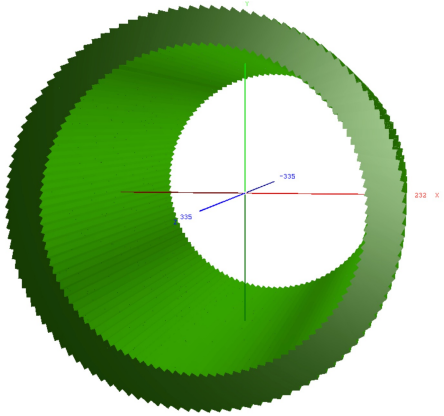
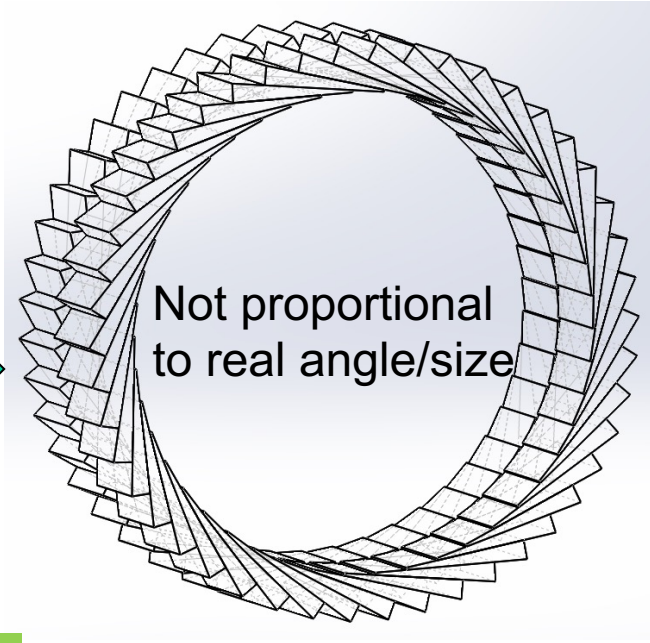
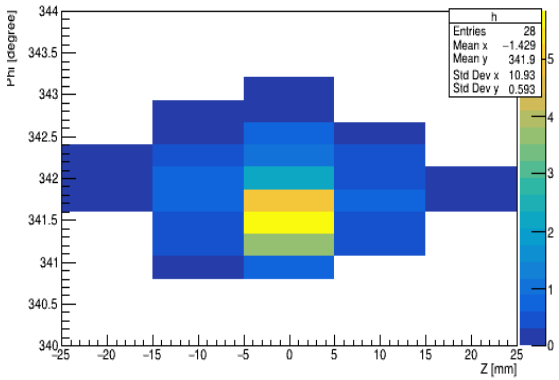
Stereo Crystal Electromagnetic Calorimeter: Design

- To improve the 3D position resolution
  - Pointing angle of even layers alone Z: α
  - Pointing angle of odd layers alone Z: $\alpha' = -\alpha$

