

Detector R&D at IHEP

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IHEP, CAS

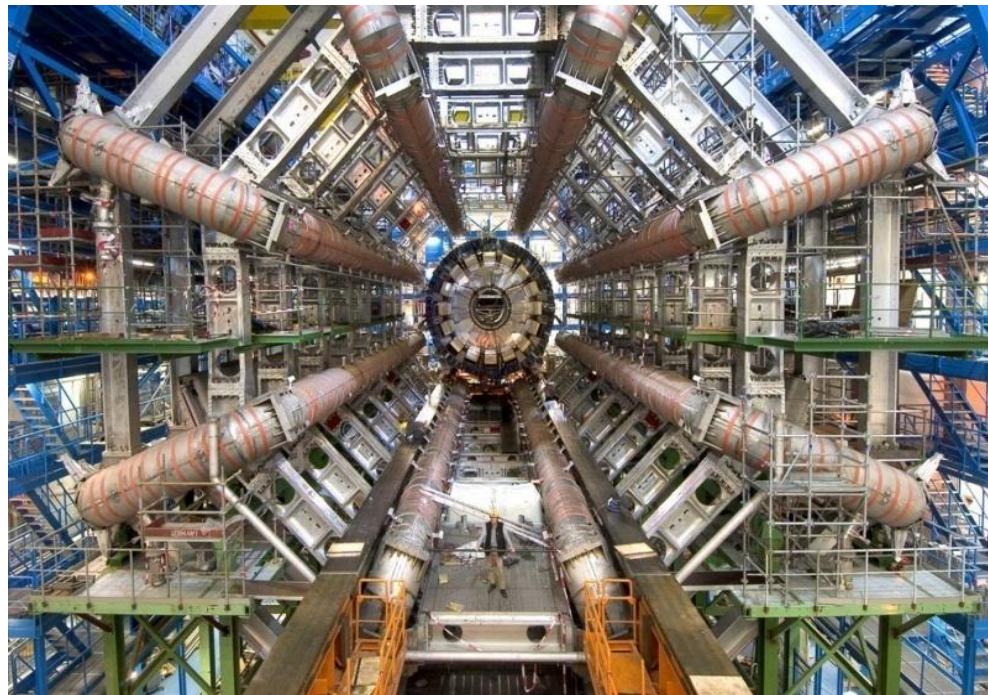
2012-6-1

Beijing-Chicago Workshop on Detector R&D

Development Trend of Particle detection

◆ **Lager Scale、Lower Price、
Higher Density、More
precision、Digitalization**

- **Si、Ge、CZT、2D/3D Si pixel
detector**
- **Micro Pattern Gas detector: GEM,
Micromegas, ...**
- **Resistive Plate Chamber : RPC,
MRPC, ...**
- **Large Liquid Scintillator/Water
Cherenkov**
- **New kind of Scintillator**
- **Digitalization: Digital
calorimeter...**



Representing: ATLAS

- 9000 tons
- 90 million channels
- 3000X10 years

Outline

- ◆ Detectors at several projects
 - **BESIII**
 - **Dayabay Neutrino Experiments**
 - **LHAASO**
- ◆ New detectors R&D
 - **Gas detectors**
 - **Scintillator detectors**
 - **Semiconductor detectors**
 - **Detectors for application**

Experiments and Detectors of IHEP



Yangbajing Cosmic Ray Exp.

- RPC
- Plastic Scintillator + PMT
- Water Cherenkov
- Scintillator + Fiber + PMT

IHEP at Beijing

- State Key Laboratory of Particle Detection and Elec.
- BESIII: DC+TOF+EMC+RPC
- PET and detectors in application
- Synchrotron Radiation Detector
- Satellite: HXMT
-

中国

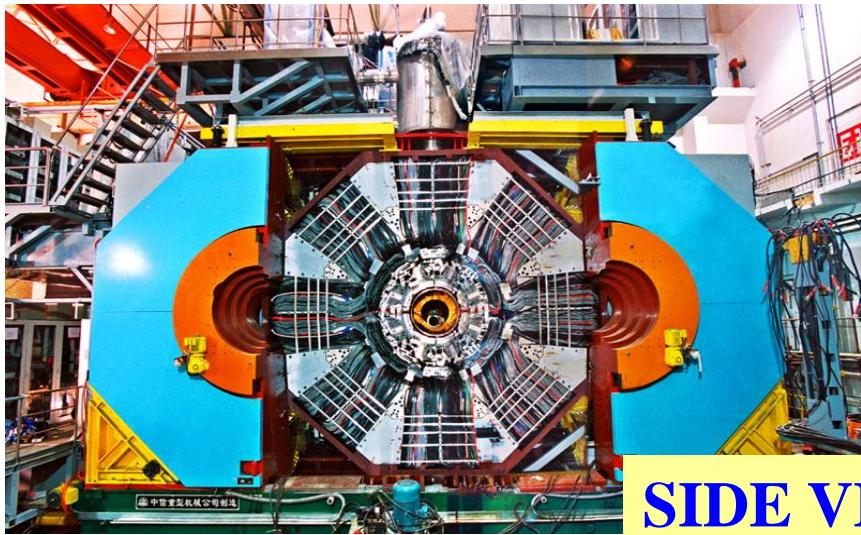
CSNS

- ^3He High pressure MWPC
- Fiber + ZnS: $^6\text{Li}(\text{Ag})$
- GEM + Boron

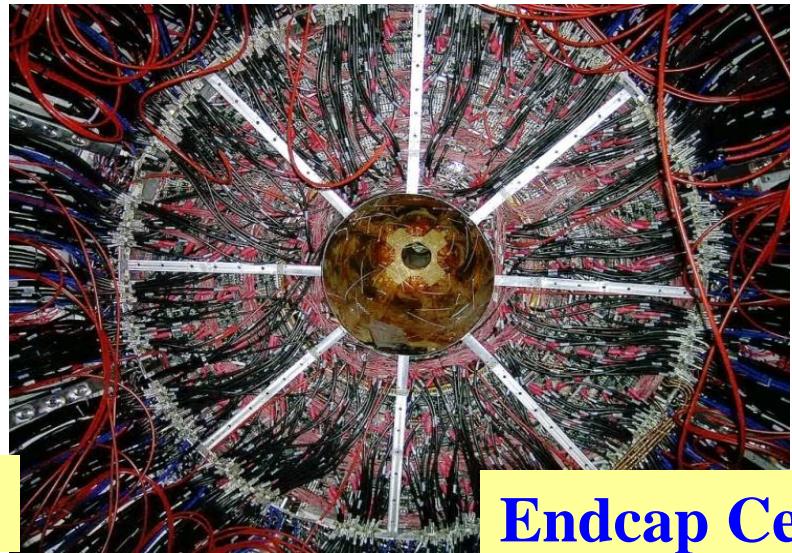
Dayabay Neutrino Exp.

