中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

The Chinese Academy of Sciences

Would the very Fast Photon Detector (LAPPD) Benefit for JUNO and CEPC?

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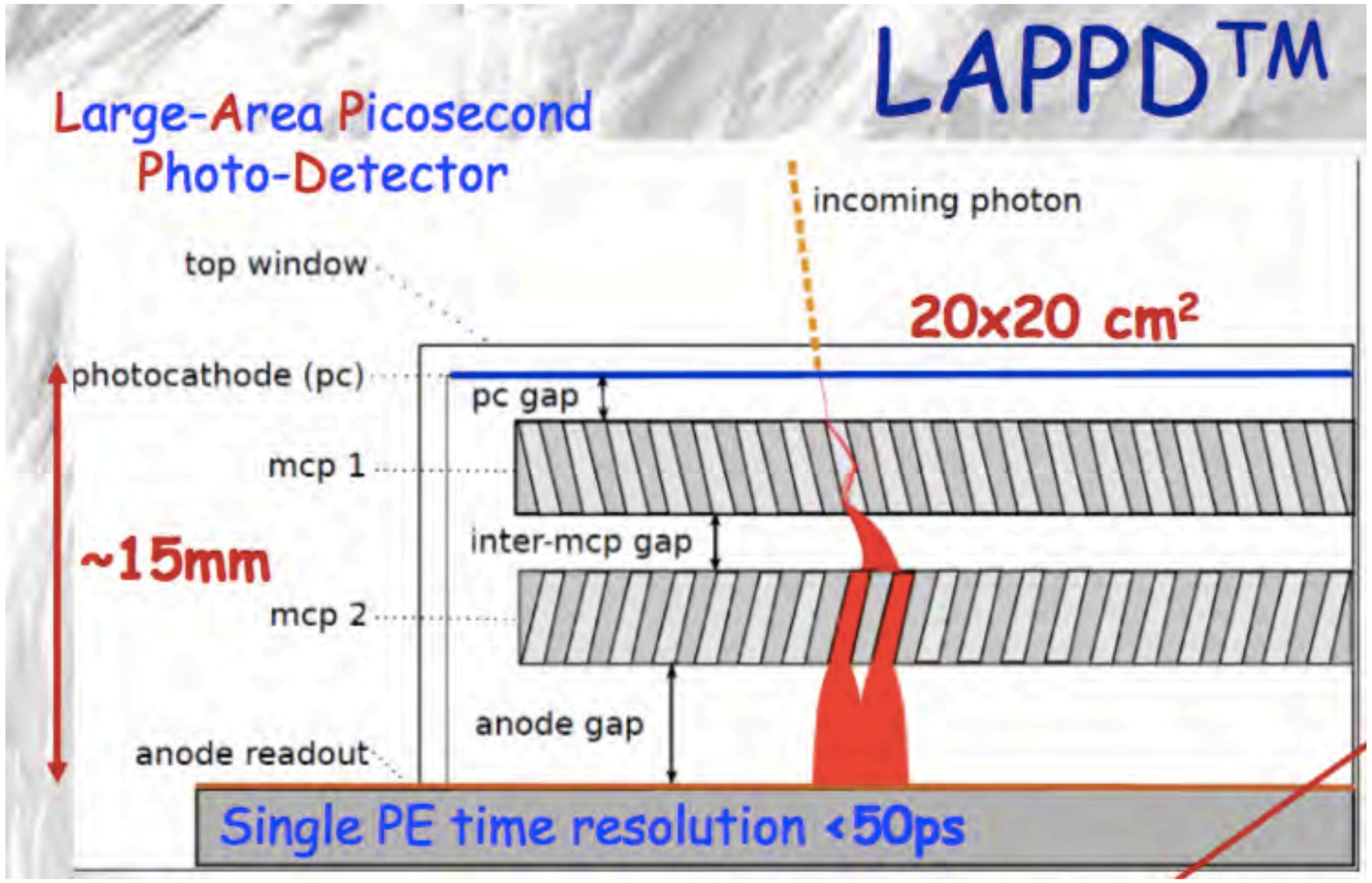
17th. Mar. 2018

Fermilab-Chicago Timing Planning Meeting



Demonstrated characteristics:

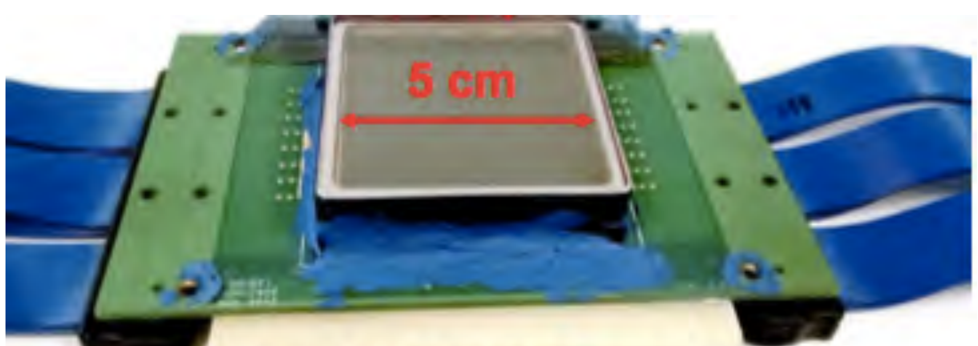
single PE timing: **~50ps**

multi PE timing: **~35 ps**

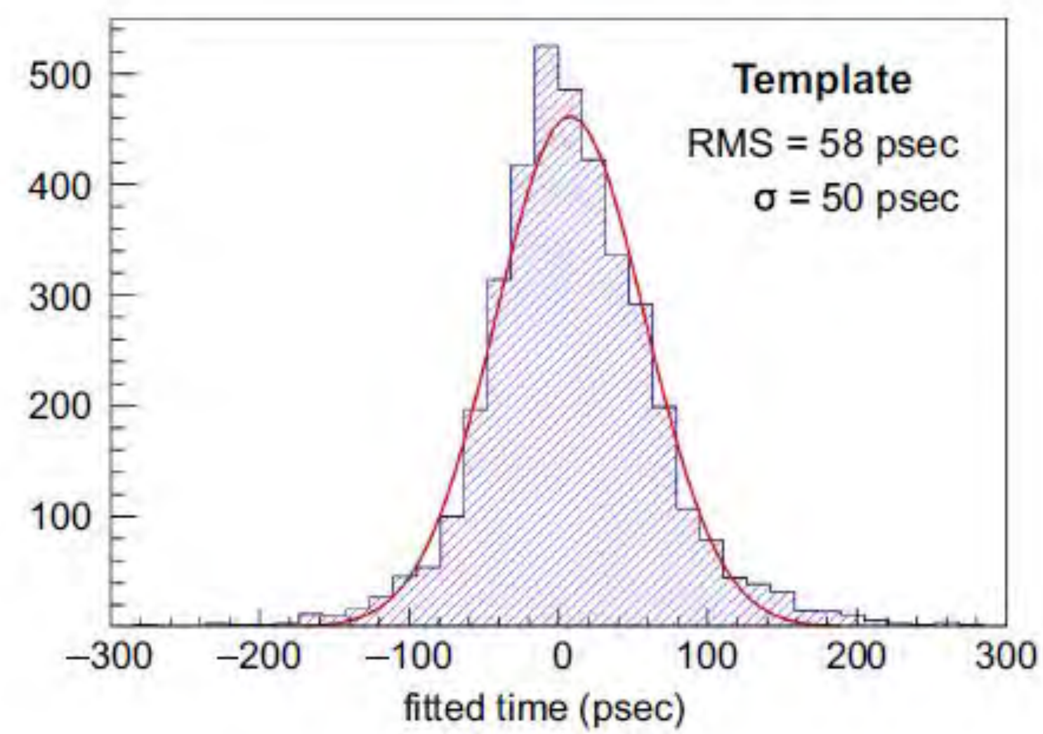
differential timing: **~5 ps**

position resolution **< 1 mm**

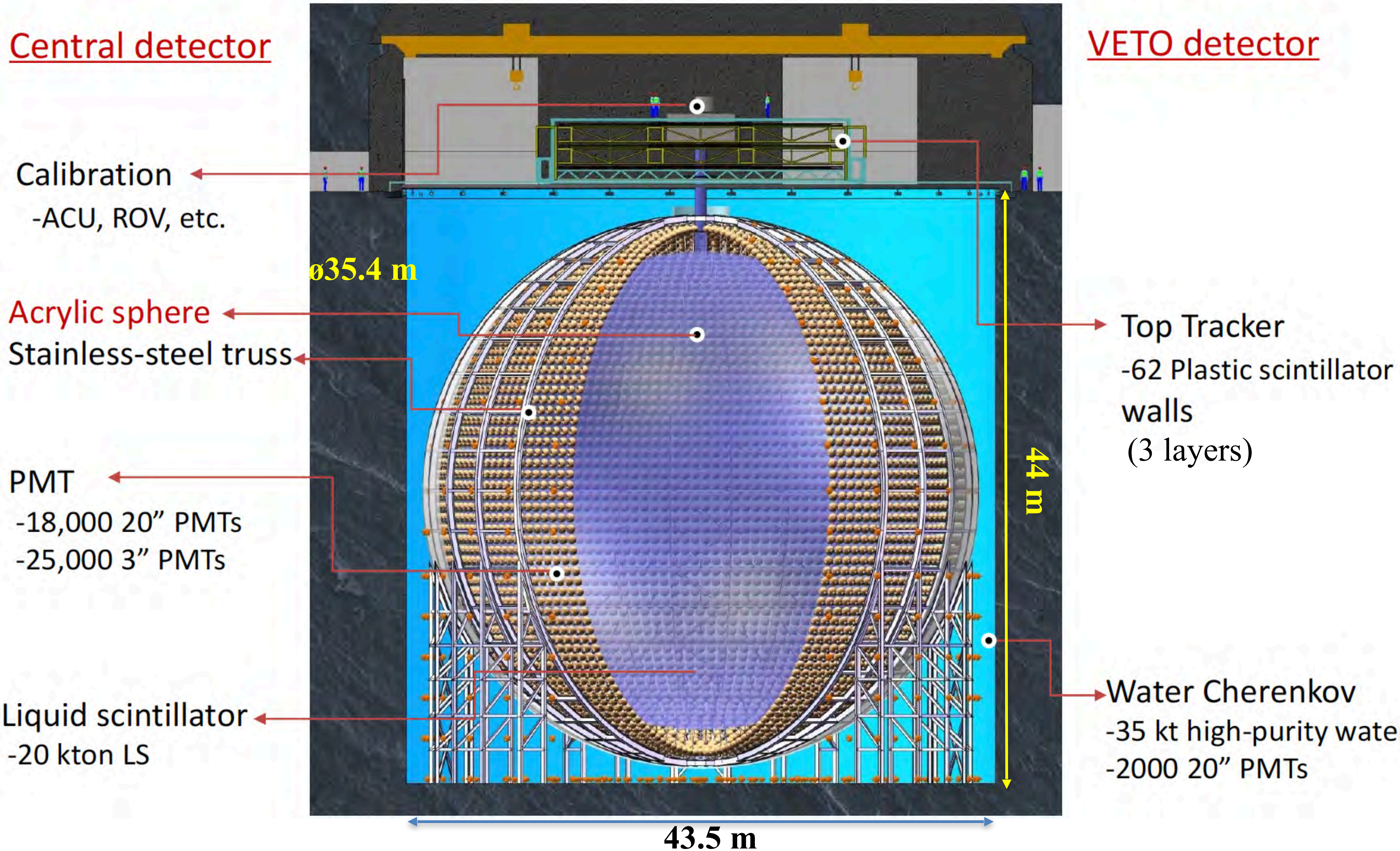
gain $>10^7$



Five Photonis Planacons

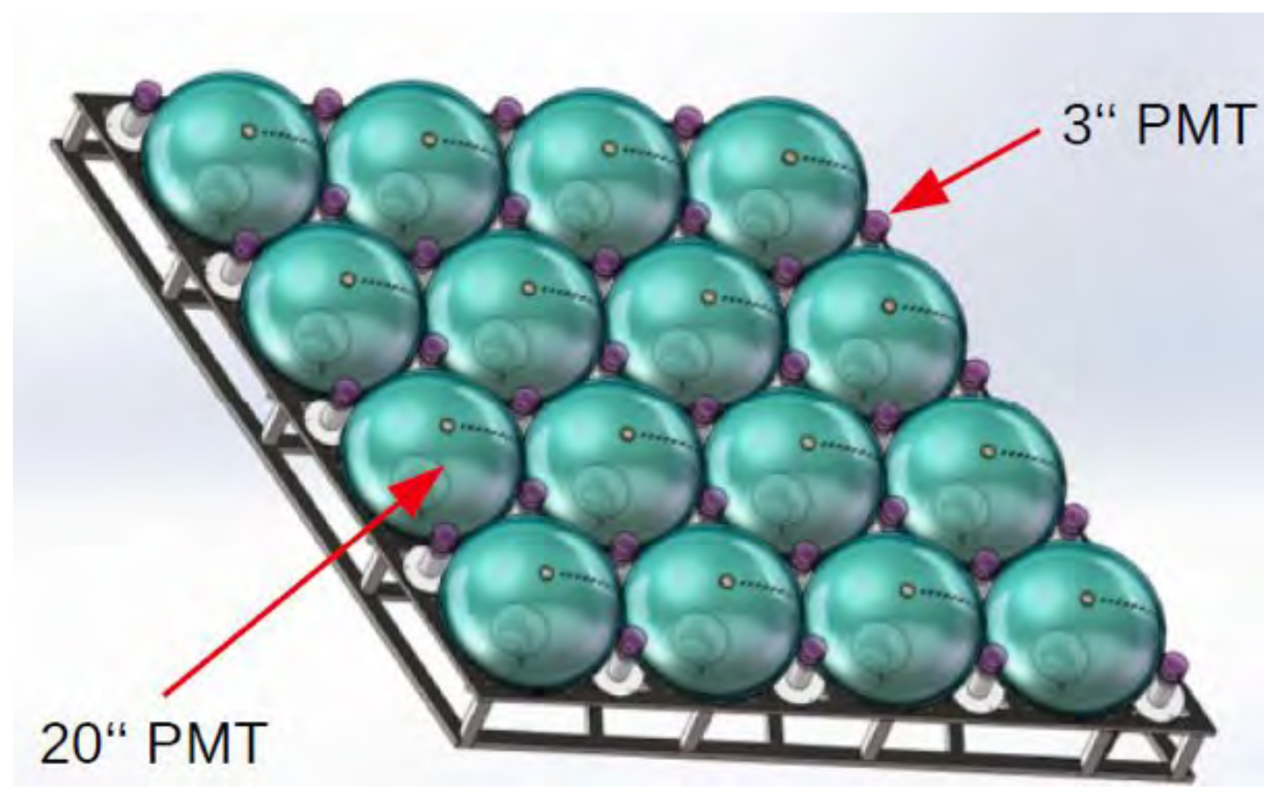


1.0. The overview of JUNO



➢ 1.1. The PMTs in JUNO

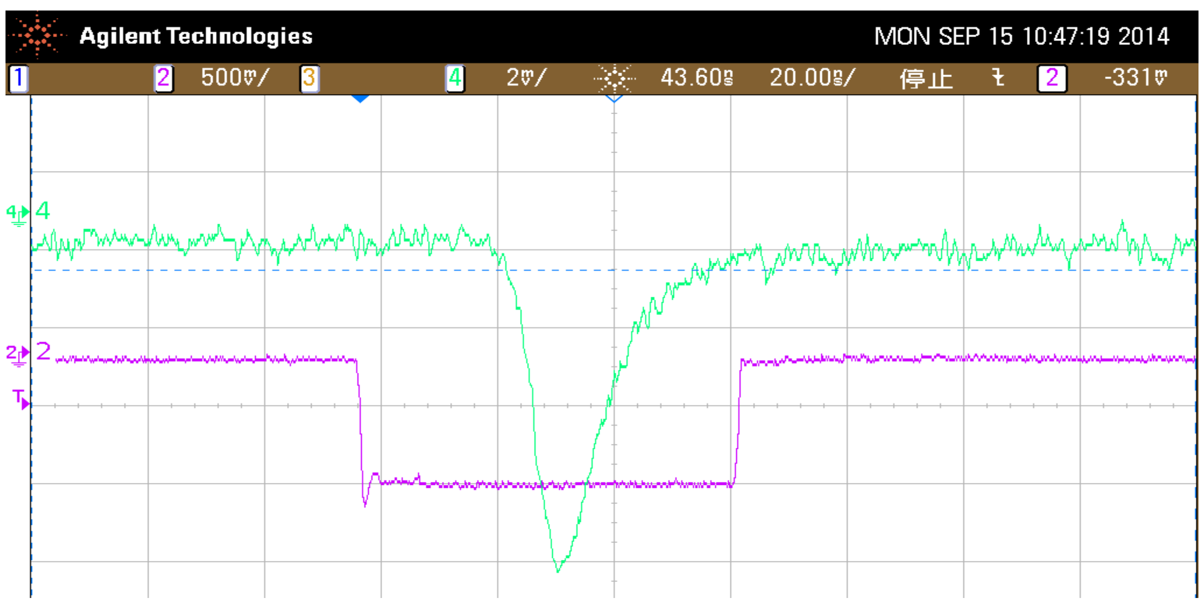
Characteristics	unit	MCP-PMT（NNVC）	R12860（Hamamatsu）
Detection Eff.(QE*CE*area)	%	27%, > 24%	27%, > 24%
P/V of SPE		3.5, > 2.8	3, > 2.5
TTS on the top point	ns	~12, < 15	2.7, < 3.5
Rise time/ Fall time	ns	R~2 , F~12	R~5, <7; F~9, <12
Anode Dark Count	Hz	20K, < 30K	10K, < 50K
After Pulse Rate	%	1, <2	10, < 15
Radioactivity of glass	ppb	238U:50 232Th:50 40K: 20	238U:400 232Th:400 40K: 40



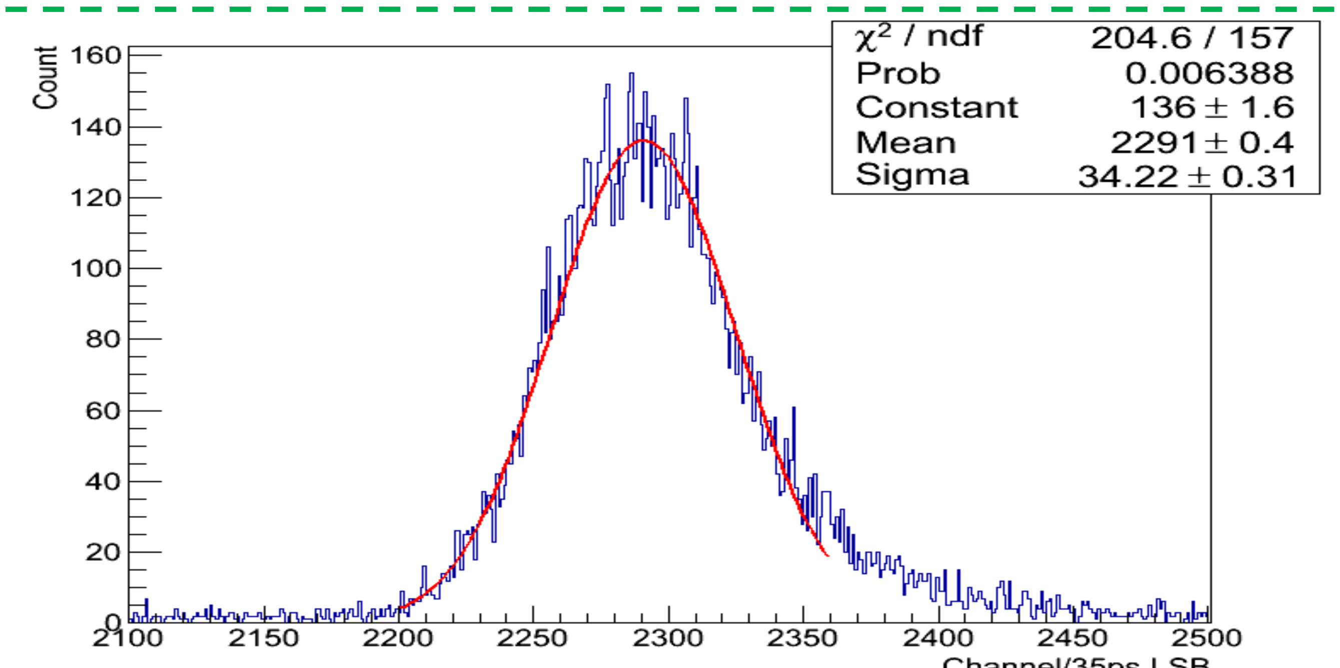
The time characteristics of the PMTs in JUNO @ Gain~1X10^7

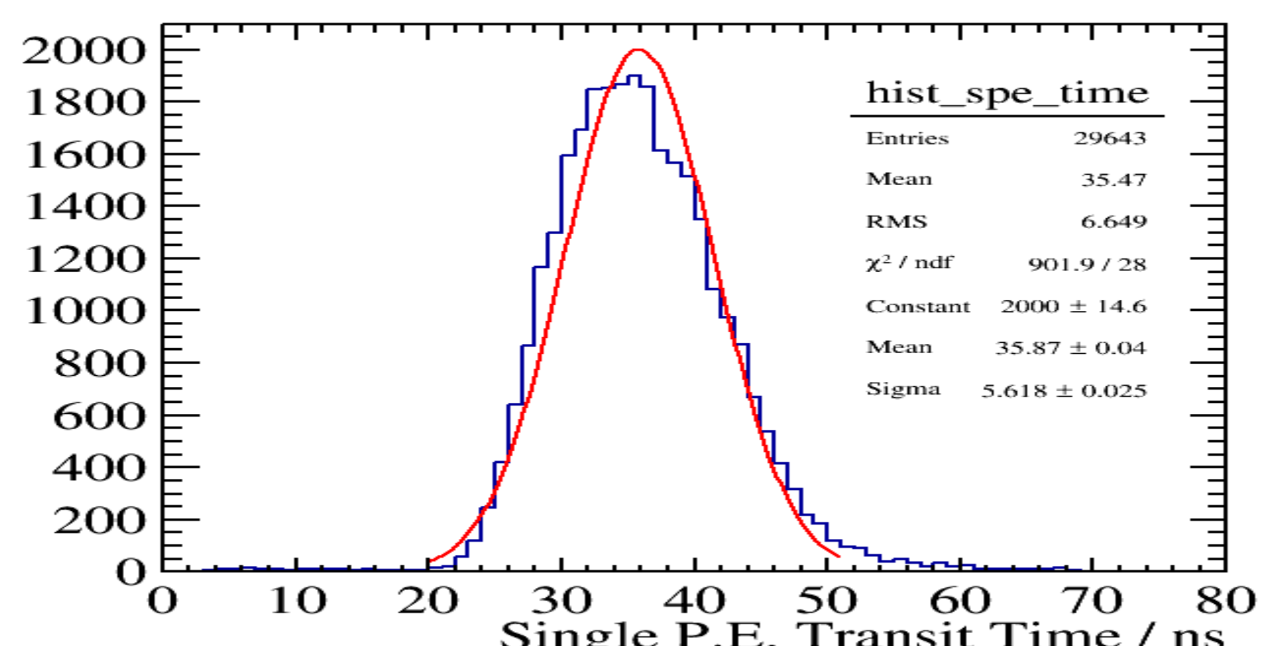
PMTs	Hamamatsu	MCP-PMTprototype	~300 MCP-PMTs	~1000 MCP-PMTs	~4703 MCP-PMTs
TTS @ FWHM	**2.8 ns**	**13.2 ns**	**19.2 ns**	**19.5ns**	**20.4ns**
TTS @sigma	1.19 ns	5.62ns	8.17ns	8.30ns	8.64ns
RT @ Gain~1X10^7	6.7 ns	1.2 ns	1.4 ns	1.4 ns	1.4 ns
FT @ Gain~1X10^7	17.7 ns	10.2 ns	24.4 ns	25.2 ns	25.5 ns

Hamamatsu Prototype



MCP-PMT-prototype





Performance-resolution

If no TTS is considered, the vertex resolution is about 7cm@1MeV.

In simulation,5000 Hamamatsu PMT TTS: 3ns, 12739 MCP-PMT TTS: 12ns($TTS = 2.354\sigma$) ,

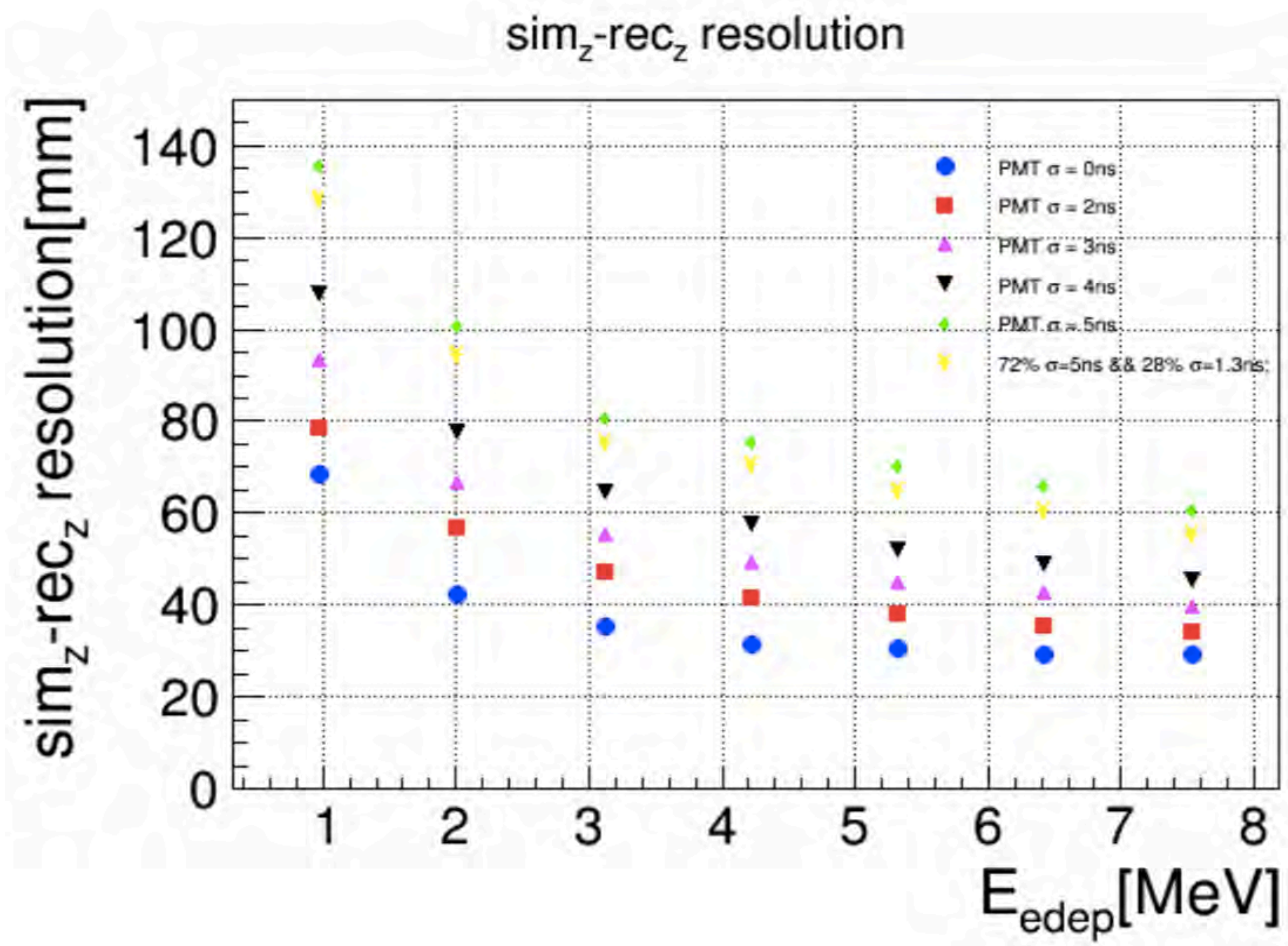
Corresponding to vertex resolution ~13cm@1MeV (yellow).