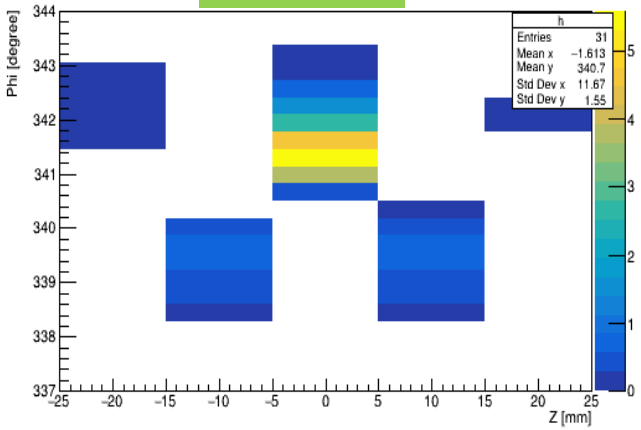




Traditional Crystal Ecal



SCEcal

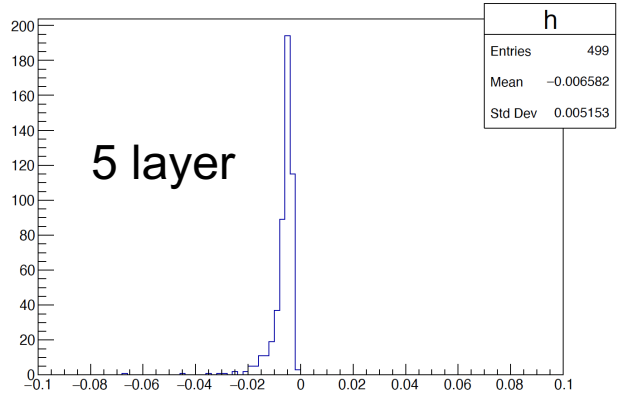


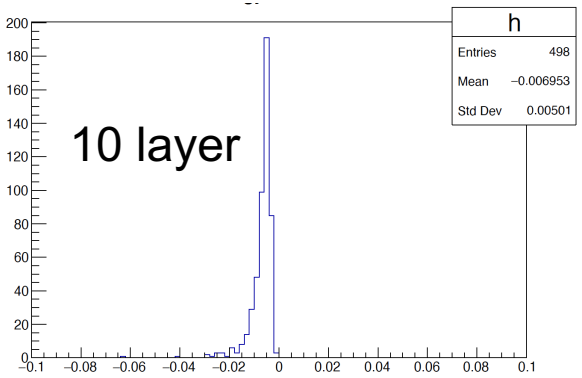
Left eye

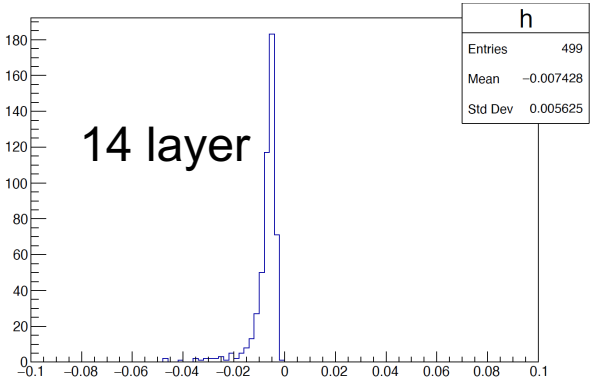
Right eye

Configuration of 5/10/14 layers along R

- Taget: change layers along R, keep similar Z/phi segmentation
  - 5 layers: α=10°; crystal size: [9]*10*304 mm^3, n = 1309 * 671;
  - 10 layers: α=20°; crystal size: [8.8-8.9]*10*316 mm^3, n = 1276 * 671
  - 14 layers: α=30°; crystal size: [9.1-9.4]*10*339 mm^3, n = 1141 * 671
- Simulated 30 GeV photon pointing at theta = 90, phi = [10-350]
- Simpler clustering algorithm with threshold of 1 MeV
- Energy/Z resolution do not change for different layers along R







E std. dev. ~0.5%@30GeV

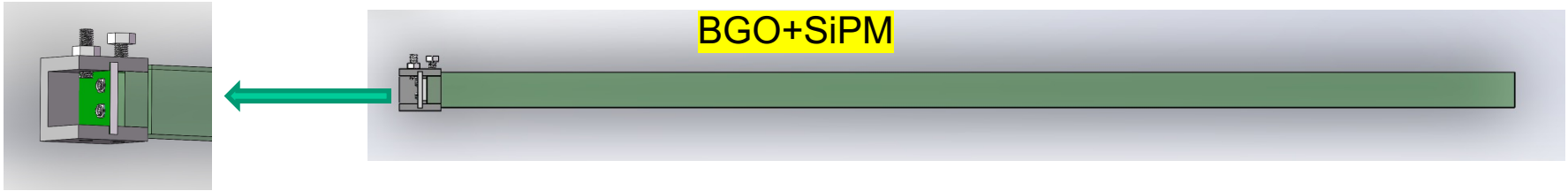
Design of Endcap SCECal

- Total shape looks like bottle stopper

not in Simulation yet

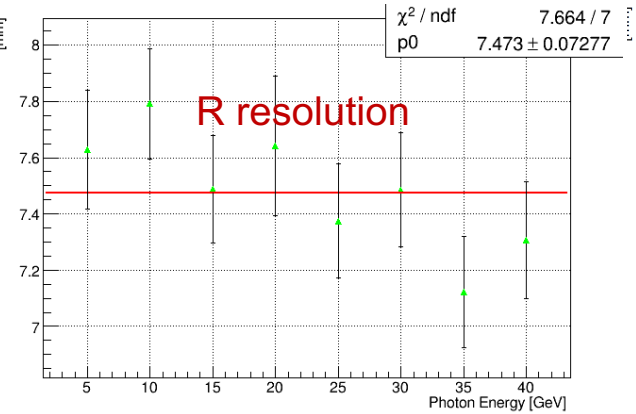
- Option 1:
  - Similar idea of pointing angle definition along phi for each layer with same polar angle.
  - Adjacent layers(same polar angle) with reversed pointing angle
- Option 2:
  - The pointing angle defined as angle between beam direction in (ex. Horizontal plane) for crystals in the same horizontal plate
  - Adjacent layers(same horizontal plane) with reversed pointing angle

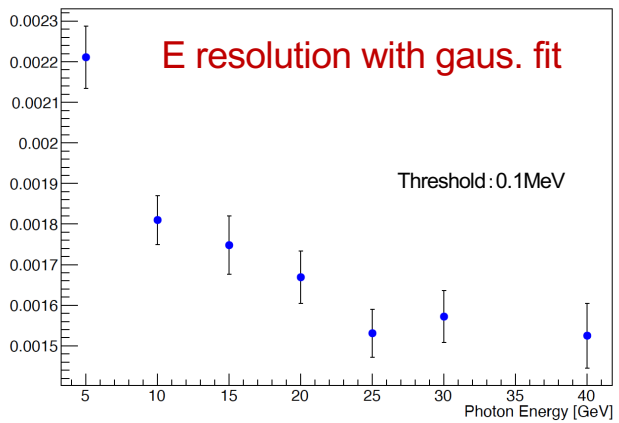
- SiPM Readout and mounting at outside plane(same as Barrel)