- Neutrino Detector
- Water Cherenkov
- RPC

BESIII



SIDE VIEW



Endcap Center



Control room

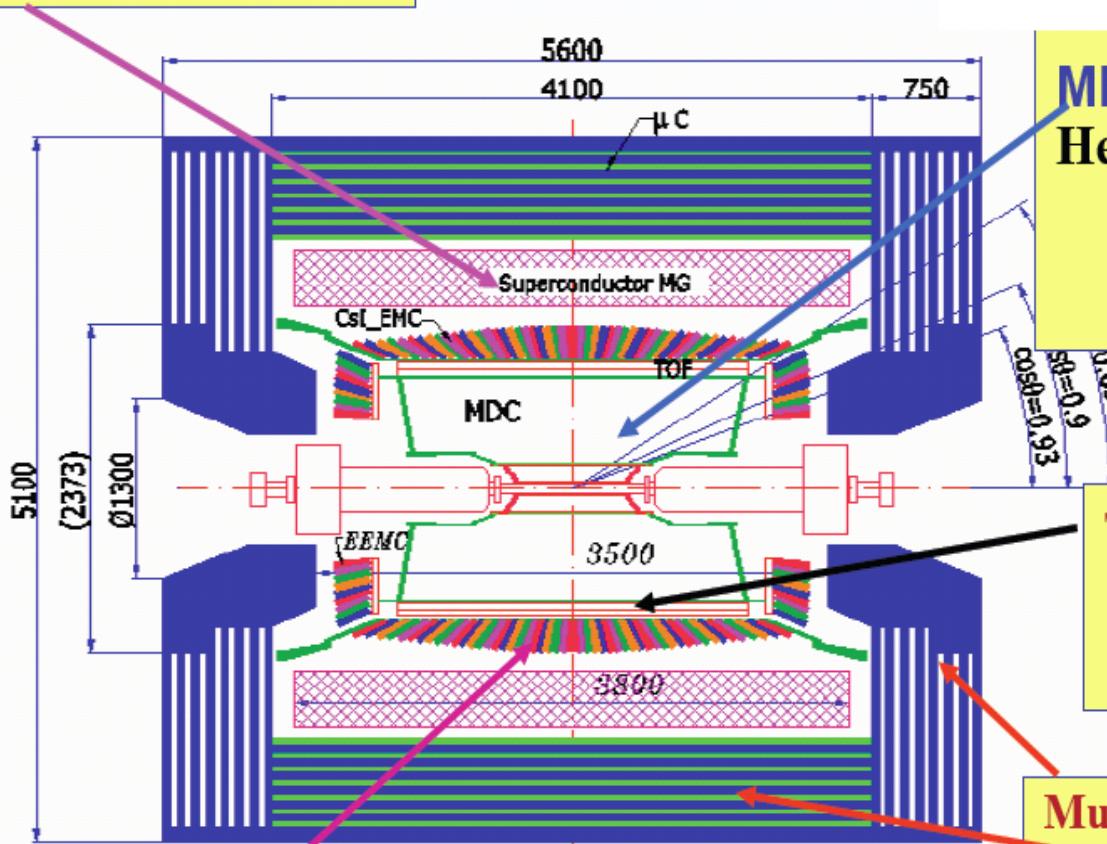


Readout Elec.

BESIII detector: all new !

BESIII Detector

Magnet: 1 T Super conducting



EMC: CsI crystal, 28 cm
 $\Delta E/E = 2.5\% @ 1 \text{ GeV}$
 $\sigma_z = 0.6 \text{ cm}/\sqrt{E}$

Data Acquisition:
Event rate = 4 kHz
Total data volume $\sim 50 \text{ MB/s}$

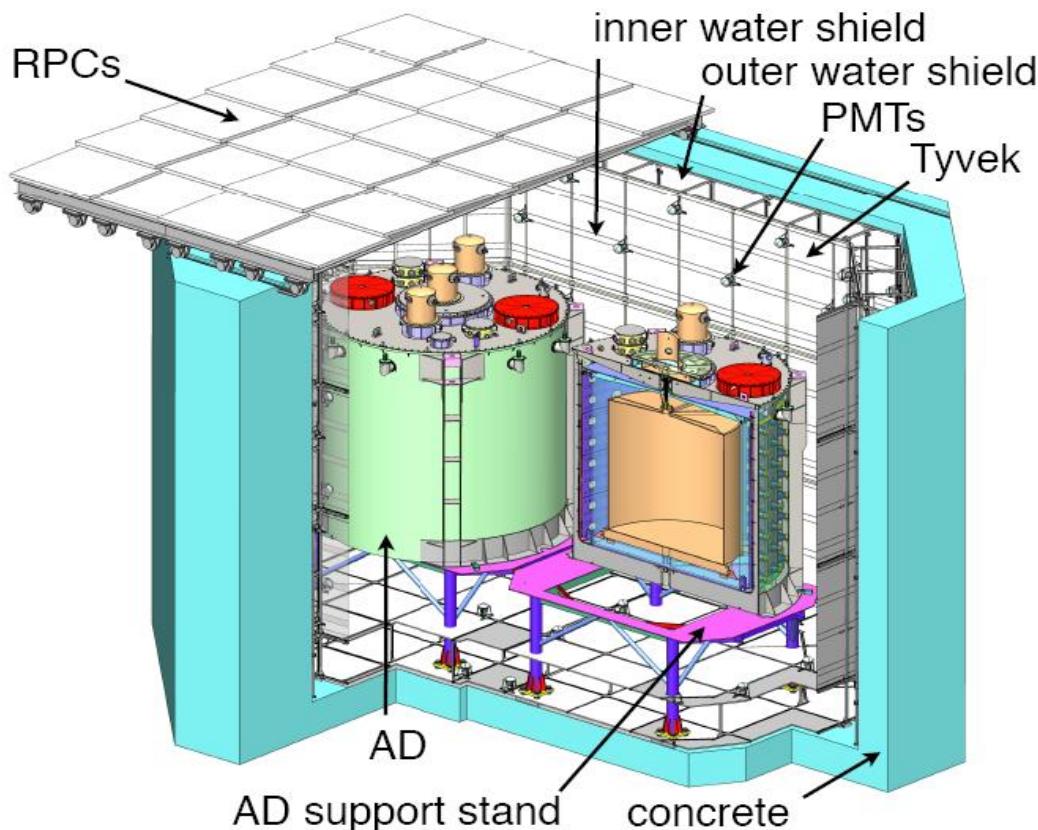
CsI calorimeter
Precision tracking
Time-of-flight + dE/dx PID

MDC: small cell & Gas:
He/C₃H₈ (60/40), 43 layers
 $\sigma_{xy} = 130 \mu\text{m}$
 $\sigma_p/p = 0.5\% @ 1 \text{ GeV}$
 $dE/dx = 6\%$

TOF:
 $\sigma_T = 78 \text{ ps} \quad \text{Barrel}$
 $110 \text{ ps} \quad \text{Endcap}$

Muon ID: 9 layers RPC
8 layers for endcap

Detectors of Dayabay Neutrino Exp.