The position Resolution is **13cm**;

The TTS of PMTs for JUNO is

about **2~3 ns** is OK,

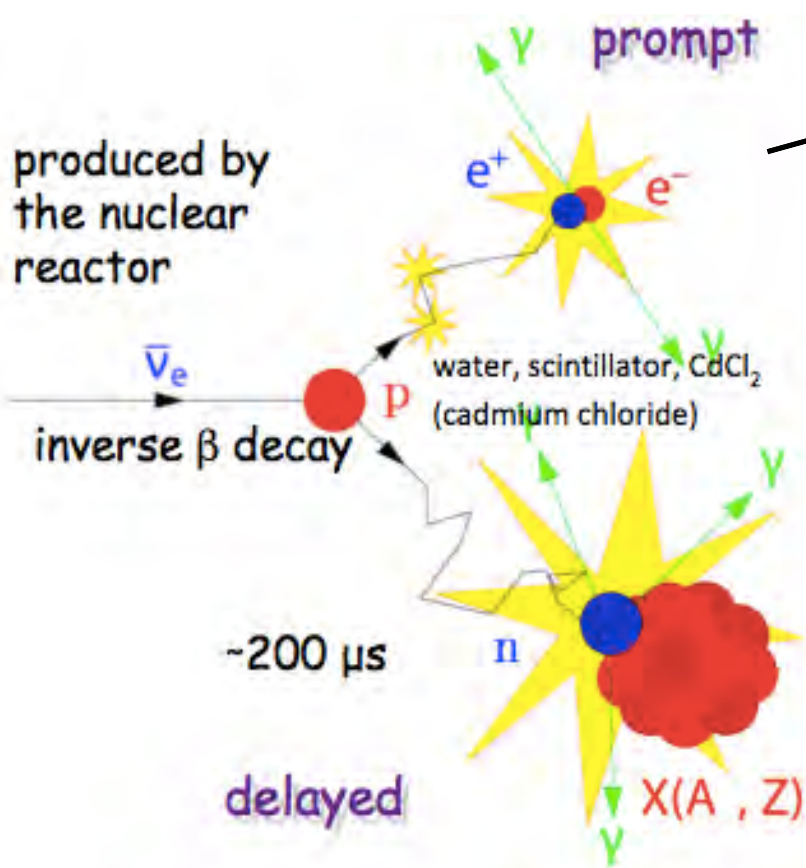
no need the very fast PMTs.

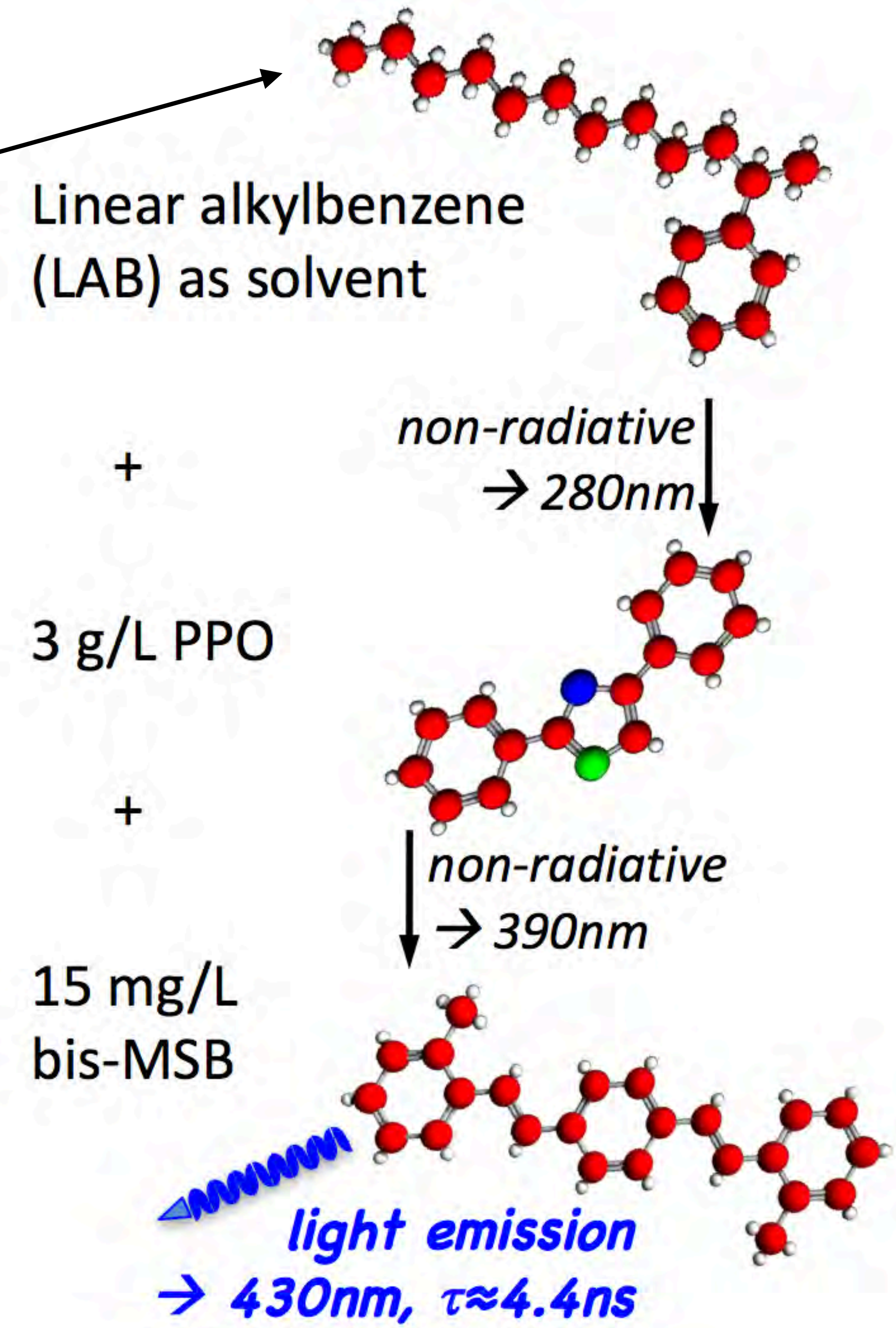


Discussed with Dr. Liang Zhan zhanl@ihep.ac.cn

Reactor $\bar{\nu}_e$ are detected via Inverse Beta Decay (IBD)

$$\bar{\nu}_e + p \rightarrow e^+ + n$$





- Using a recipe inspired from Daya Bay's experience
- Requirements:
  - Long attenuation length > 20 m@430 nm:
  - High light-yield:
  - Good radio purity:

Why it is very difficult to see direct Cherenkov light in LS detector?

Because: more than 90% of original Cherenkov lights would be absorbed by LAB/PPO/bis-MSB;

If absorbed by PPO/bis-MSB, there will be a photon re-emitted.

The re-emitted photon has the same property with scintillation ones.

Total p.e. / MeV	Scintillation contribution	Cherenkov contribution
~1200	~1160	~40

The numbers are not exact.

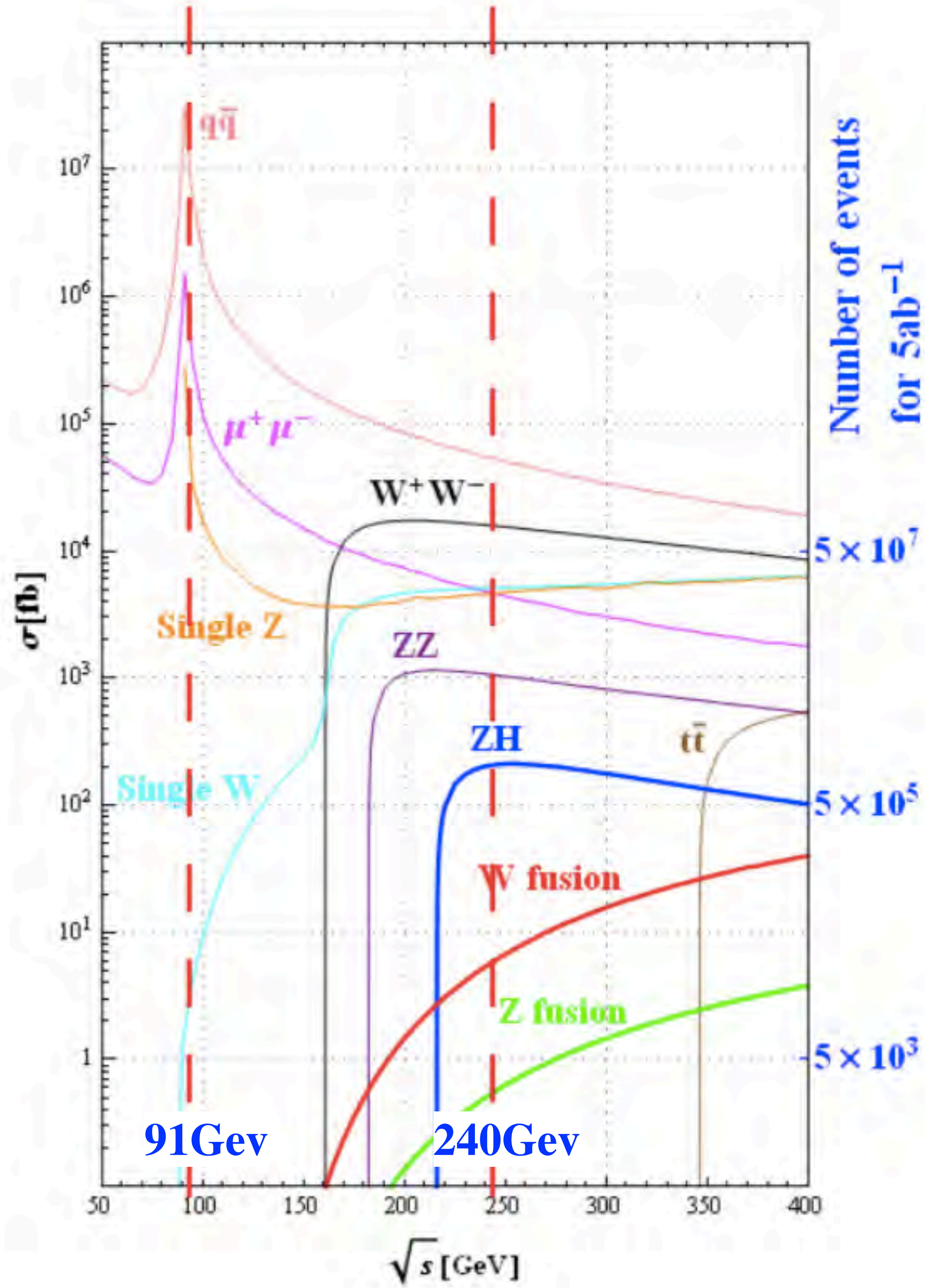
Direct	Absorbed by LS and re-emitted
~4	~36

At 1 MeV, if all JUNO PMTs are fast, only 4 direct Cherenkov photons can be separated. Difficult to use!

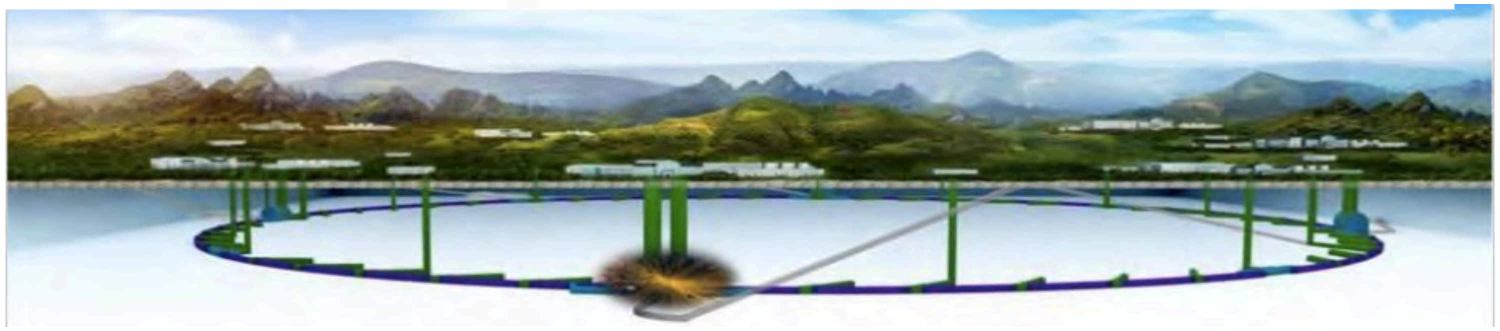
Discussed with Dr. Liangjian Wen wenlj@ihep.ac.cn

Discussed with Dr. Zeyuan Yu yuzy@ihep.ac.cn

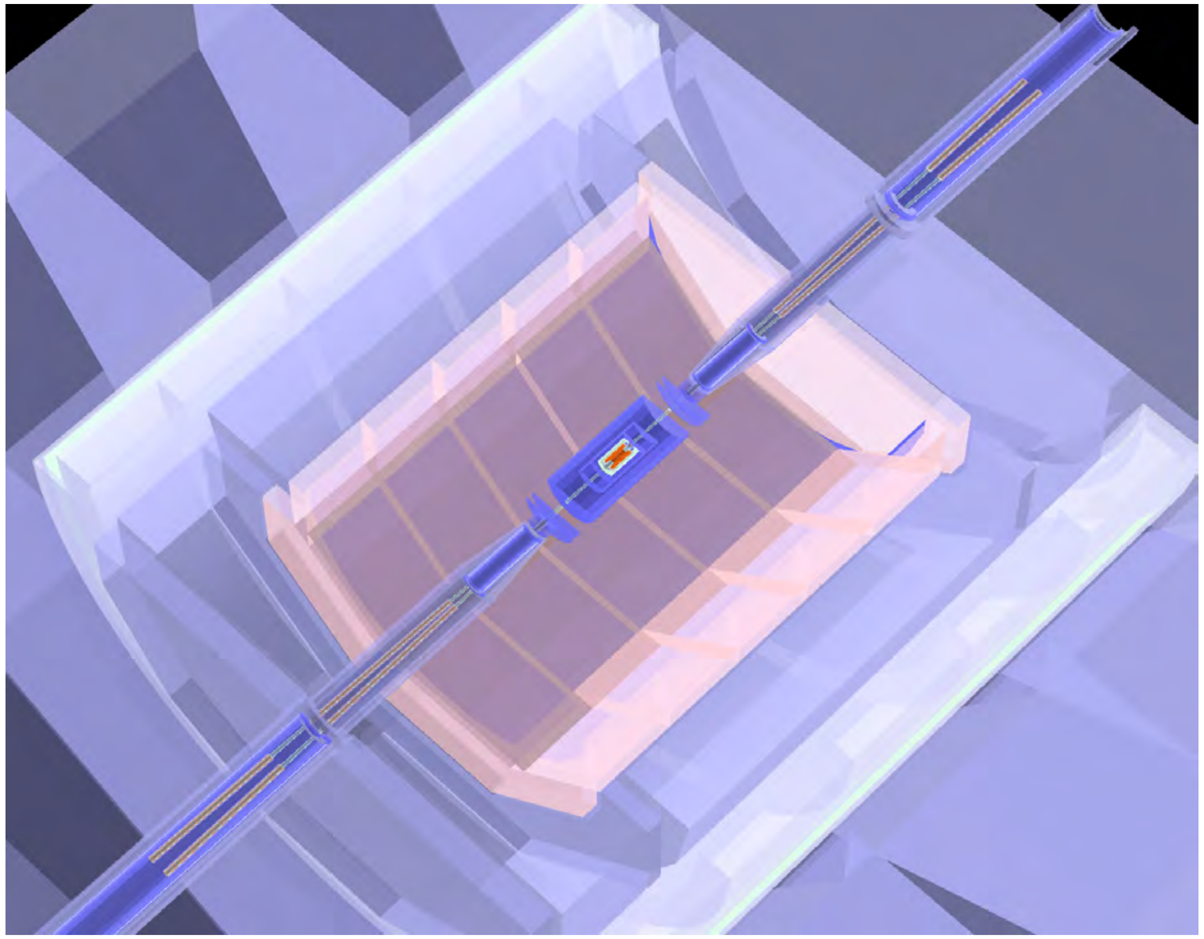
- CEPC Productivities:
  - 10^6 Higgs + 10^8 W + $10^{10\text{-}11}$ Z Bosons
- Physics requirements
  - Higgs: High efficiency/purity identification and precise measurement of **Core Physics Objects** (Lepton, Photon, Tau, JET & MET)
  - Z & W:
    - Same requirement for Core Physics Objects
    - **Particle ID** (identify Kaon, Proton, Pion...)
  - **Systematic control**
    - High Stability, High homogeneity
    - Calibration & Alignments
    - Luminosity monitoring