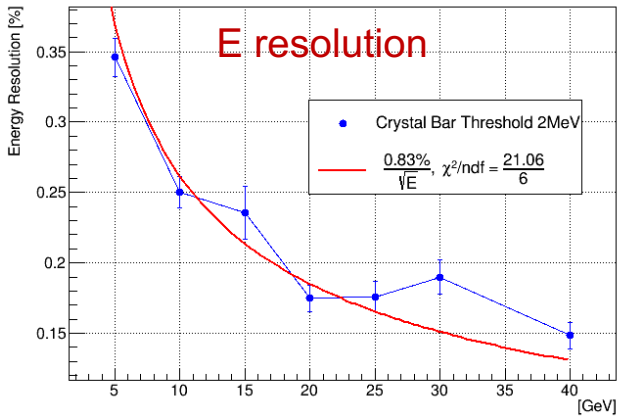


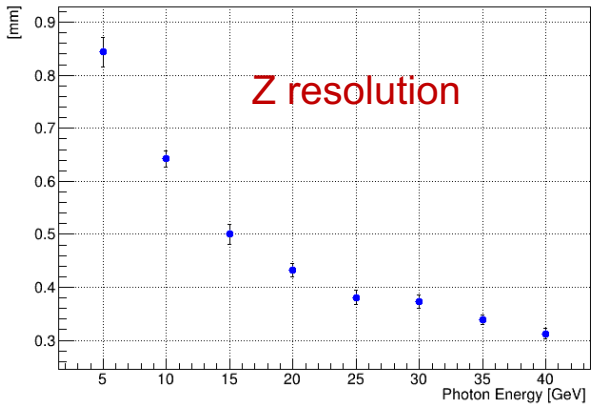
Performance of Energy and 3D positioning resolution

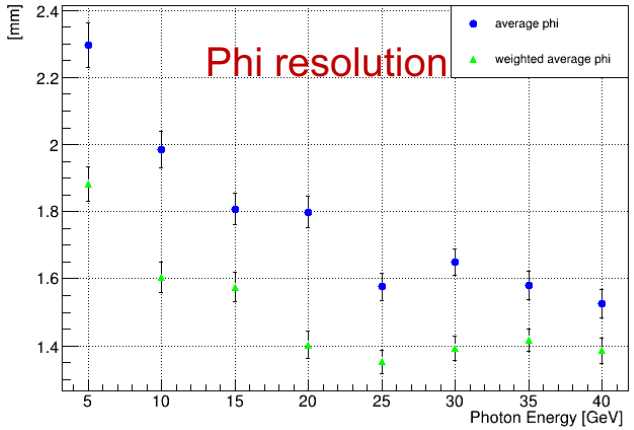
- **5GeV gamma, phi: 10~350°(bugfix needed around 0), theta: 90°**
  - Z resolution ~ 0.84 mm; Phi resolution ~ 1.9 mm
  - R resolution ~ 7.6 mm; Energy resolution as function of Threshold

