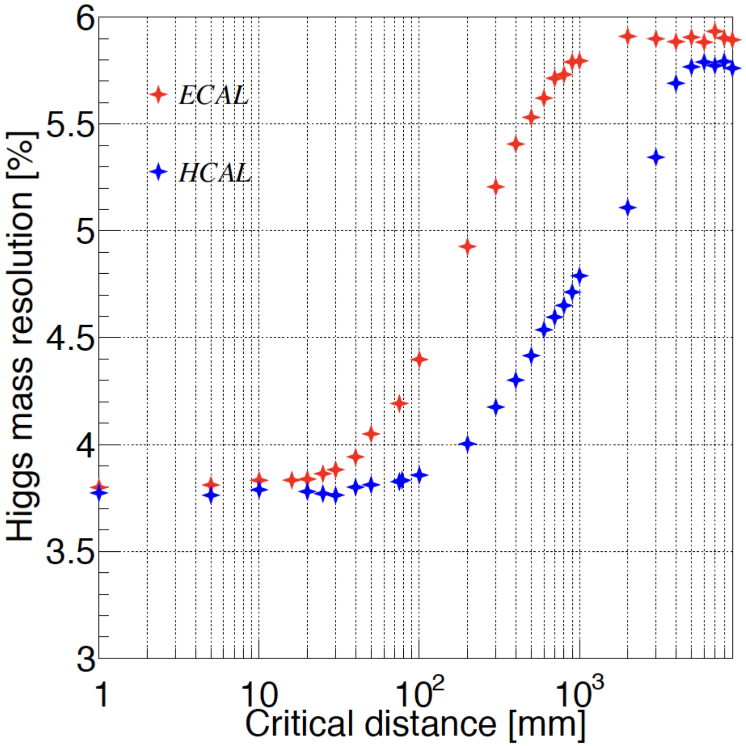
YX. Wang

Exercise so far fits well with the model...

二、粒子流重建算法中误差源的拆解分析与模型构建

➢ 依赖关系分析——临近粒子分离能力

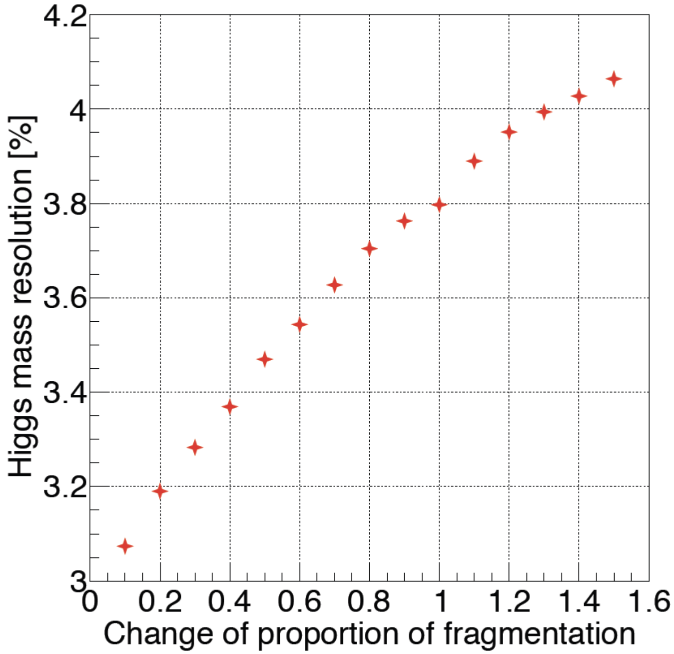
- ➢ 分离能力越差，BMR 越大，最终趋于强子能量分辨
- ➢ 左侧拐点
  - ➢ 电磁簇射 < 20mm
  - ➢ 强子簇射 < 100mm
- ➢ 基线临界分离距离
  - ➢ 电磁簇射 ~16mm
  - ➢ 强子簇射 ~78mm
  - ➢ 基本满足需求