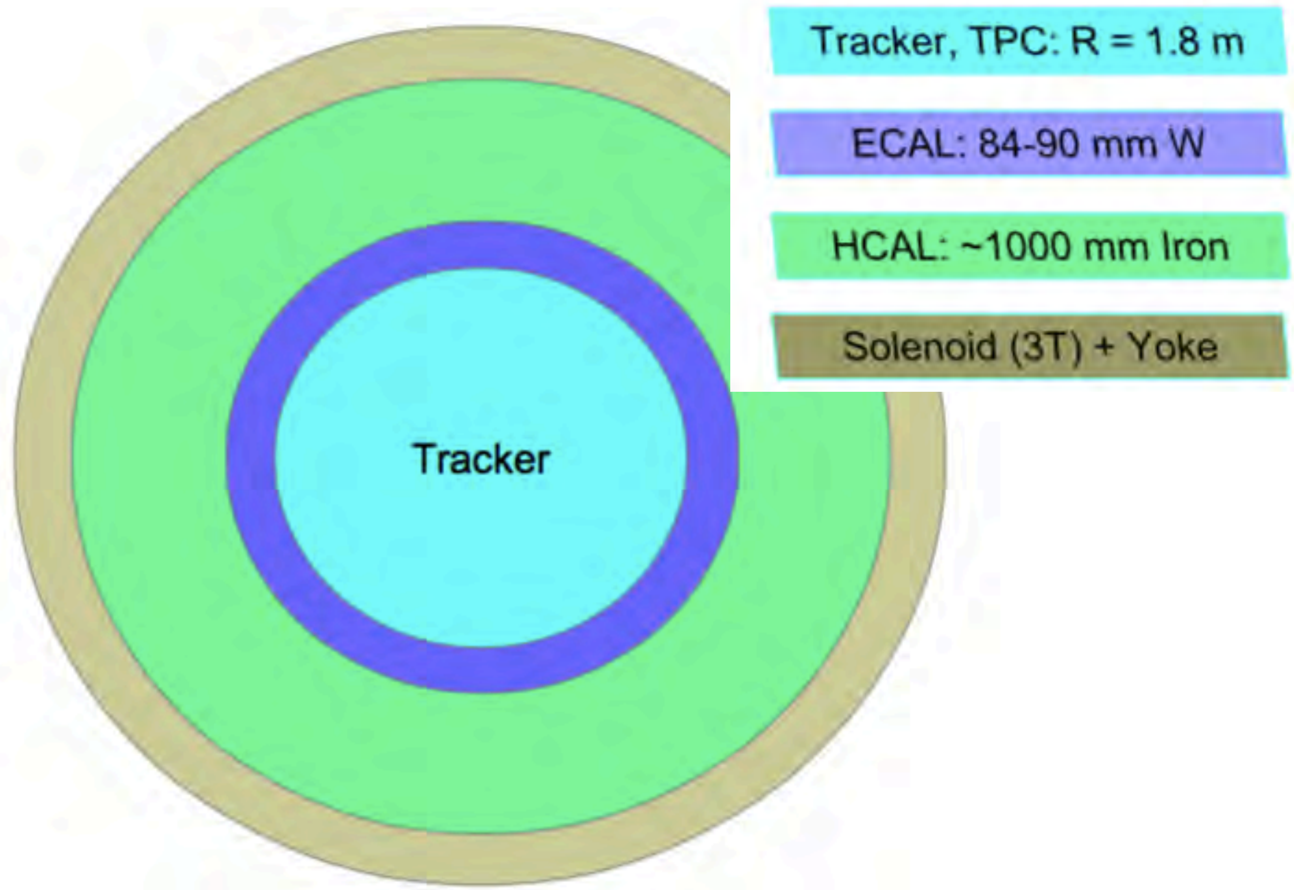
the energy of CEPC from 91Gev-240GeV



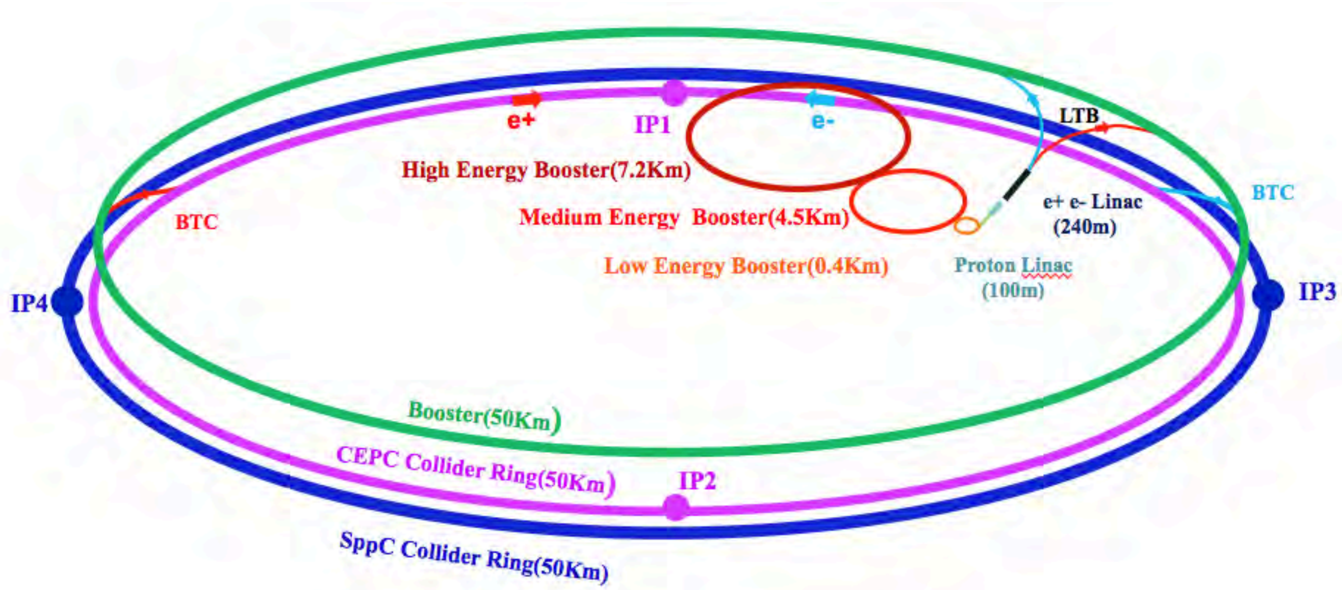
➢ 2.1. The overview of CEPC Detector

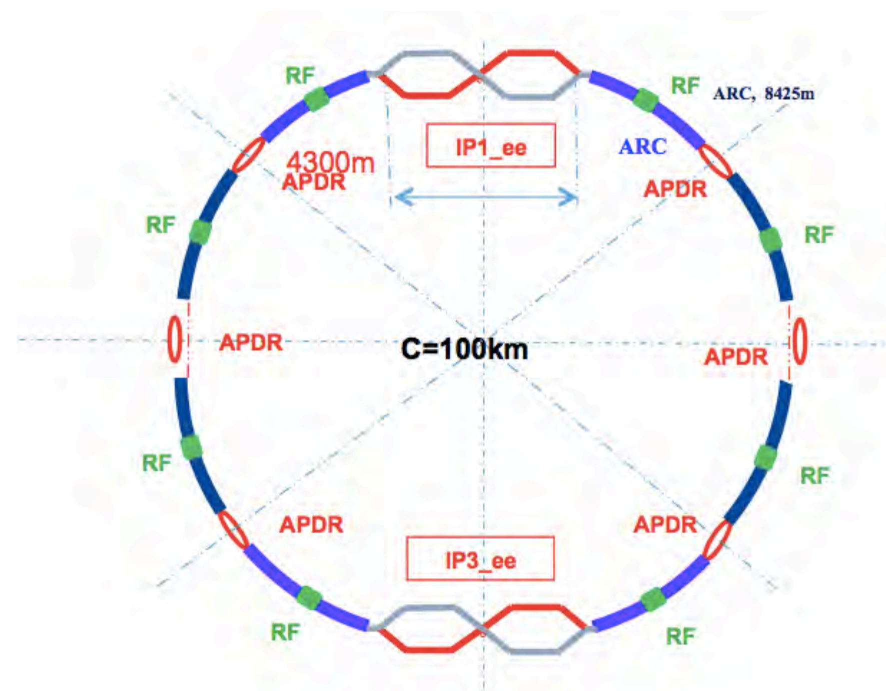


Detector structure for CEPC



the reduced graph of the CEPC Detector

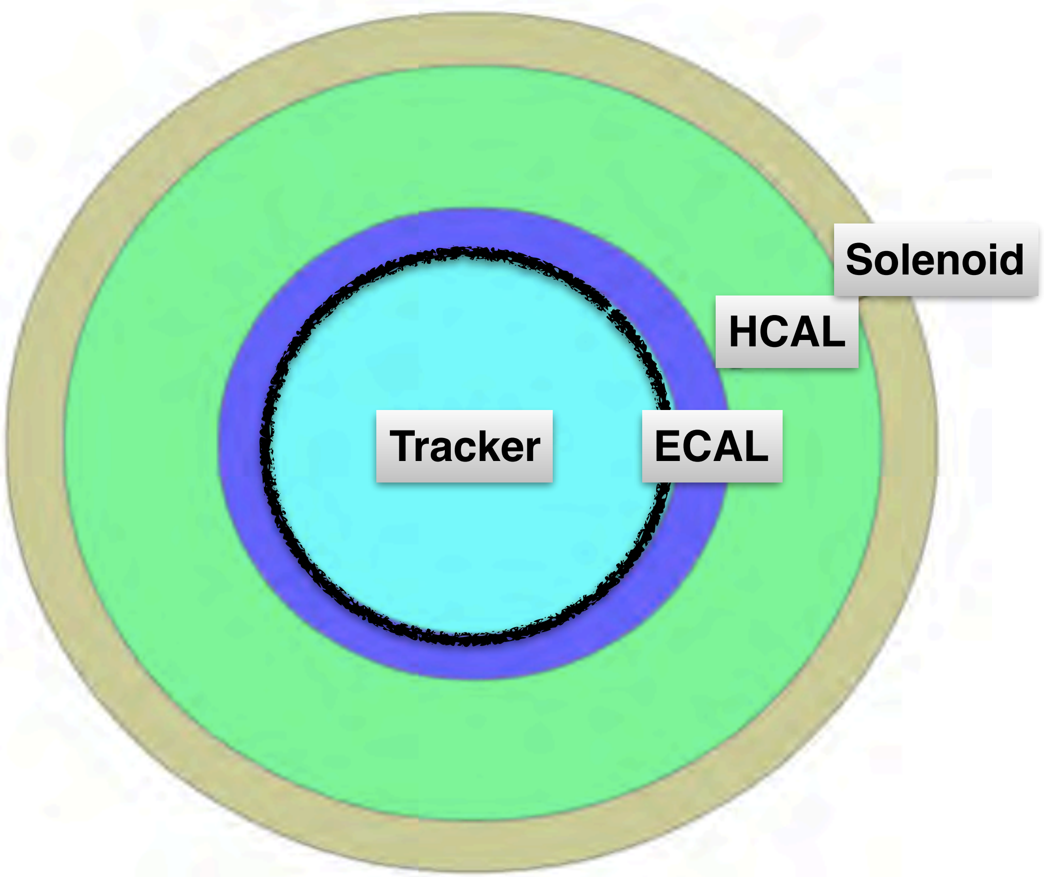




http://cepc.ihep.ac.cn

the perimeter is changed from 50Km to 100Km for more energy;

➢ 2.2. LAPPD can be used in ECAL?