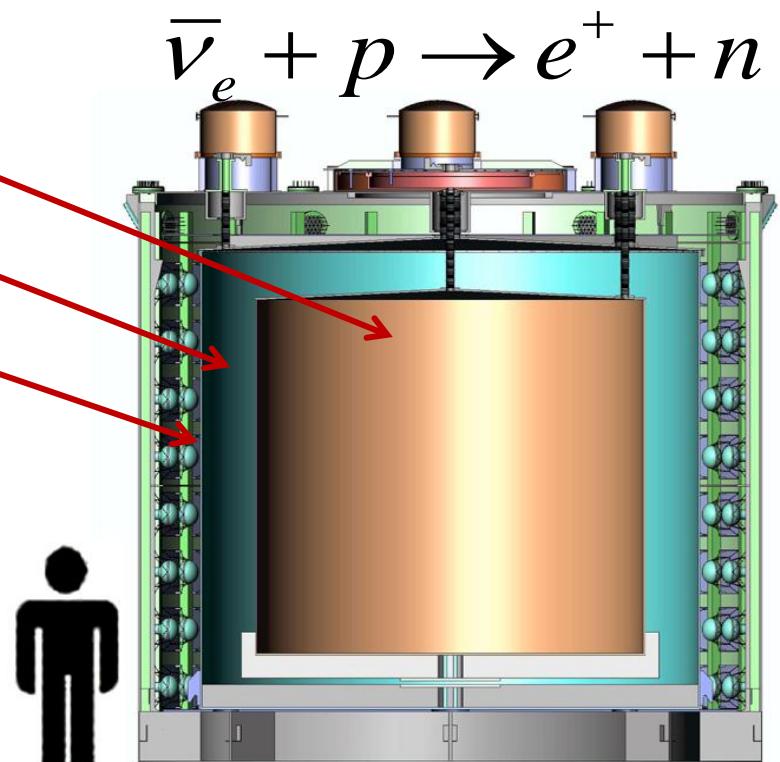
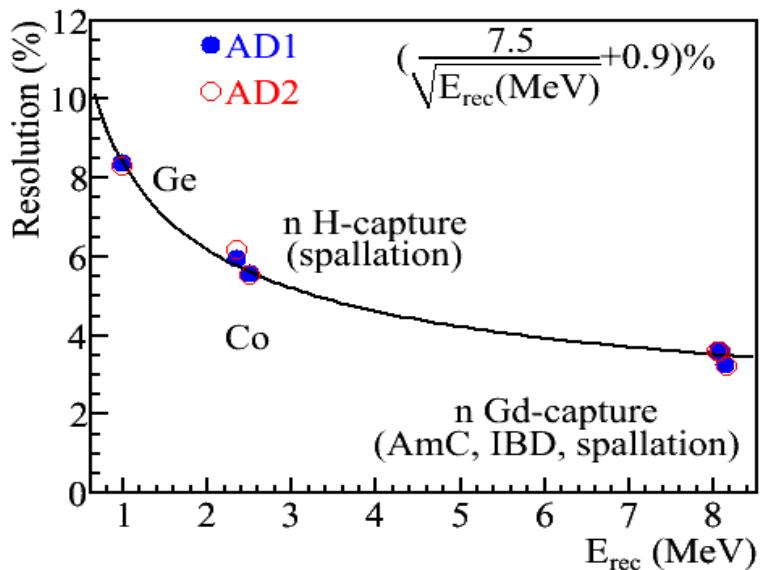
- ◆ **AD(Anti-neutrino Detector)**
- ◆ **RPCs**
 - **4 layers/module**
 - **54 modules/near hall, 81 modules/far hall**
 - **2 telescope modules/hall**
- ◆ **Water Cerenkov detector**
 - **Two layers, separated by Tyvek/PE/Tyvek film**
 - **288 8" PMTs for near halls; 384 8" PMTs for the far hall**

Two active cosmic-muon veto's

- Water Cerenkov: Eff.>97%
- RPC Muon tracker: Eff. > 88%

Anti-neutrino Detector (AD)

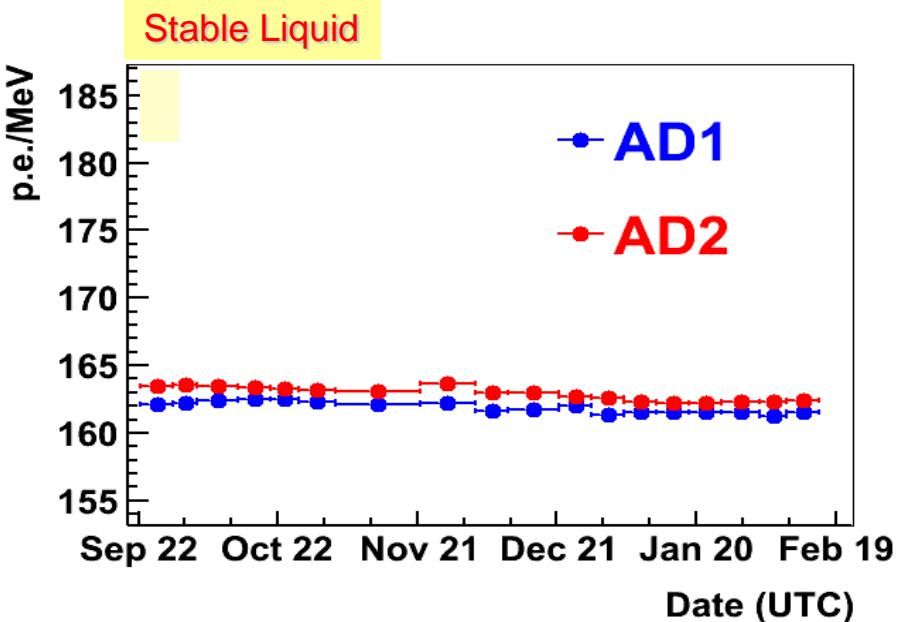
- ◆ Three zones modular structure:
 - I. target: Gd-loaded scintillator
 - II. γ -catcher: normal scintillator
 - III. buffer shielding: oil
- ◆ 192 8" PMTs/module
- ◆ Two optical reflectors at the top and the bottom, Photocathode coverage increased from 5.6% to