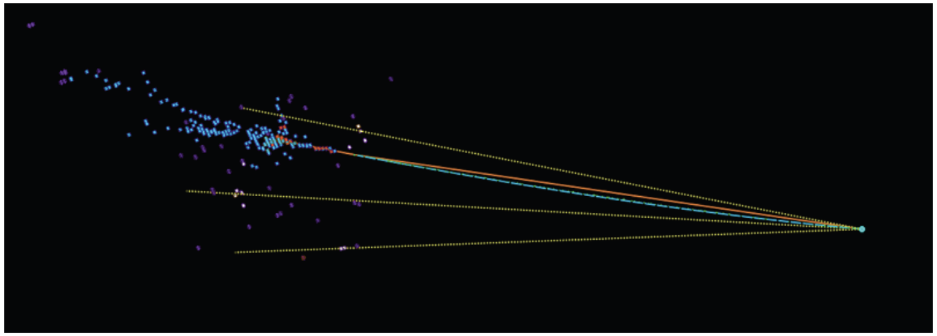


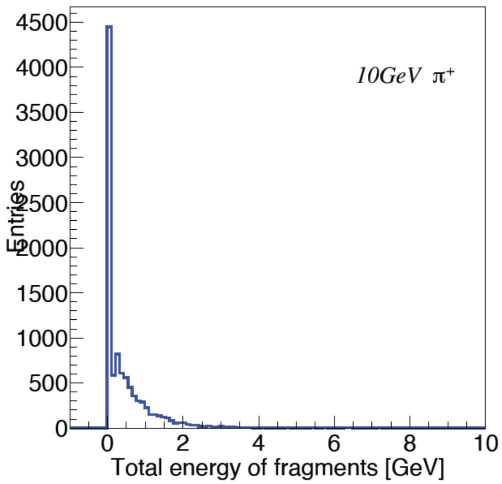
二、粒子流重建算法中误差源的拆解分析与模型构建

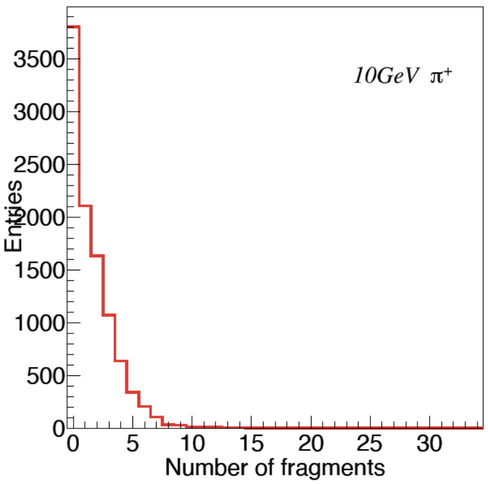
➢ 依赖关系分析——带电强子碎裂簇团

- ➢对 BMR 的影响最显著
- ➢若能完全消除：BMR ~3.8% → 3%
- ➢消除一半：BMR ~3.8% → 3.5%





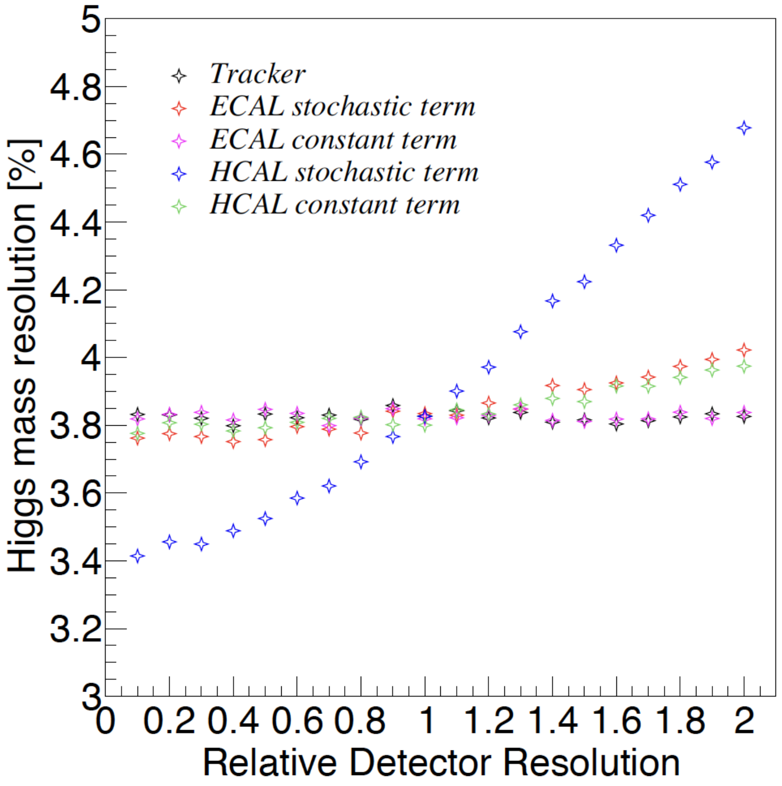




二、粒子流重建算法中误差源的拆解分析与模型构建

➢ 依赖关系分析——探测器本征分辨率

- ➢ 基线性能（基准点1）
  - ➢ 径迹动量分辨率 ~0.1%
  - ➢ 电磁能量分辨率 $17\%/\sqrt{E} \oplus 1\%$
  - ➢ 强子能量分辨率 $59.2\%/\sqrt{E} \oplus 6.3\%$
- ➢ 依赖关系
  - ➢ 对强子能量分辨率统计项最敏感
    - ➢ $59.2\%/\sqrt{E} \rightarrow 40\%/\sqrt{E}$
    - ➢ BMR 3.8% → 3.6%
  - ➢ 电磁统计项和强子常数项的影响次之
  - ➢ 电磁常数项和径迹动量分辨率影响最弱



低温超导方案（不包括轭铁）

		Inside（万元）	Outside（万元）
超导线圈	超导电缆	3050	5760
	线圈加工测试	1500	1885
磁体内部低温	阀箱、吊挂、冷却结构、恒温器	1500	2215
制冷系统	低温系统，管道及支架、低温控制	2000	2000
真空系统	机械泵、分子泵、质谱仪等	310	310
电源及失超保护	电源、失超保护系统、母排	2000	2000
控制系统	检测及联锁控制	160	160
磁测系统	测磁机安装设计制造	376	376
总额		10,896	14,706

高温超导方案（不包括轭铁）

	Inside		Outside	
超导电缆	电缆长 9 km，其中有带材 35 层，共 315 km，目前市场价 350 元/米，1.1 亿元，电缆覆铝加工 1 千万元。	12,000 万元	电缆长 21 km，其中有带材 30 层，共 630 km，目前市场价 350 元/米，2.2 亿元，电缆覆铝加工 2 千万元。	24,000 万元
	考虑 5 年后电缆性能的提升，带材用量的减少，以及大批量采购带来的价格降低，170-200 元/米	6,355 ~ 7,300 万元	考虑 5 年后电缆性能的提升，带材用量的减少，以及大批量采购带来的价格降低，170-200 元/米	12,710~ 14,600 万元
线圈加工	比低温超导多电缆接头制作	1,800 万元		2,200 万元
其他部分与低温方案相同	1500+2000+310+2000+160+376	6,346 万元	2215+2000+310+2000+160+376	7,061 万元
总额		18,729 万元		33,261 万元
		14,501 ~ 15,446 万元		21,971 ~ 23,861 万元