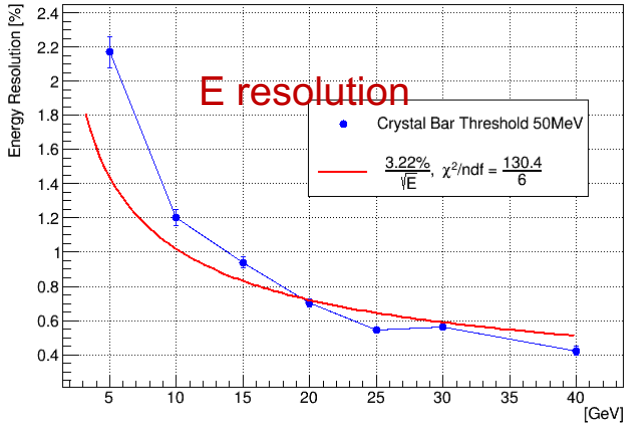






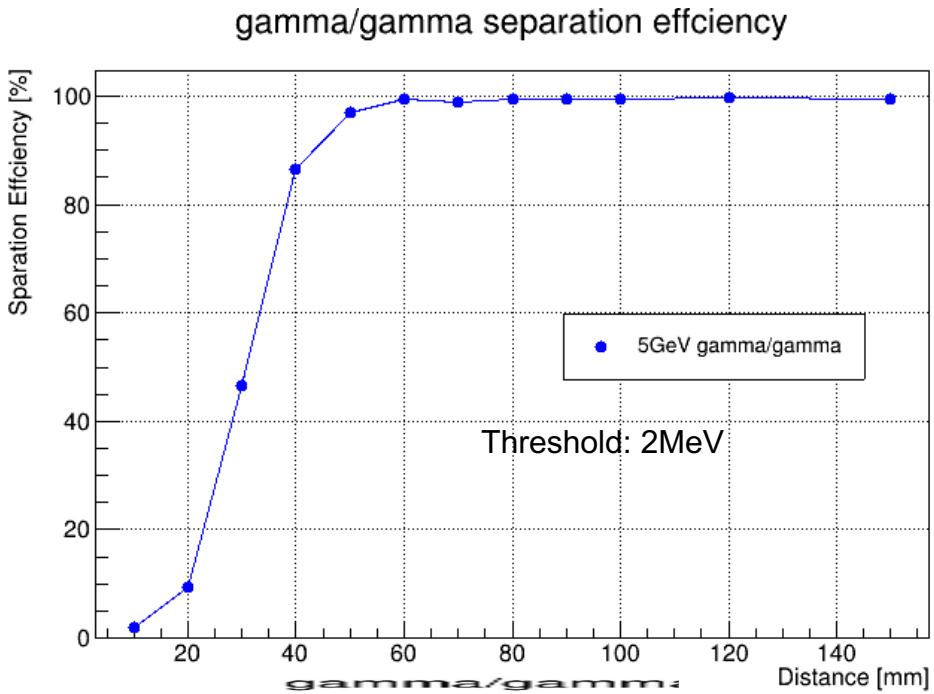


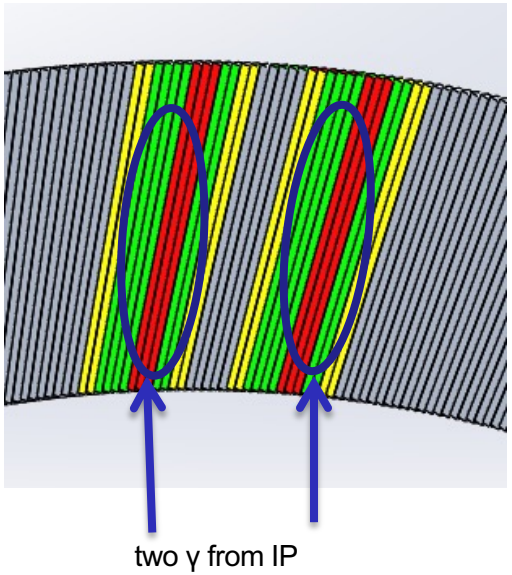


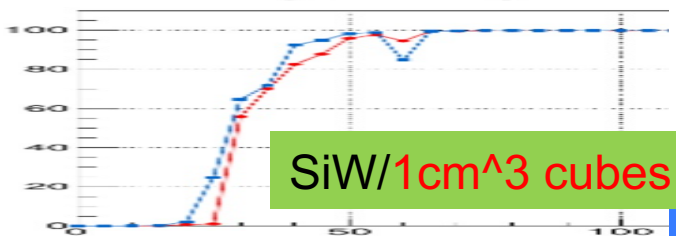


Separation between two 5 GeV photons

- Two 5 GeV photons, vary distance along phi between them
- Success reconstruction: 2 neutral particles, 3.3GeV<Eγ<6.6GeV for each photon