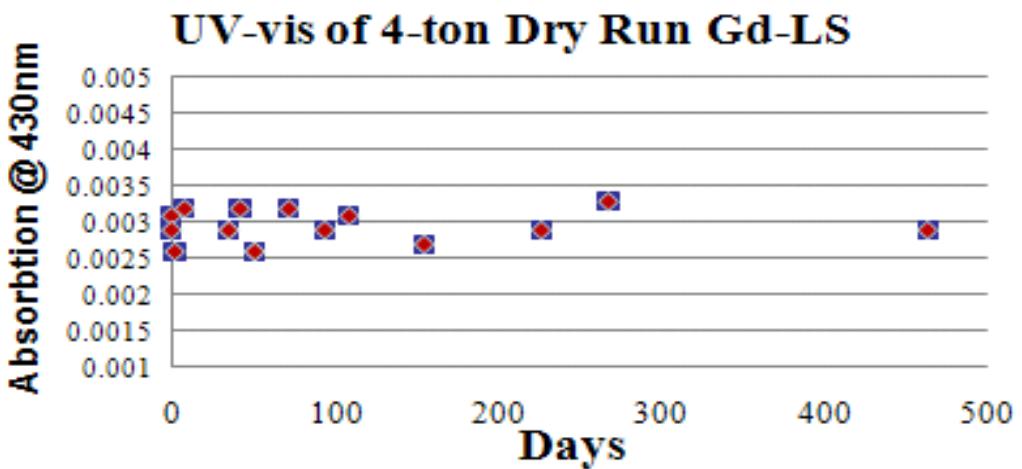
Target: 20 t, 1.6m
 γ -catcher: 20t, 45cm
 Buffer: 40t, 45cm
 Total weight: ~110 t

Gd-loaded Liquid Scintillator

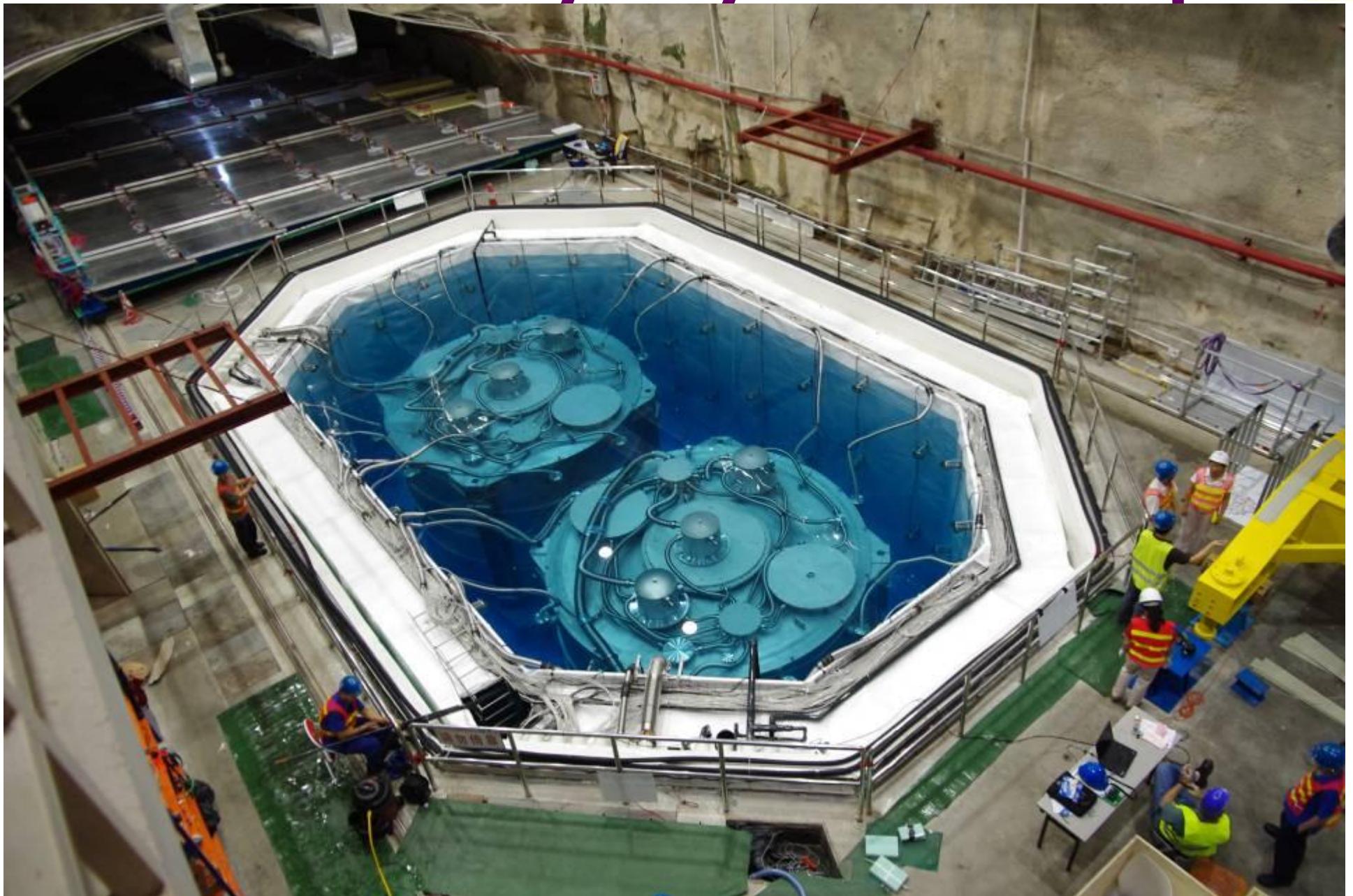
- ♦ Liquid production, QA, storage and filling at Hall 5
 - **185t Gd-LS, ~180t LS, ~320t oil**
- ♦ LAB+Gd (TMHA)³+PPO+BisMSB
- ♦ Stable over time
 - **Light yield: ~163 PE/MeV**