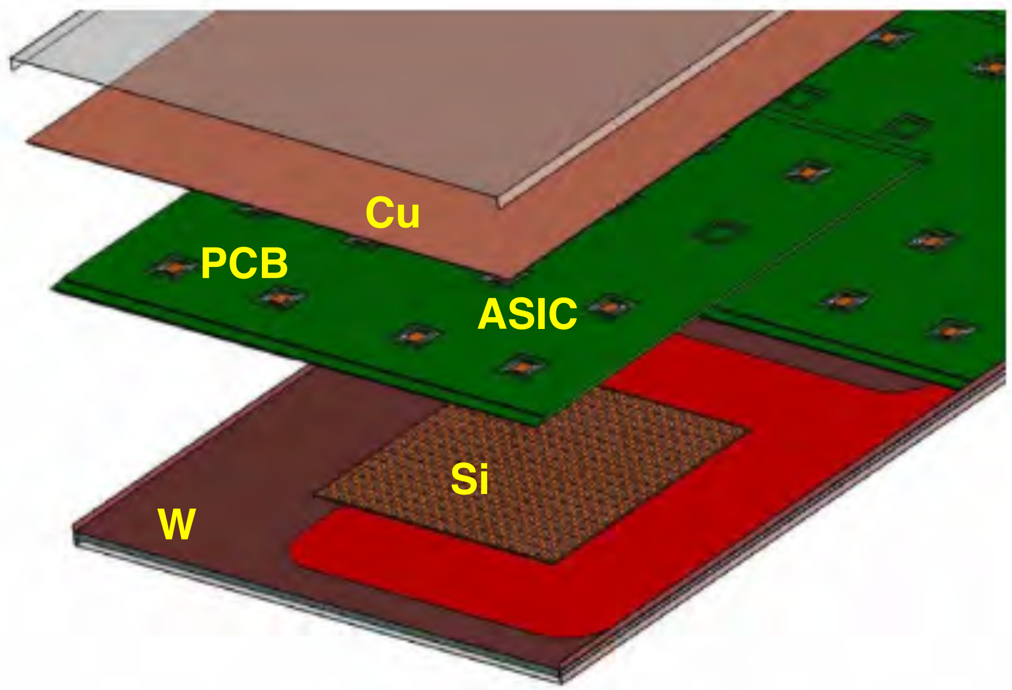
Two detector options for the CEPC ECAL：

SiW ECAL： consists of layers of active sensors-silicon pads or pixels；

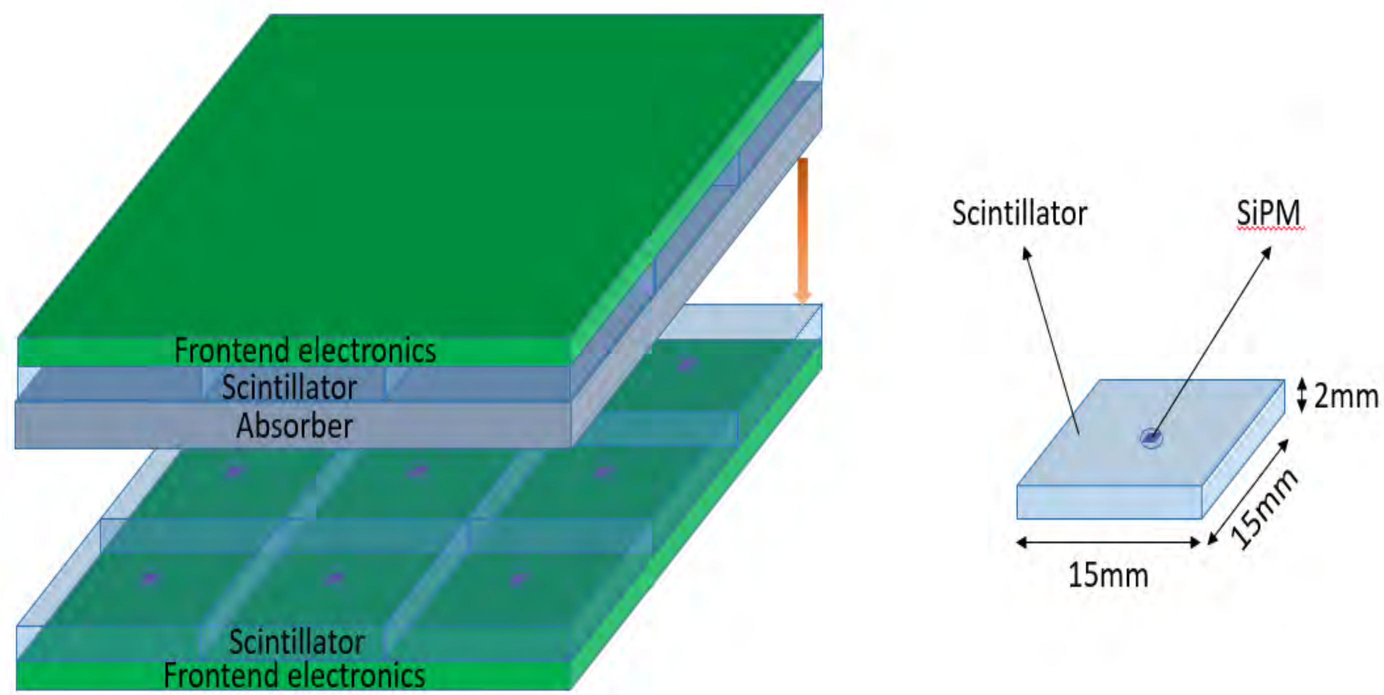
ScW ECAL： scintillator detector with MPPC;

The ECAL sensor interleaved with tungsten absorber plates.

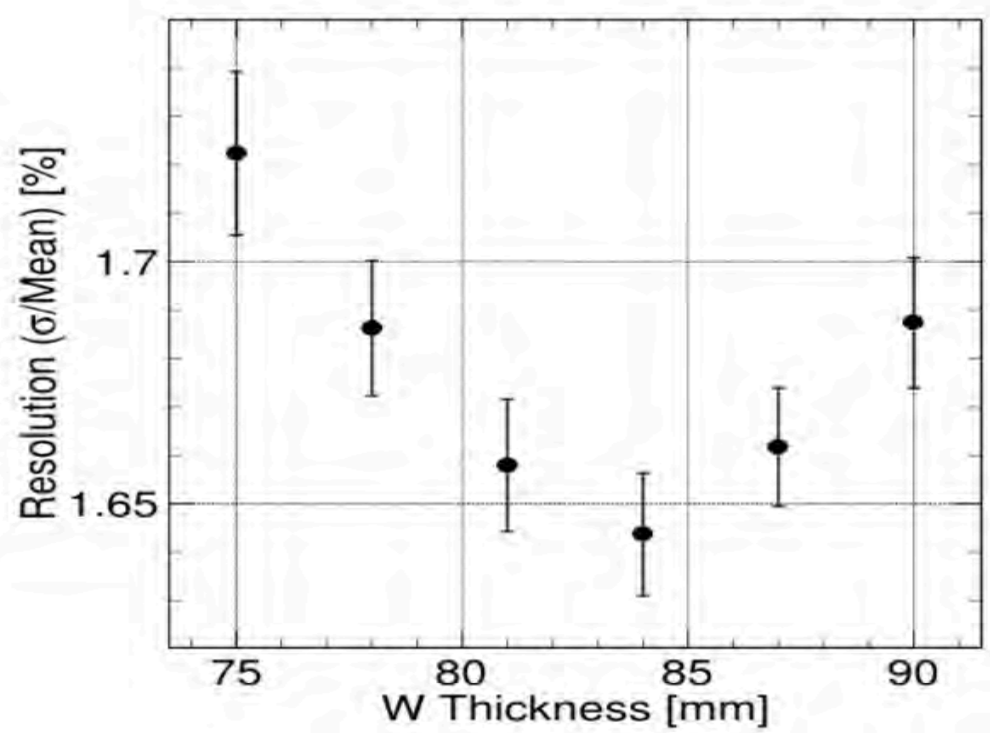
The layer number of the ECL is about 25 in 90mm.



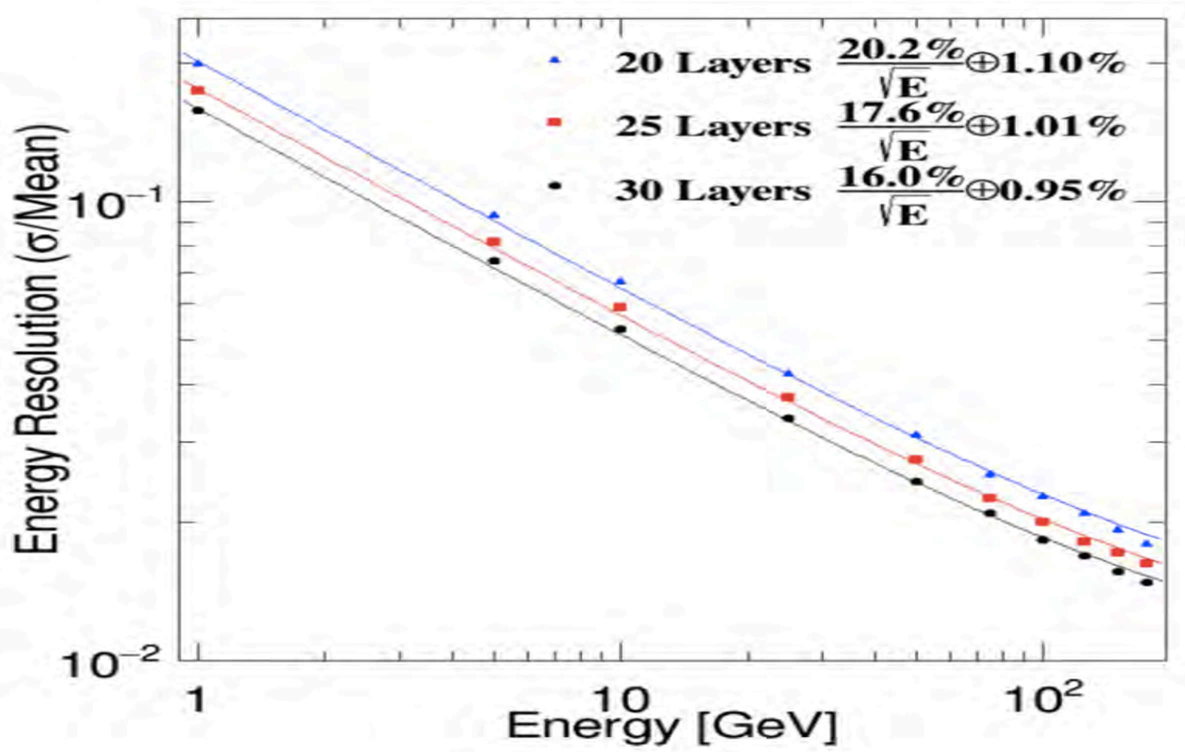
Detector structure of SiW ECAL



Detector structure of ScW ECAL



the resolution (σ/Mean) of reconstructed Higgs boson mass at different tungsten thickness. @120GeV



the layer number of the SiW ECAL with energy resolution

(1) Silicon sensors for ECAL is 3$/cm2;Total silicon sensors for ECAL is 112M$.

(2)Total thickness of absorber W is 90mm,

Silicon: **SiW ECAL**： **30** silicon layer； thickness ~ 500um; PCB ~2mm；

Yes! **ScW ECAL**： **25** scintillator layer； thickness ~ 2mm; PCB ~2mm；

MCP-PMT?

(1)MCP sensor is ？ $/cm^2; Total MCP sensor for ECAL is？ M$.

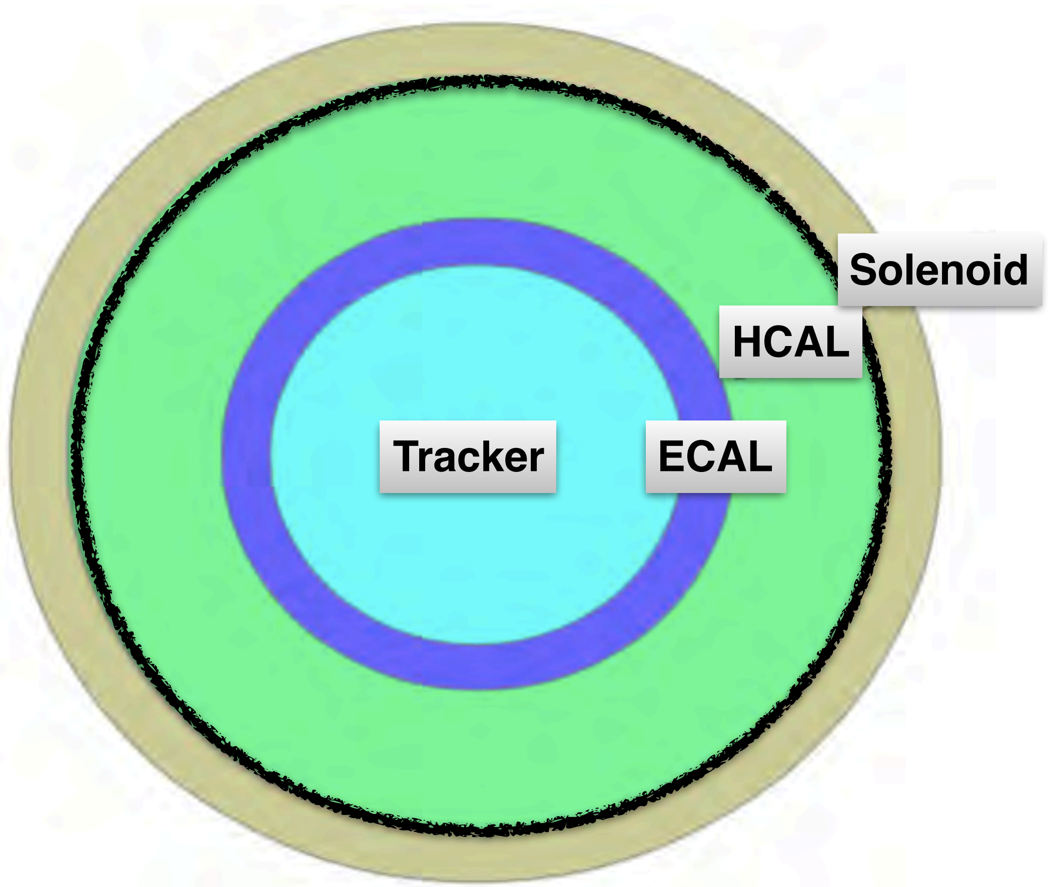
(2)Thickness of **MCP at least is 15 mm**, what about PCB?

If the silicon is replaced by MCP, the total thickness of ECAL will increase .

The cost of magnet will be increased accordingly.