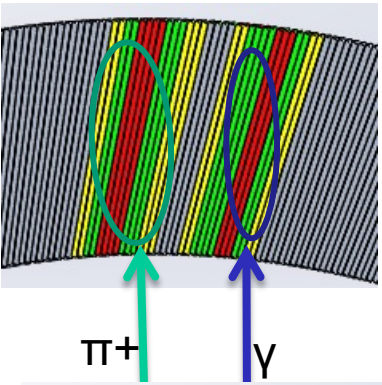


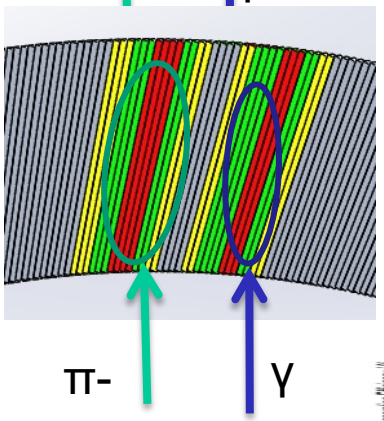


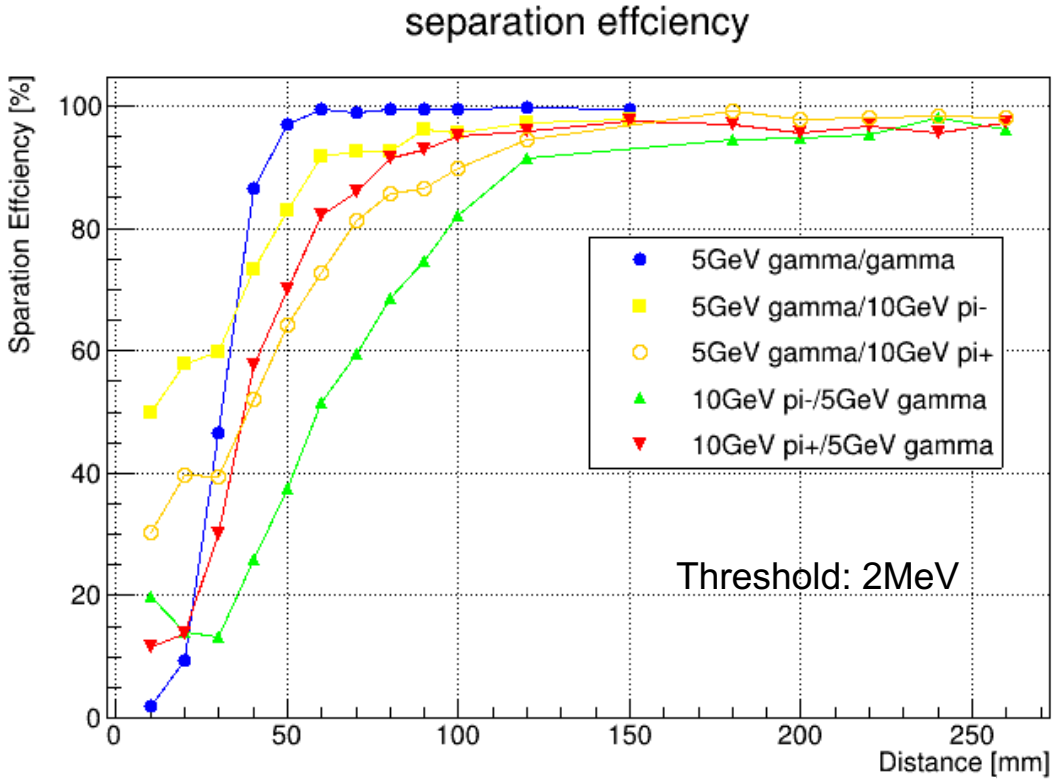
SiW/1cm^3 cubes Crys.

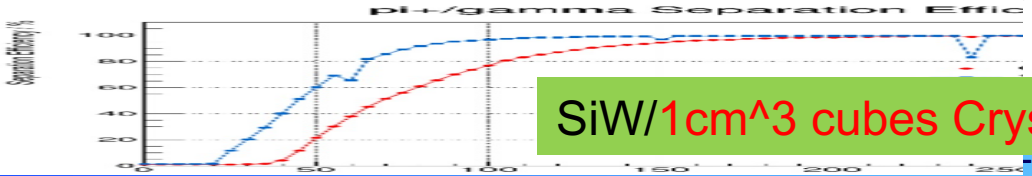
Separation between γ/π

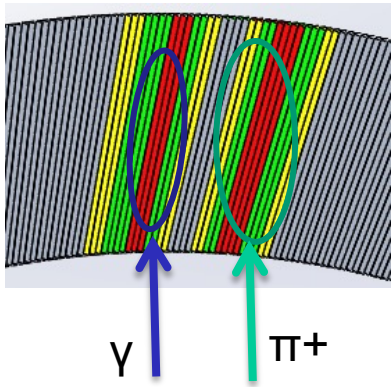
- 5 GeV γ/10GeV π, vary distance along phi between them
- Success reconstruction: 3.3GeV<E_γ<6.6GeV
- Different π/γ separation power: pointing angle / magnetic field