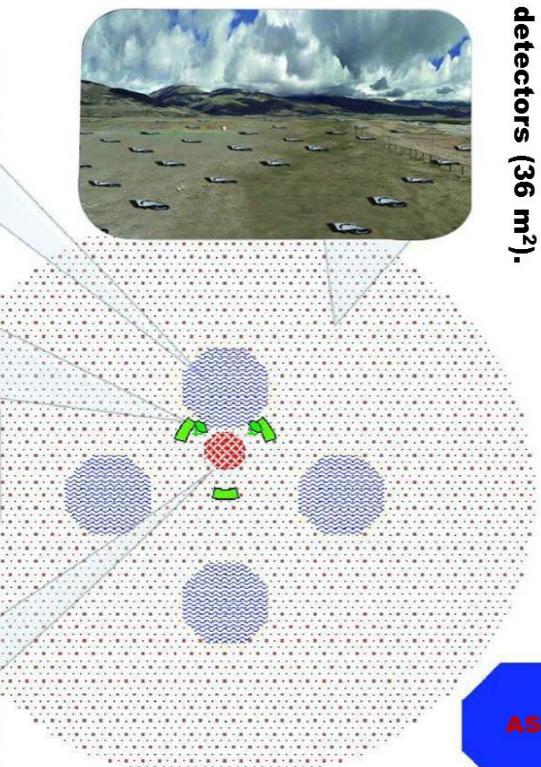
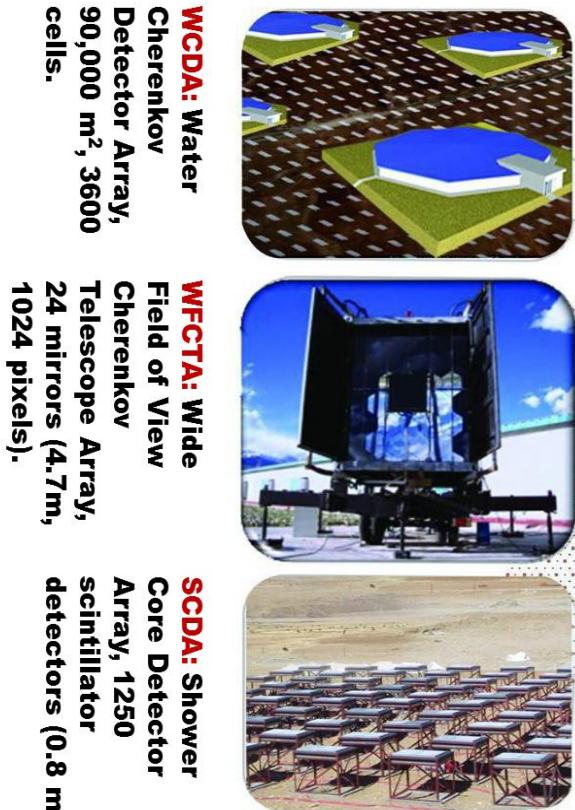
Liquid hall: LS production and filling



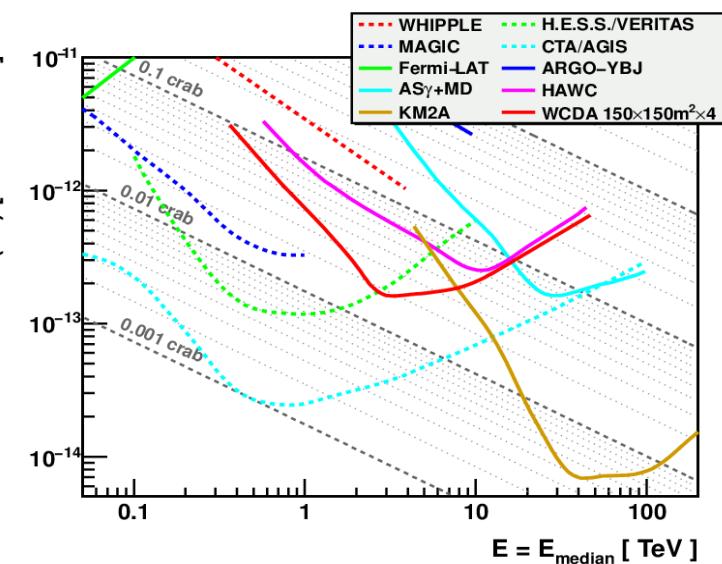
Detectors of Dayabay Neutrino Exp.



LHAASO Project



KM2A: 1 km² Array, 5000 scintillators (1 m²) and 1200 water Cherenkov muon detectors (36 m²).



Sensitivity: 1 yr
(IACT: 50 h)

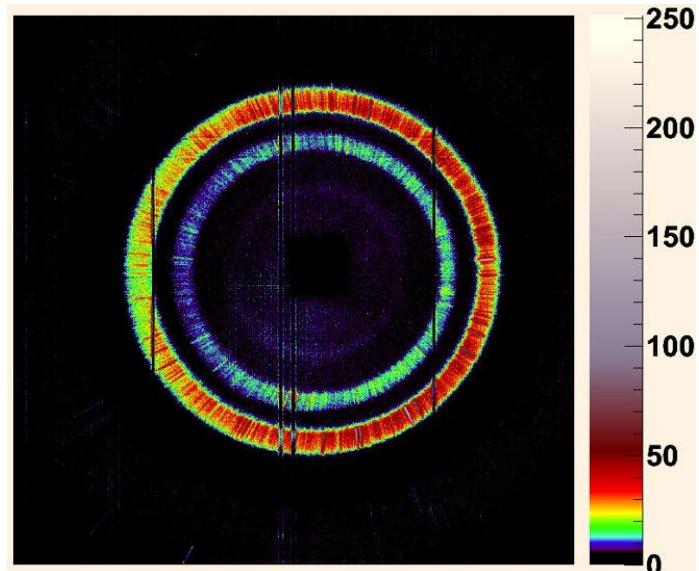
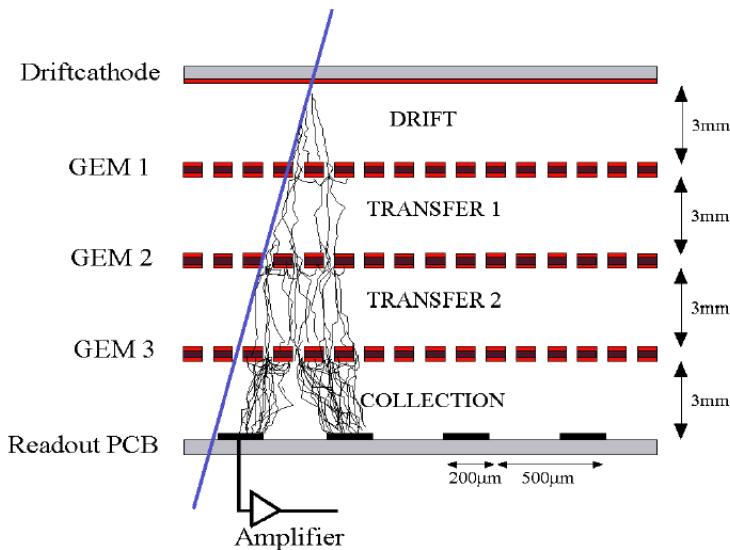
- ◆ Physics Goals:
 - VHE gamma astronomy: sky survey & flares & deep observation;
 - Cosmic ray physics: deliver energy scale from direct observation to UHE & knee composition.