Discussed with Dr. Zhigang Wang, wangzhg@ihep.ac.cn

2.3. LAPPD can be used in HCAL?

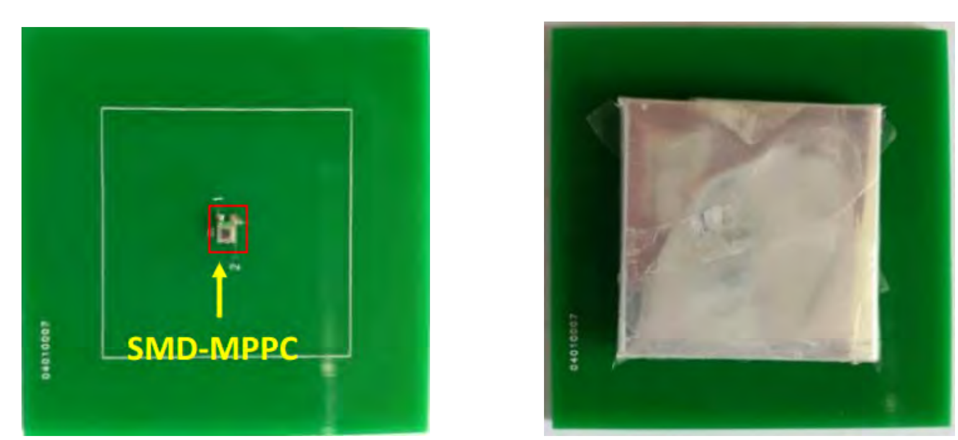


Detector unit: a scintillator tile (30×30×3 mm^3) with a SiPM

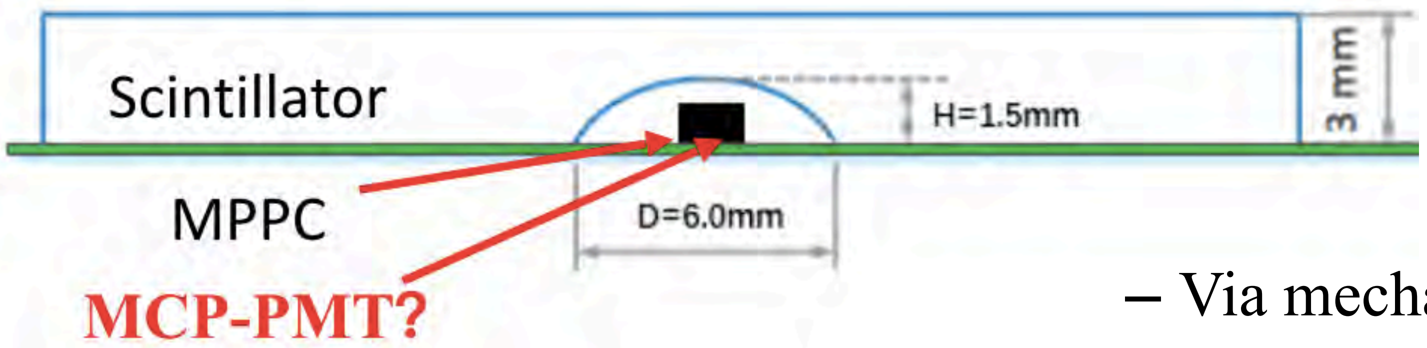
Yong Liu's talk @LCWS2016

— Analog hadron calorimeter based on scintillator:

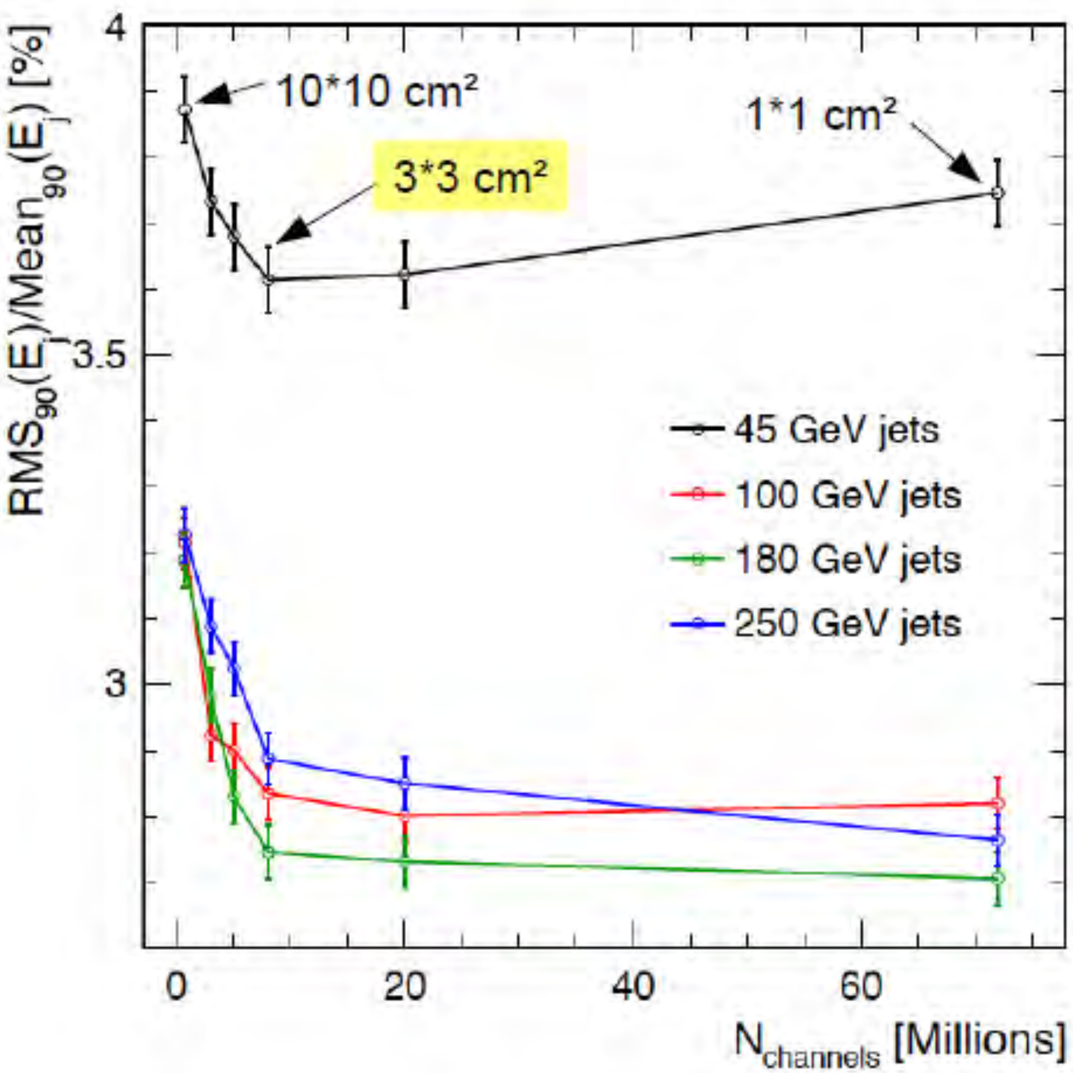
- The absorber: 2cm Stainless steel;
- Detector cell size: 3cm×3cm (baseline) , 4cm×4cm, 5cm× 5cm？
- Position Resolution： **5mm?**
- Readout chip: ASIC SPIROC2E
- The sensitive detector : Scintillator(PS or inorganic scintillator);
- 40 sensitive layers, total readout channel: ≈5 Million (3cm× 3cm)



Scintillator tile wrapped by ESR foil was glued on the PCB



- Via mechanical drilling and polishing, a dome-shaped cavity in the center of plastic scintillator was made
- The sizes of $30\times30\times3mm^3$, $30\times30\times2mm^3$, $40\times40\times3mm^3$ and $50\times50\times3mm^3$ were made.
- Scintillator(BC408) were wrapped by ESR foil
- SiPM or MPPC(surface-mounted) ,



Katja's talk @CHEF2017

—MCP-PMT? **No!**

①: 5mm position resolution is enough, the cell size is 30mmX30mm, only copping 1 MPPC;

②: the MPPC is cheaper than the MCP-PMT;

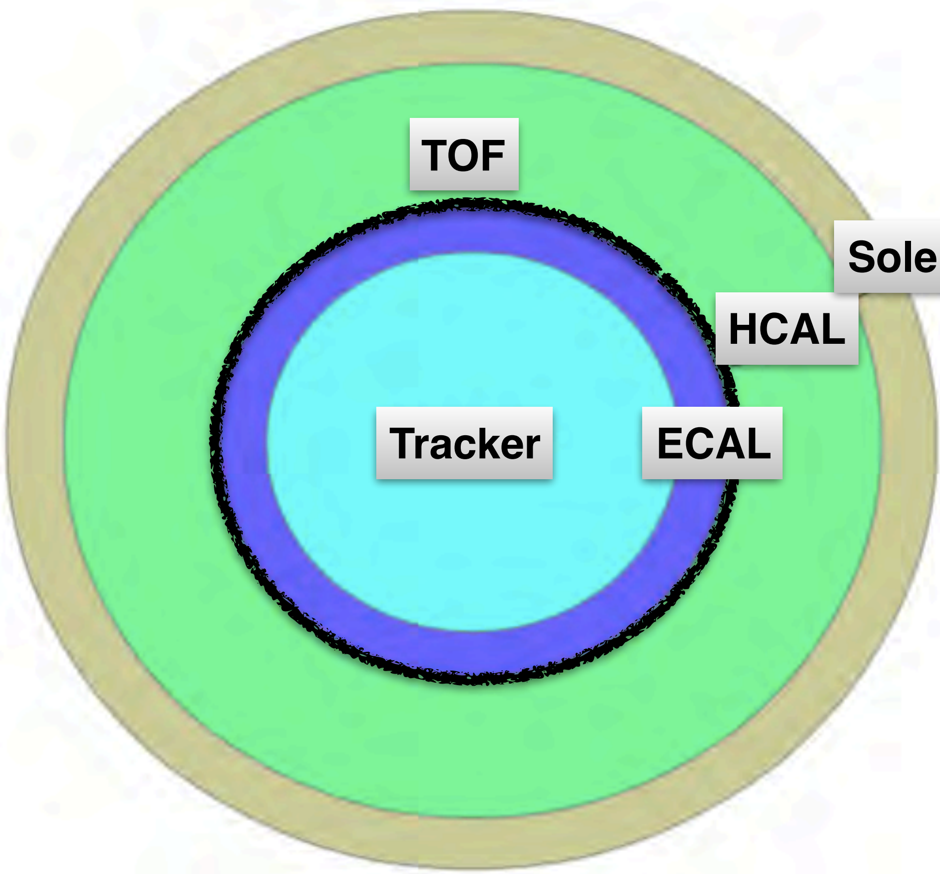
for 2Million pic, the price of the MPPC:

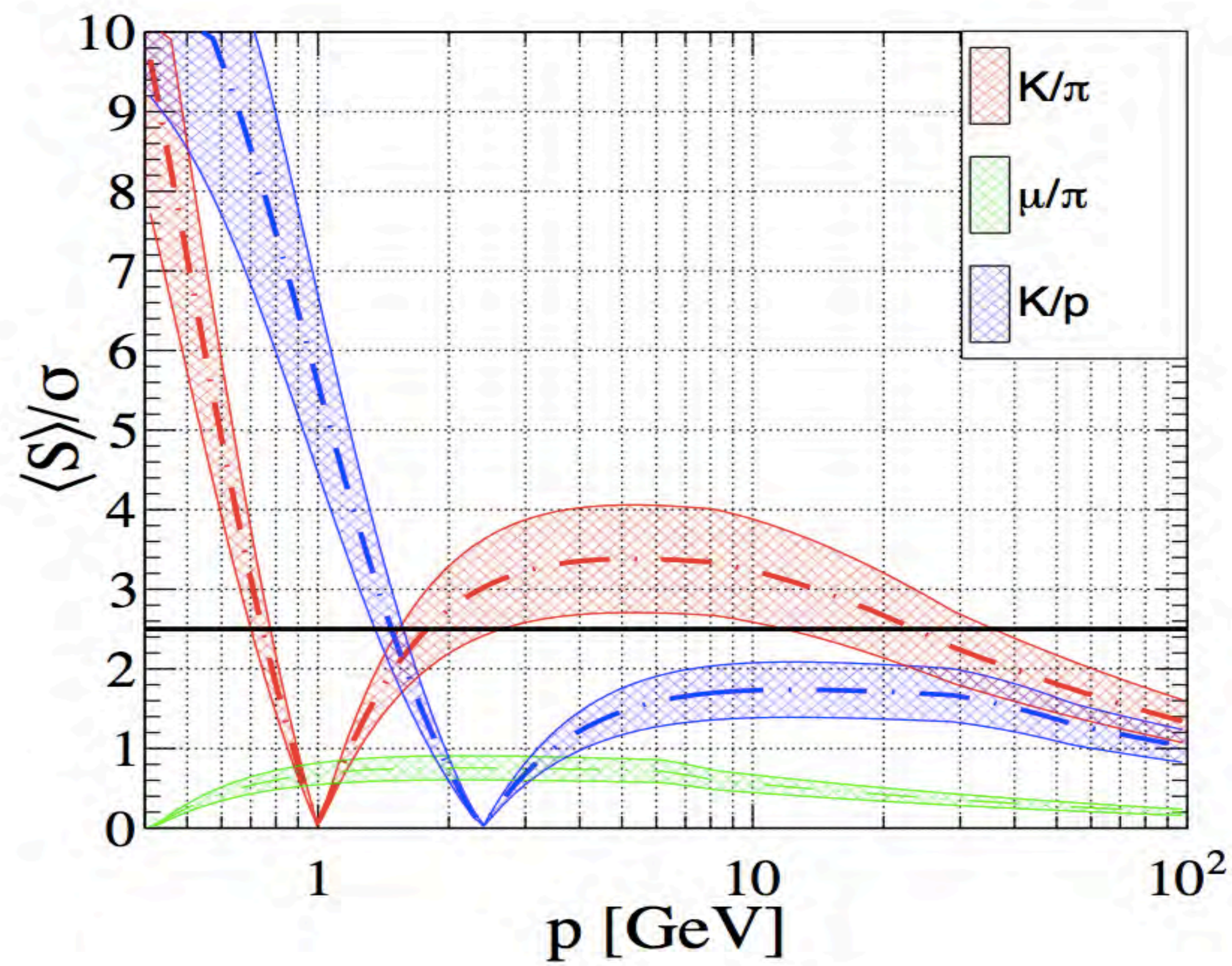
5$/1pic from Hamamastu; 1.5$/1pic from BNU

Discussed with Dr. Boxiang Yu, yubx@ihep.ac.cn

PFA Oriented concept with Calorimeter based ToF measurement

Multi-LAPPD layers could be installed inside HCAL, providing ToF measurements to Hadrons. Detailed optimization/simulatin study is needed.





the Resolution of the dE/dx with different energy

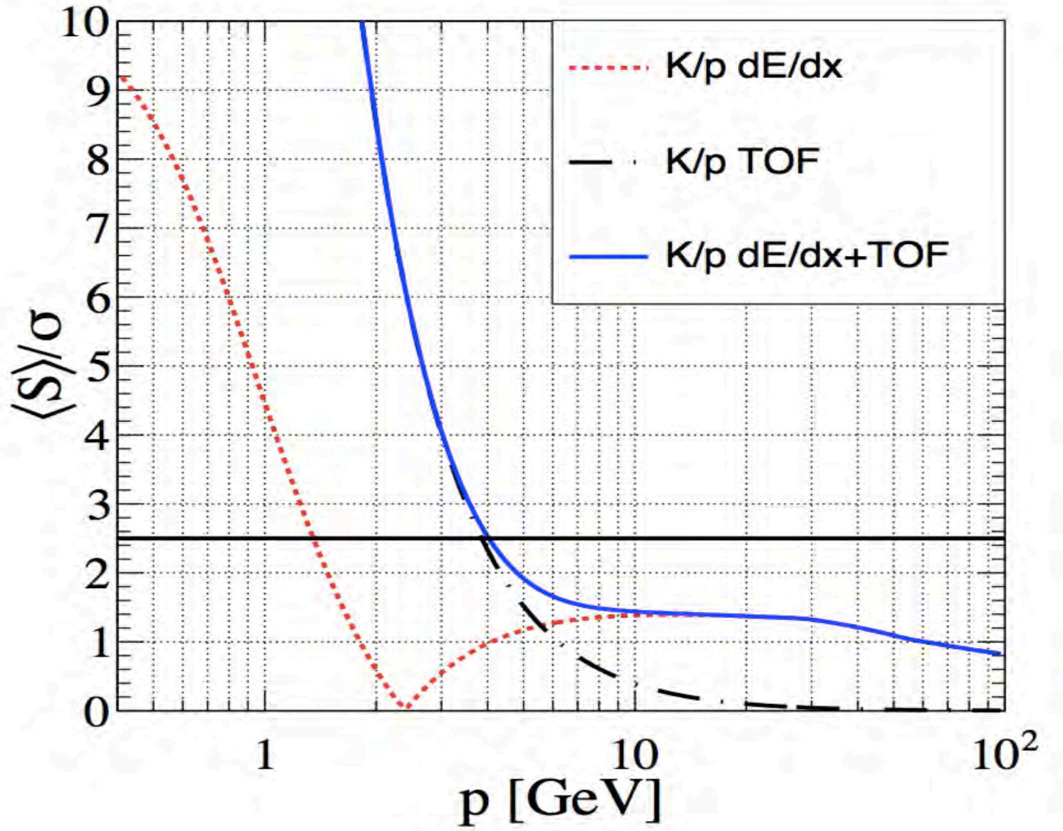
dEdx & ToF:

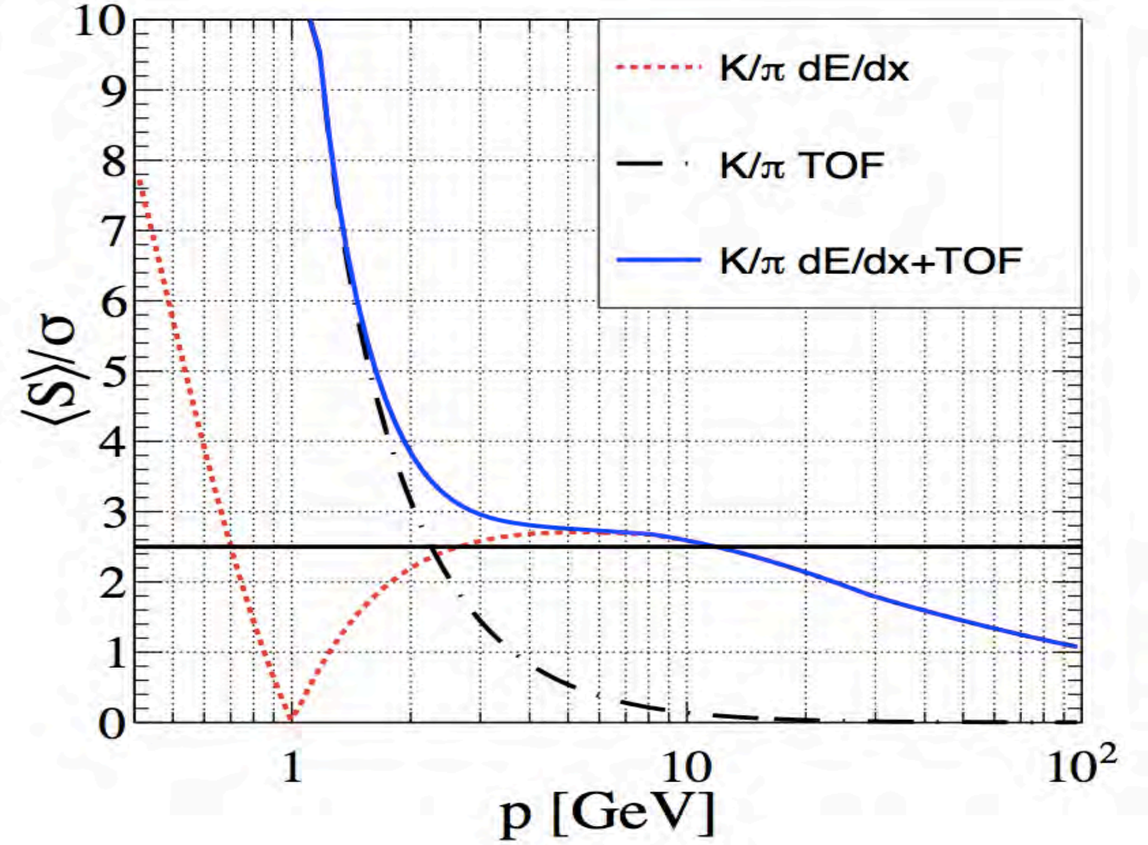
complementary performance for PiD

A few Calorimeter Layer Equipped with ToF Sensor

(i.e., HPTPMT, Silicon, MRPC...) delta(T) ~ 50 ps

Pid Using TPC dEdx + ToF for the CEPC





combining the dEdx and ToF (~50 ps for each particle) measurements leads to an efficient distinguish between different hadrons. At relevant momentum range for the CEPC Z pole operation, the over all efficiency/purity for the Kaon id could reach 95%/95%.

Condition		#σ(π-K / K-p)	Efficiency	Purity
MCTruth	dE/dx only	3.9 / 1.5	88%	86%
	+ TOF	4.0 / 3.2	98%	98%
20% degraded	dE/dx only	3.1 / 1.2	81%	79%
	+ TOF	3.3 / 3.0	96%	96%
50% degraded	dE/dx only	2.4 / 0.9	68%	68%
	+ TOF	2.8 / 2.9	91%	94%

To balance the efficiency & Purity of time measurement...

➢ 2.5. The result

—> Beside the PMTs,MPPC and Si-Sensor, the CEPC Detector need new types Detector for better design.

—>Combining ToF & dEdx leads to promising PiD performance for the CEPC Z pole physics program, and is highly appreciated (especially for the flavor physics and jet measurements)

—> LAPPD (**50ps->10ps->1ps?**) is benefit for the CEPC ToF measurements, and could be integrated into the Calorimeter system.

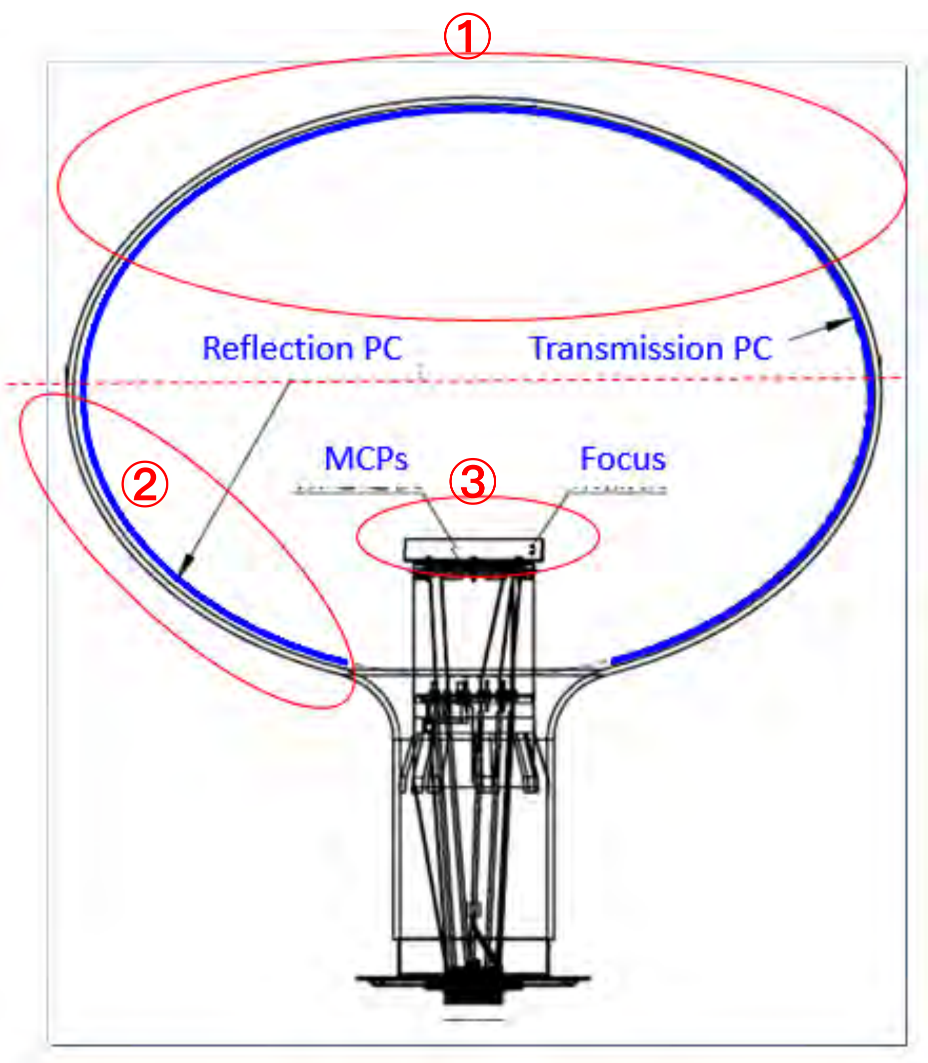
—> More studies are needed to establish an concept design.

Thank！ 谢谢！

Thanks for your attention!

Any comment and suggestion are welcomed!

➢ Why the TTS of MCP-PMT is so Large



The contribution to the TTS

①The distance between the PC to the MCP;

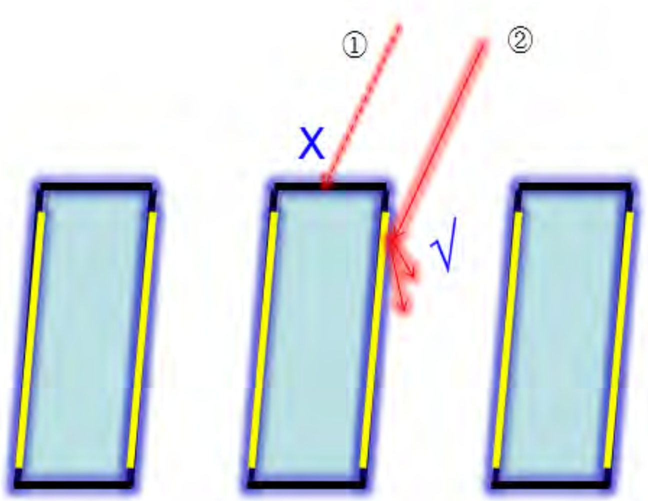
==By adjusting the Electronic optical focusing

② The difference between the Trans. & Ref. PC;

==No way to adjusting; (for better QE)

③ The second electron emission part of the MCP;

==No way to adjusting; (for better DE)



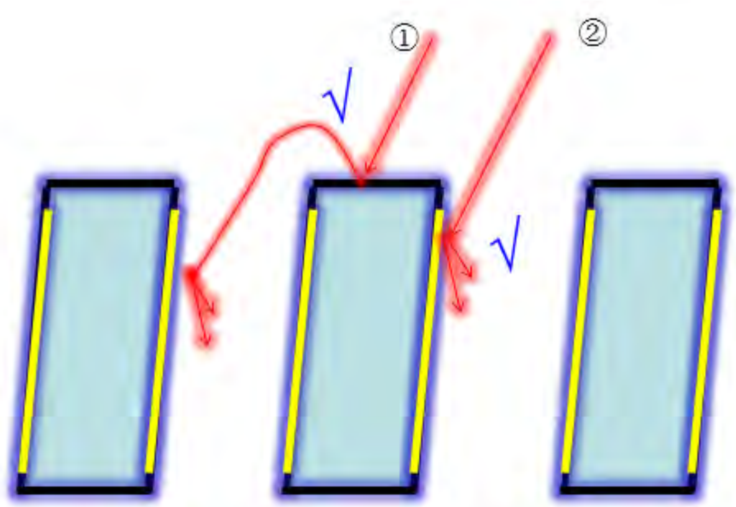
CE = 60%

The prototype

--> with Trans. + Ref. PC for better QE;

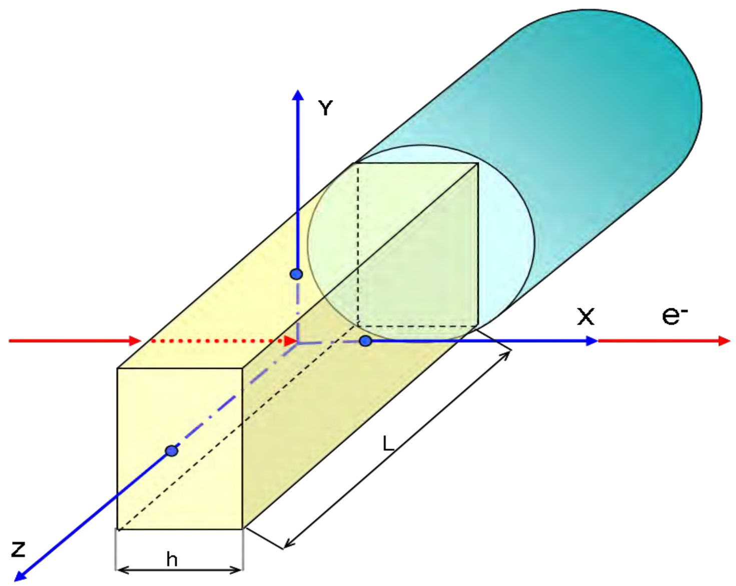
--> with special MCP for better DE;

But the TTS will be worse!