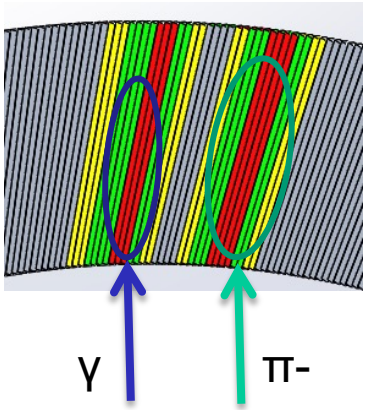








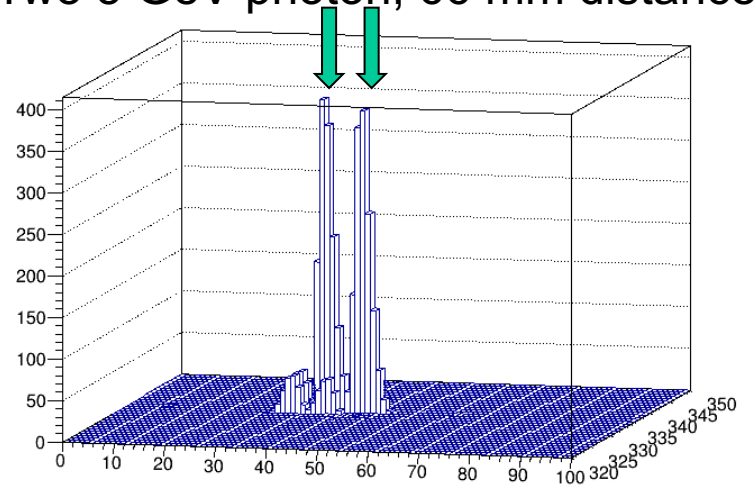




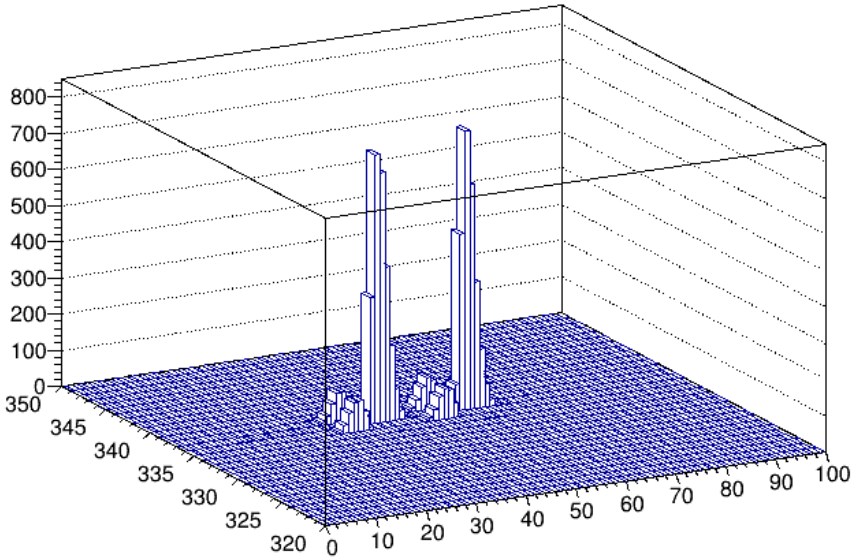
SiW/1cm^3 cubes Crys.