- ◆ Schedule:
 - **1/100 prototype array for each component has been built at 4300 m a.s.l.;**
 - **Full array is planned to be constructed by 2017.**

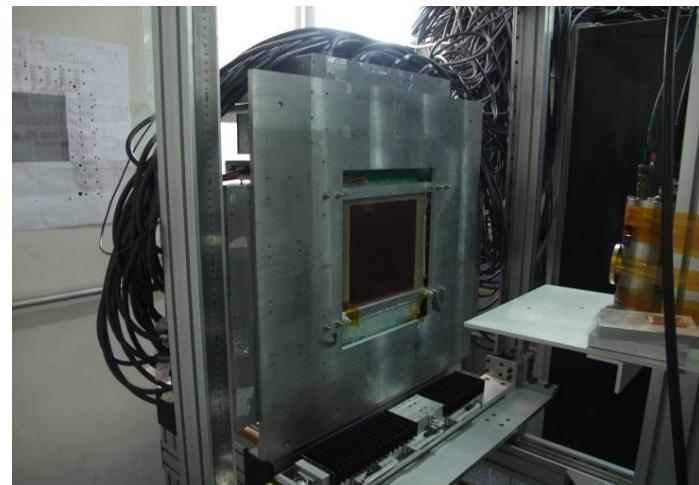
Outline

- ◆ Detectors at several big experiments
 - **BESIII**
 - **Dayabay Neutrino Experiments**
 - **LAASHO**
- ◆ New detectors R&D
 - **Gas detectors**
 - **Scintillator detectors**
 - **Semiconductor detectors**
 - **Detectors for application**

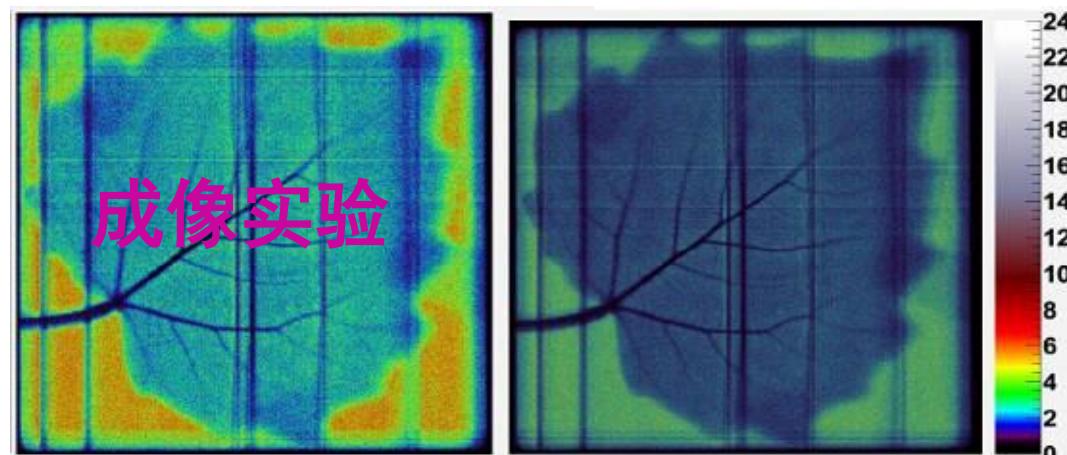
2D-GEM for X-ray



SiO₂ powder , 8keV Synchrotron



- 200 mm \times 200mm
- Rate: \sim 100KHz
- Resolution: \sim 200 μ m

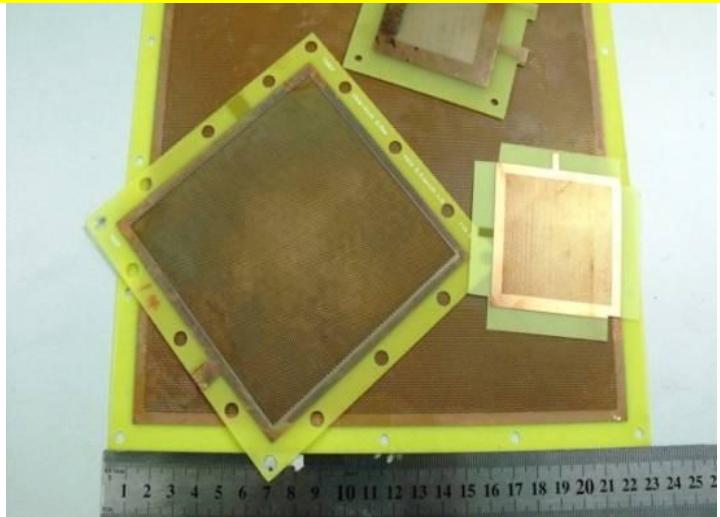


Leaf, 8keV X-ray tube

Thick GEM

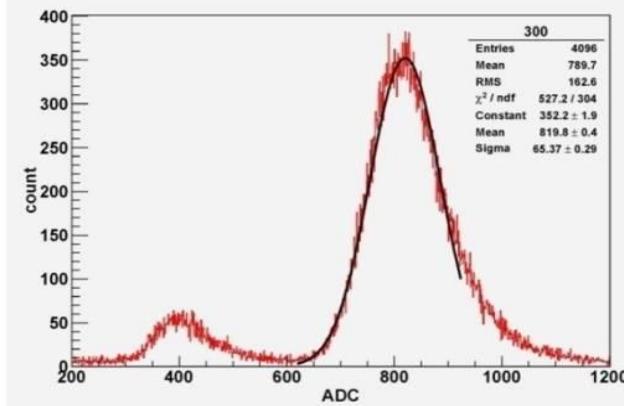
- similar to GEM but thick (0.2-1.2 mm), by PCB
- more robust ,higher gain, radiation hard, fast signal
- Hole diameter (pitch) ~ 2-2.5 thickness)

MAX Size: 20cmX20cm



- 1.Upto 20cm × 20cm
- 2.Energy reso. 19% for ^{55}Fe , Gain 2×10^5 as CERN
- 3.Samples is being used

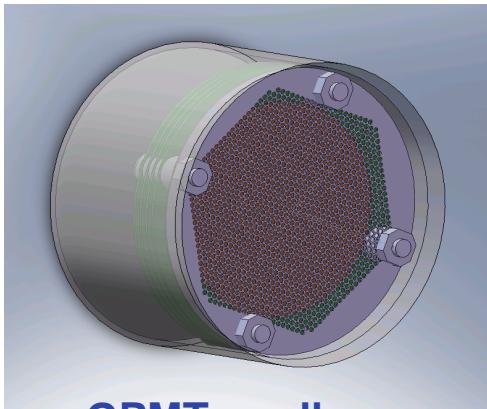
Ar/iC4H10(5%),



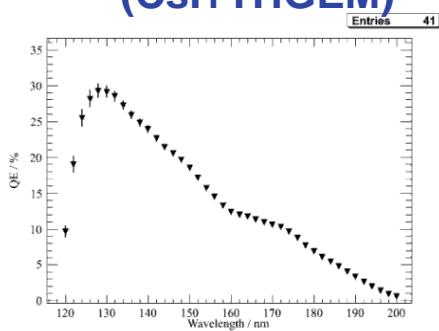
Best energy resolution is 19%

Gas PMT (CsI+thickGEM)

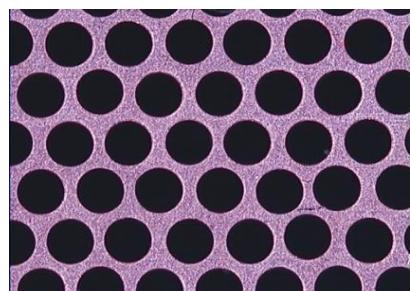
- CsI Cathode (120~210nm)
- QE: 60%@128nm.
- Gain: 2.0×10^5 ,
- Energy Resolution: 20%.