CE = 100%

A Very Fast T0 System for the beam test in IHEP for the BESIII ETOF upgrade

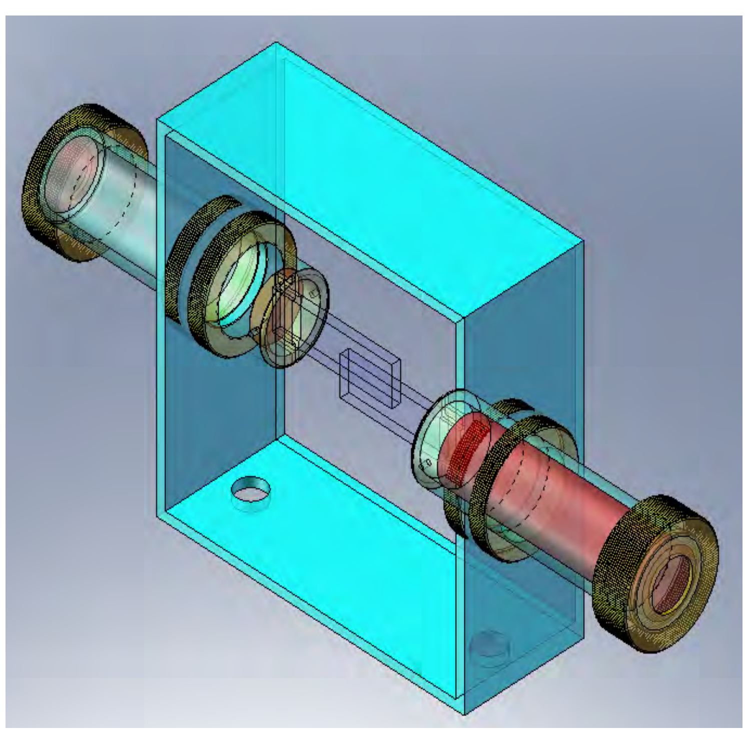


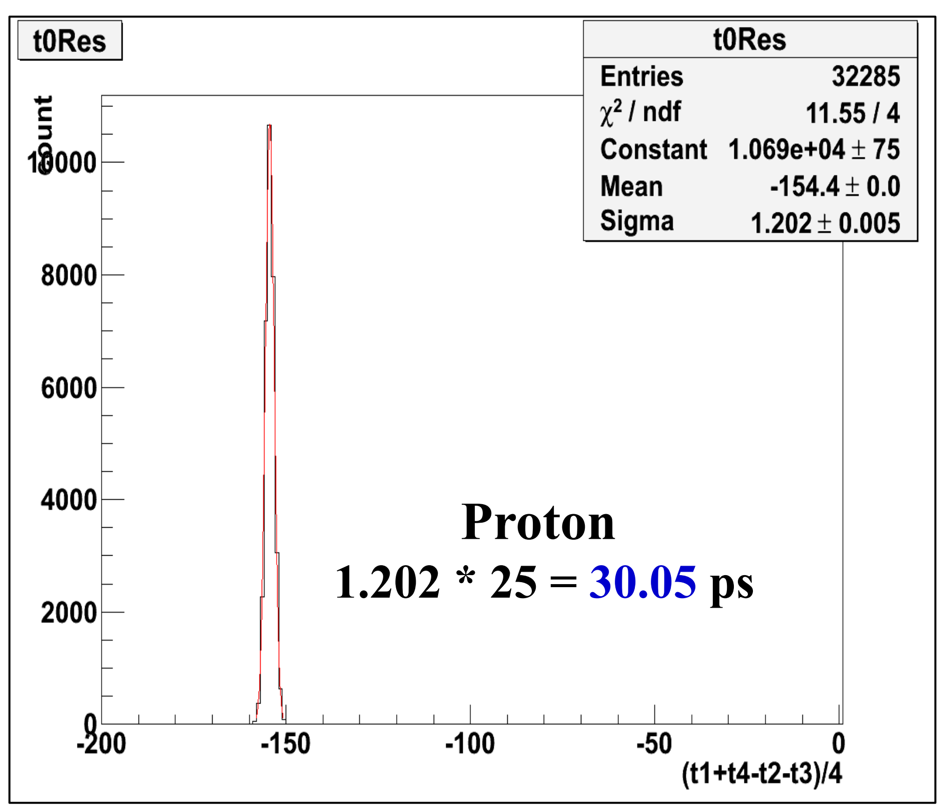
	BC-408	BC-404	BC-420	EJ-204	EJ-230	UPS-95F
$\lambda^{max}_{emission}$ (nm)	425	408	391	408	391	390
λ^{bulk}_{att} (cm)	380	160	110	-	~ 100	-
Light output % Anthr.	64	68	64	68	64	39-45
decay const. (ns)	2.1	1.8	1.5	1.8	1.5	1.2
risetime (ns)	0.9	0.7	0.5	0.7	0.5	0.7
pulse width (FWHM ns)				2.2	1.3	-

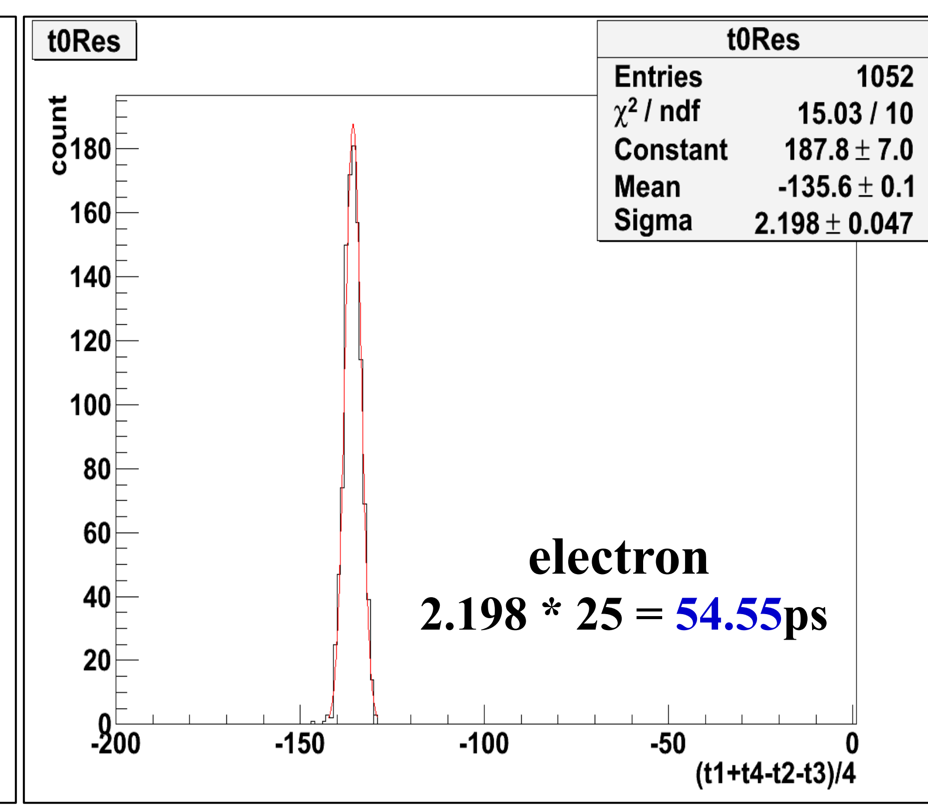
Time Response	Anode Pulse Rise Time	–	0.7	–	ns
	Electron Transit Time	–	10	–	ns
	Transit Time Spread (T.T.S.)	–	0.16	–	ns

With the fast PMT (H6533) and Fast scintillator (BC-420),

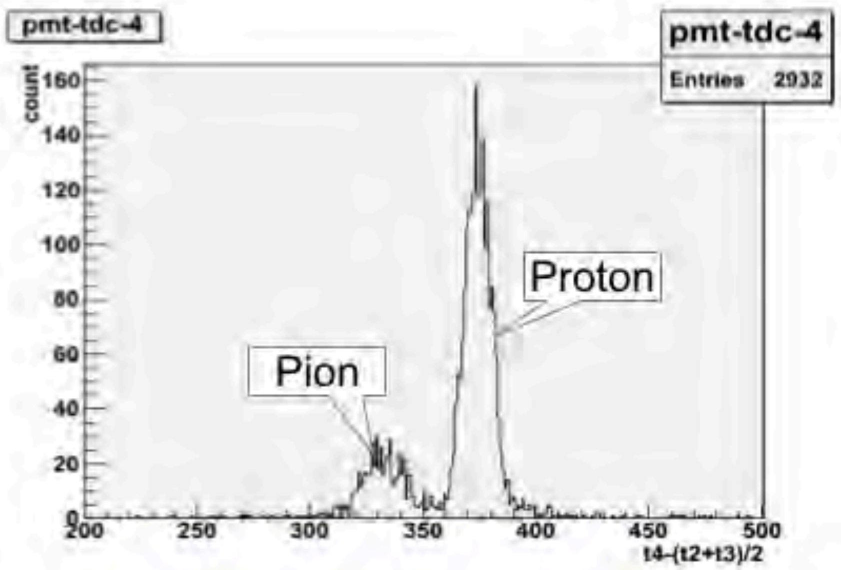
the time resolution of T0 system : 30ps@ Proton; 55ps@ Electron



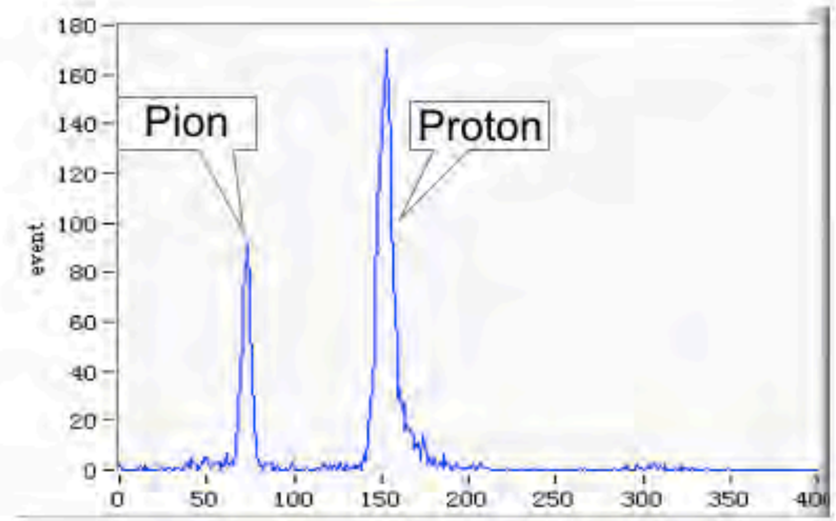




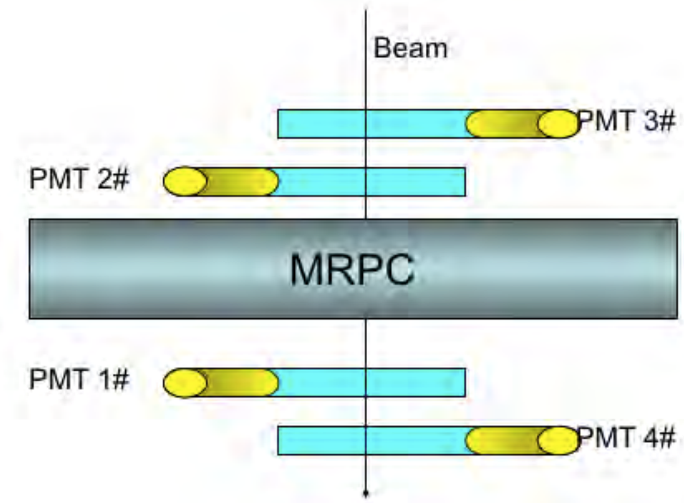
The PID of the T0 system

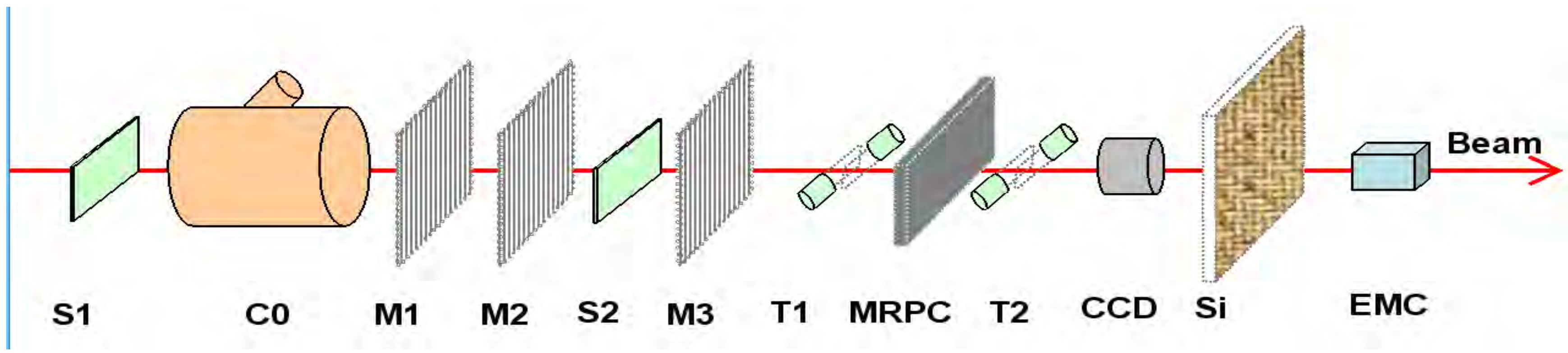


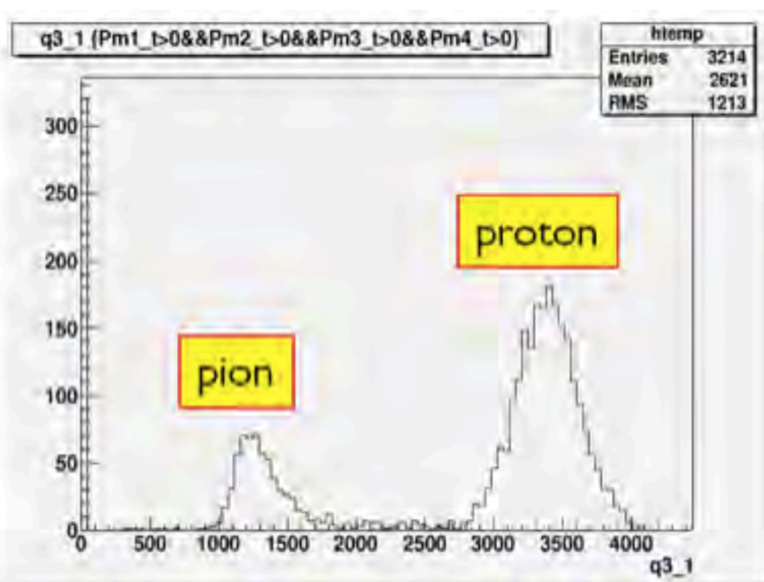
Time Spectrum of T0



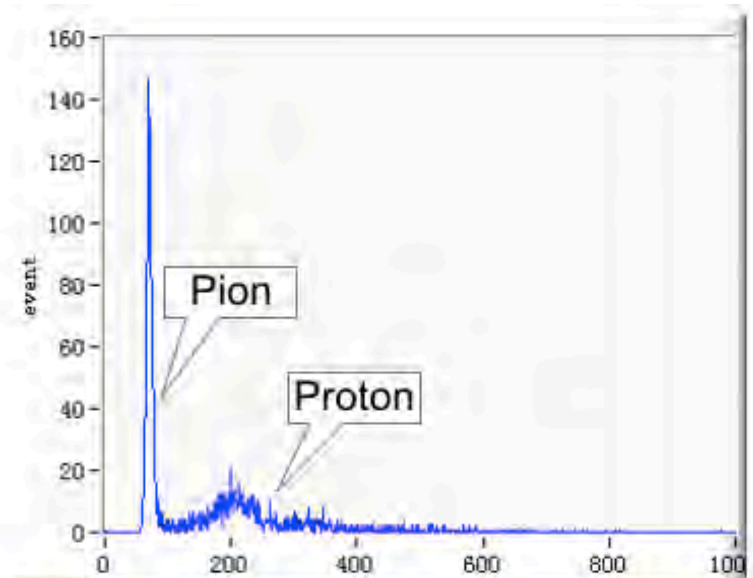
Time Spectrum of TOF







Charge Spectrum of T0 PMT



Charge Spectrum of EMC in the beam end

This T0 system not only with the 33ps average time resolution, but also can do the particle identification (proton & pion) function as the TOF of beam test system.