Event display of shower seperation

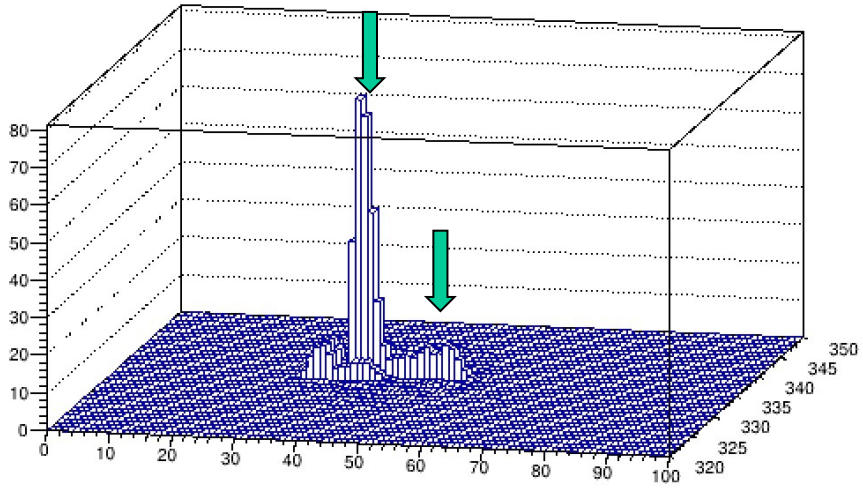
Two 5 GeV photon, 66 mm distance



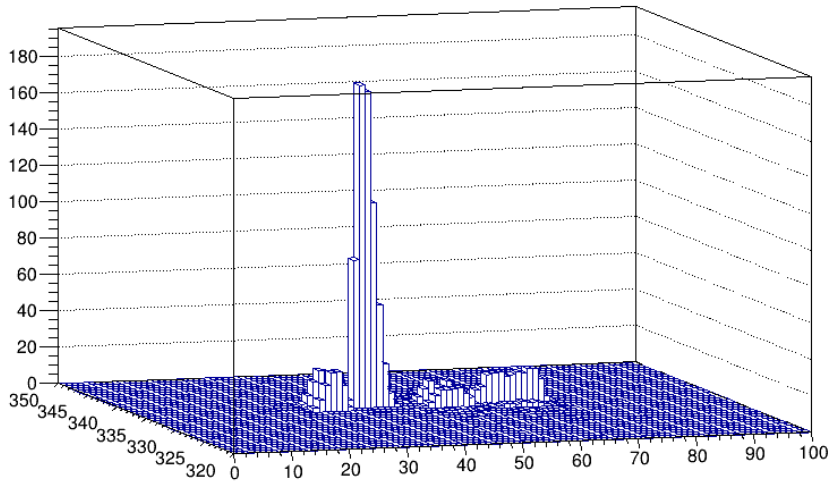
Two 5 GeV photon, 165 mm distance



5 GeV photon and 10 GeV pi-, 66mm

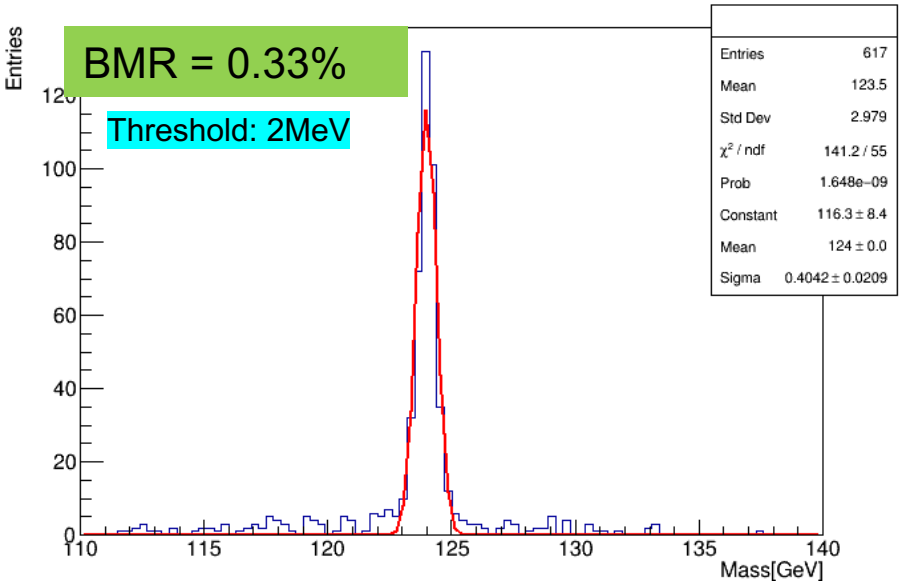


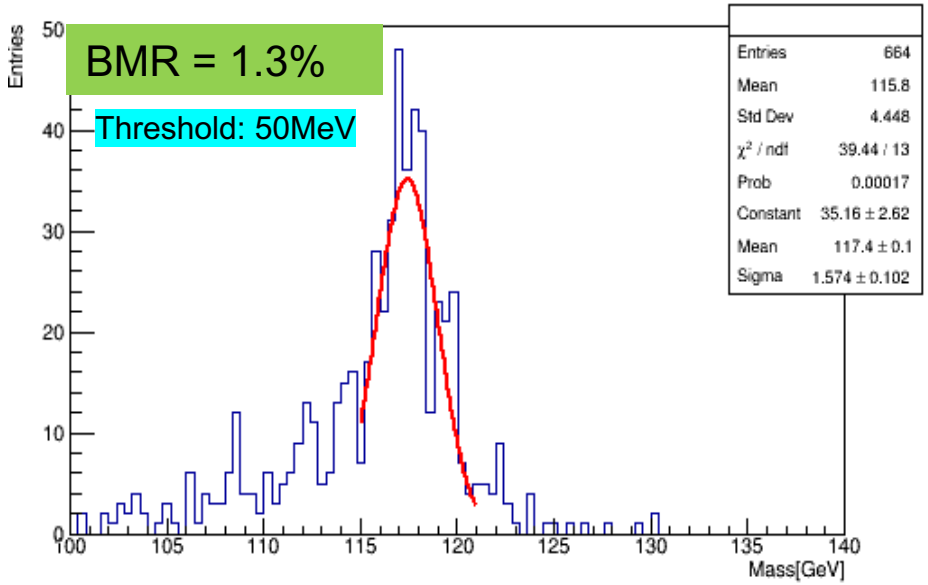
5 GeV photon and 10 GeV pi-, 195mm



Boson mass resolution in H→ γγ

- Sample: ZH->2neutrinos + γγ at 240 GeV
- Energy, position reconstruction and separation using simplified reconstruction method described above
- Crystal energy threshold: 2 MeV/50MeV