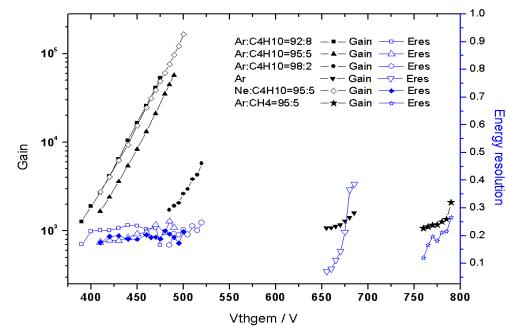
GPMT module
(CsI+THGEM)



CsI QE fine measuring



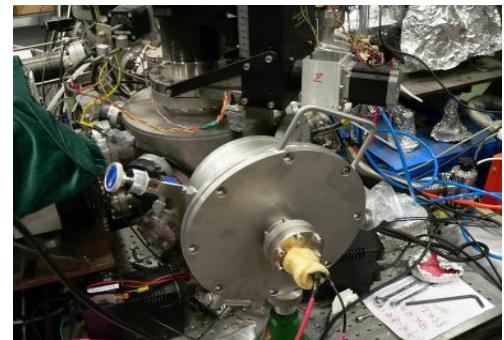
THGEM made in China



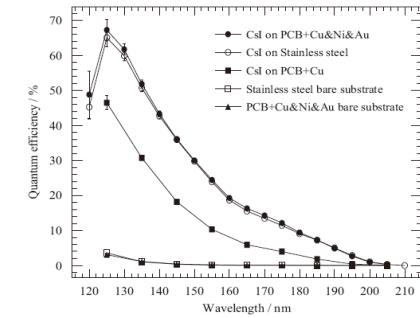
THGEM Gain



Film coating machine



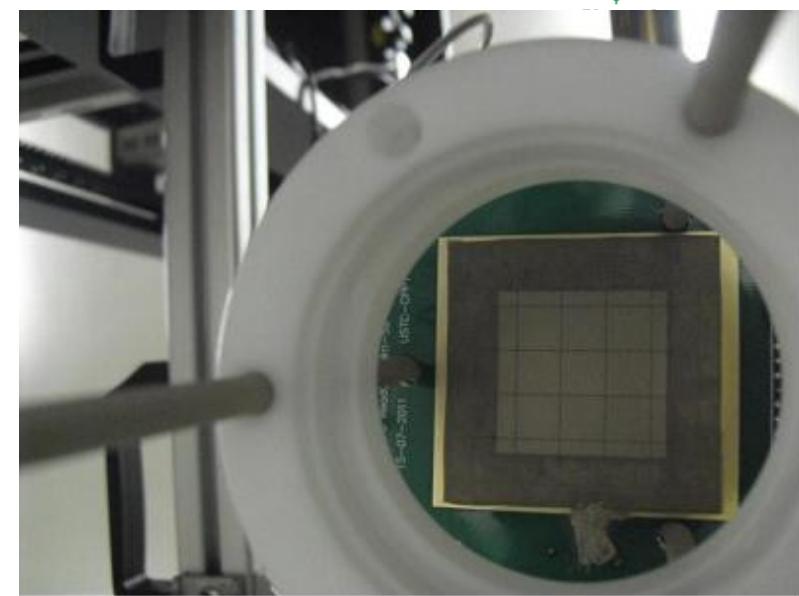
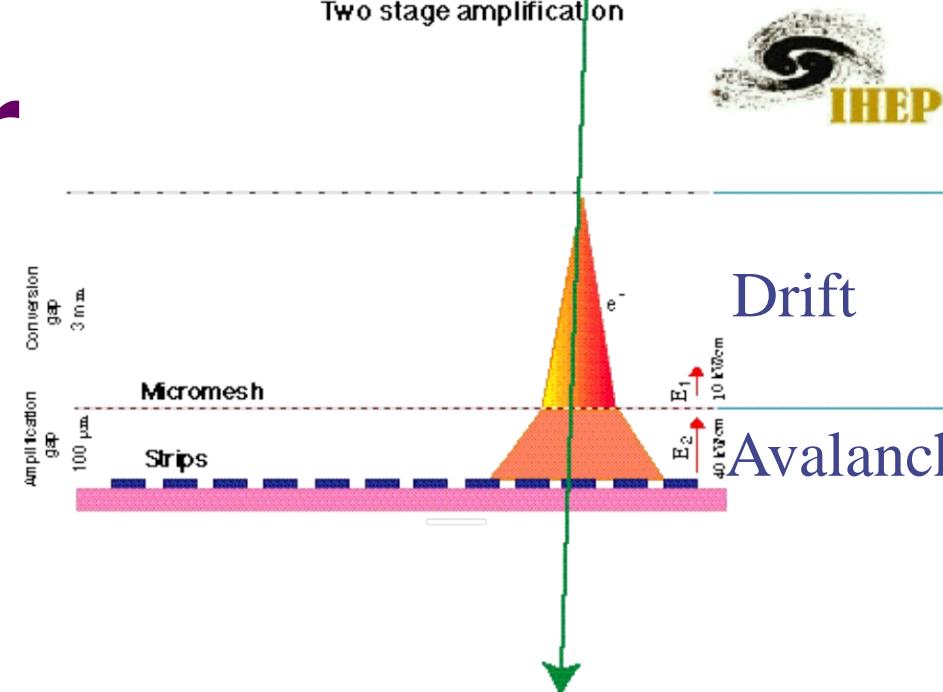
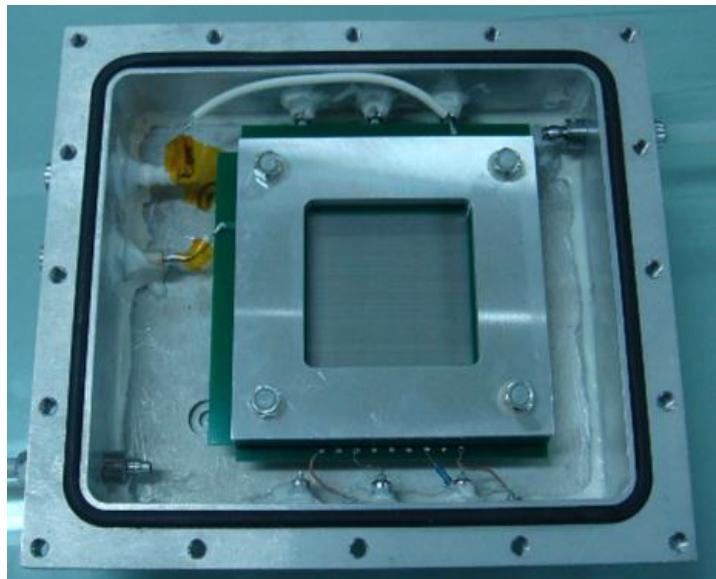
QE measurement @
synchrotron