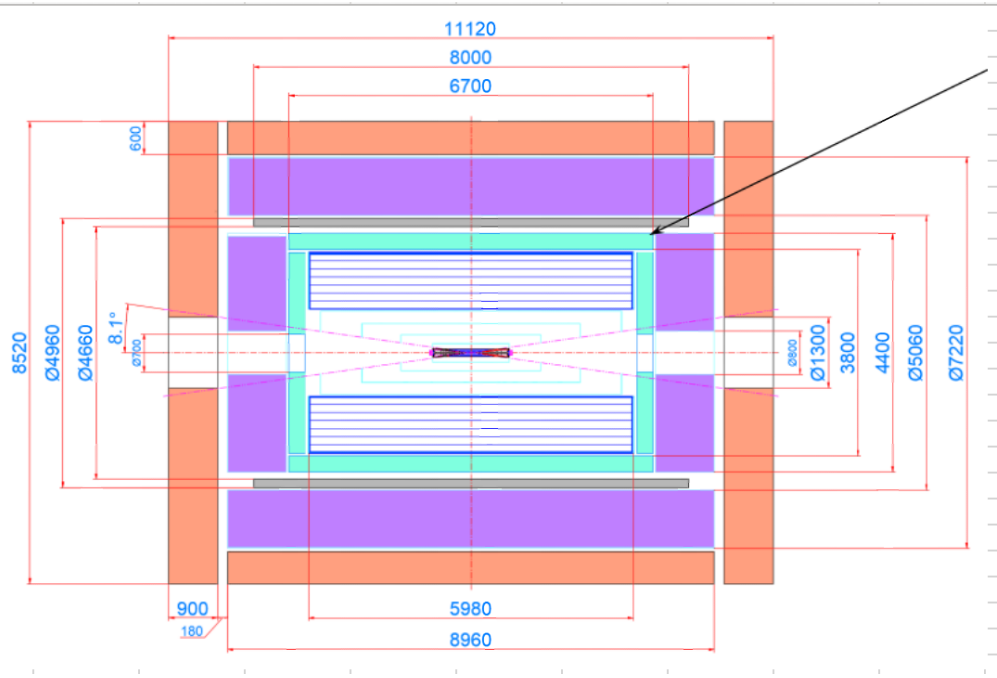




Dimension and cost

obsoleted

桶部	单位（毫米）				
内部直径	3800	外部直径	4400	长度	6700
晶体	BGO	市场参考价格：	￥1000.00/kg左右		
大小	[8.8-8.9]*10*316	数量	854,920=1276 * 670	体积	25.9m3
重量	184.6吨	价格	1.85亿		
机械设计	纯圆桶				
外径面支撑/悬挂		内径面辅助		沿4个session	
竖直组装，旋转90度后推入					
端盖*2	单位（毫米）				
内部直径	700	外部直径	3800	厚度	3000*2
晶体	BGO	市场参考价格：	￥1000.00/kg左右		
大小	[8.8-8.9]*10*316	数量	~218,000	体积	6.7 m3
重量	47.8吨	价格	4800万		
机械设计					
内径面支撑					
电子学	~1百万通道（1073k）				
前端板	1.6	母版	1.6	间隙	2
功耗	~22kW(20mw/channel?	价格	2200万（20/ch）		



Dimension and cost

桶部	单位（毫米）				
内部直径	3800	最大外部直径	4400	长度	6100
晶体	BGO（24X0）	市场参考价格：	￥4000.00/kg左右		
大小	(8.0-8.1)*10*284	数量	855220=1402*610	体积	21.0m3
重量	150吨	价格	6亿		
机械设计	纯圆桶				
外径面支撑/悬挂		内径面辅助		沿5？个session	
竖直组装，旋转90度后推入					
端盖*2	单位（毫米）				
内部直径	700	外部直径	3800	厚度	24X0*2
晶体	BGO（24X0）	市场参考价格：	￥4000.00/kg左右		
大小	8*10*284	数量	313580	体积	7.7 m3
重量	55.2吨	价格	2.2亿		
机械设计					
内径面支撑					
电子学	~1百20万通道（1169k）				
前端板	1.6	母版	1.6	间隙	2
功耗	~22kW(20mw/channel?	价格	2400万（20/ch）		
SiPM	80元/channel	价格	9600万		

Typical crystals (From Ren-yuan Zhu's slides)

Crystal	NaI(Tl)	CsI(Tl)	CsI	BaF_2	BGO	LYSO(Ce)	PWO	PbF_2
Density (g/cm^3)	3.67	4.51	4.51	4.89	7.13	7.40	8.3	7.77
Melting Point (°C)	651	621	621	1280	1050	2050	1123	824
Radiation Length (cm)	2.59	1.86	1.86	2.03	1.12	1.14	0.89	0.93
Molière Radius (cm)	4.13	3.57	3.57	3.10	2.23	2.07	2.00	2.21
Interaction Length (cm)	42.9	39.3	39.3	30.7	22.8	20.9	20.7	21.0
Refractive Index [a]	1.85	1.79	1.95	1.50	2.15	1.82	2.20	1.82
Hygroscopicity	Yes	Slight	Slight	No	No	No	No	No
Luminescence [b] (nm) (at peak)	410	550	310	300 220	480	402	425 420	?
Decay Time [b] (ns)	245	1220	26	650 0.	300	40	30 10	?
Light Yield [b,c] (%)	100	165	3.7	36 4.1	21	85	0.3 0.1	?
d(LY)/dT [b] (%/ °C)	-0.2	0.4	-1.4	-1.9 0.1	-0.9	-0.2	-2.5	?
Experiment	Crystal Ball	BaBar BELLE BES III	KTeV BELLE Mu2e	(GEM) TAPS Mu2e-II	L3 BELLE EIC?	Comet {Mu2e,SuperB) CMS MTD	CMS ALICE PANDA	A4 g-2 HHCAL?

a. at peak of emission; b. up/low row: slow/fast component; c. QE of readout device taken out.