QE of CsI on different base

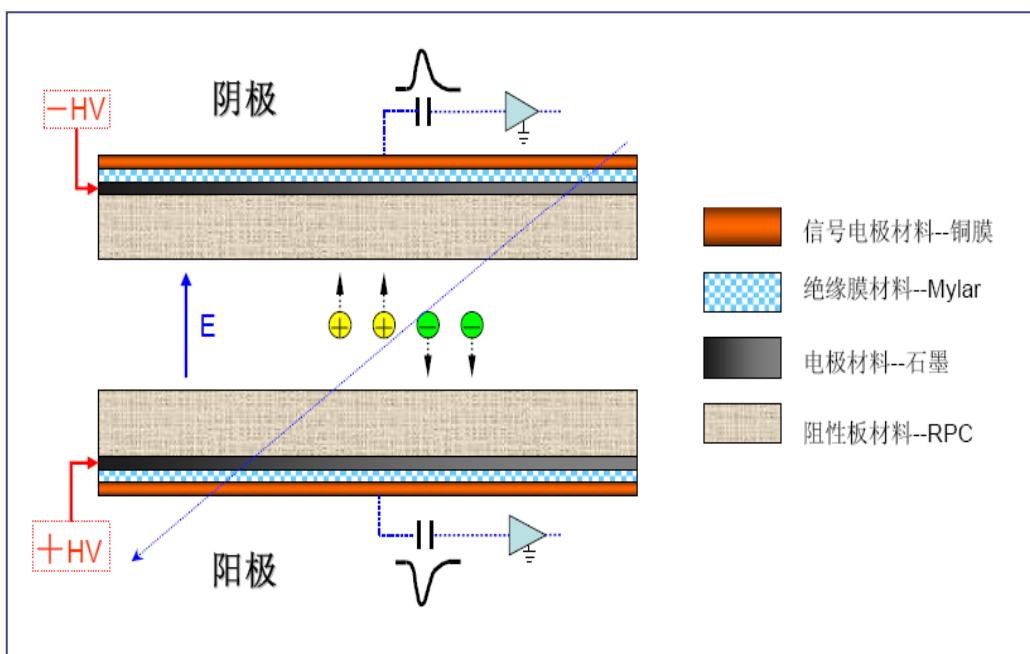
MicroMegas Detector

- ◆ **$30 \times 30, 50 \times 50, 80 \times 80, 160 \times 160$ (mm)**
- ◆ **Position Reso. $78\mu\text{m}$**
- ◆ **Gain:30000,**
- ◆ **Energy reso. 22%**



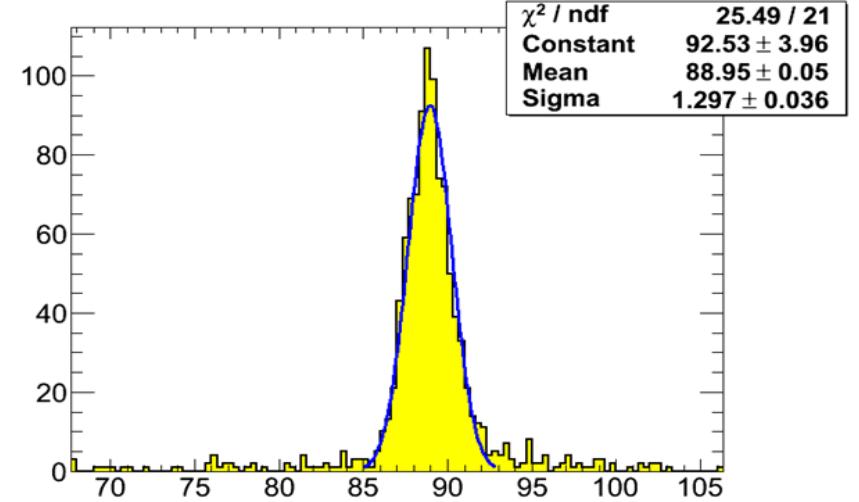
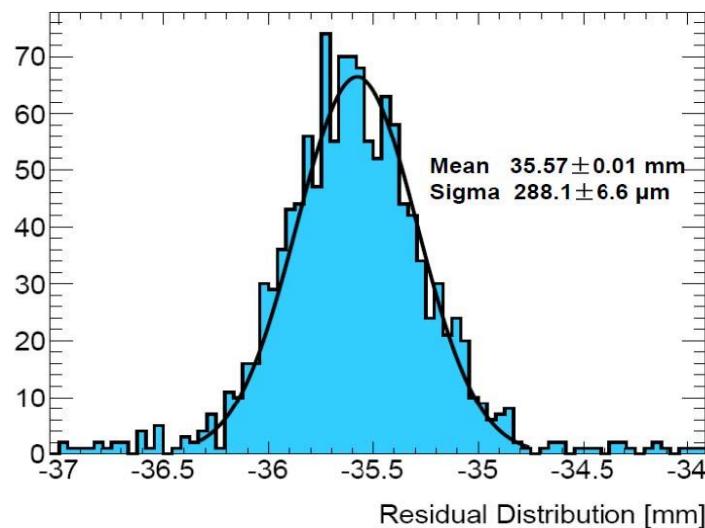
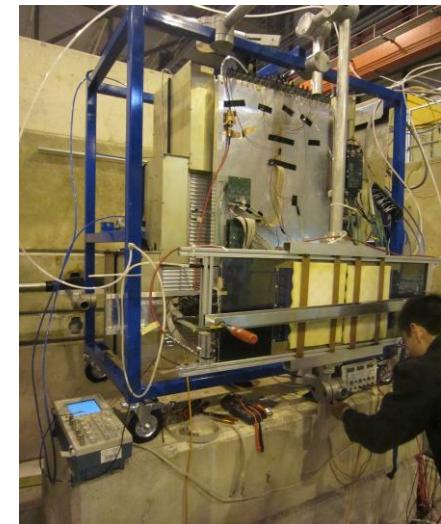
Tested on TPC at Shanghai

- ◆ Low price, used in large area
- ◆ Bakelite (L3, Babar, CMS, ...) or Glass (Belle)
- BESIII RPC, no oil
- ◆ Noise : Glass~ 0.05 Hz/cm^2 , Bakelite~ (0.03-0.1) Hz/cm^2

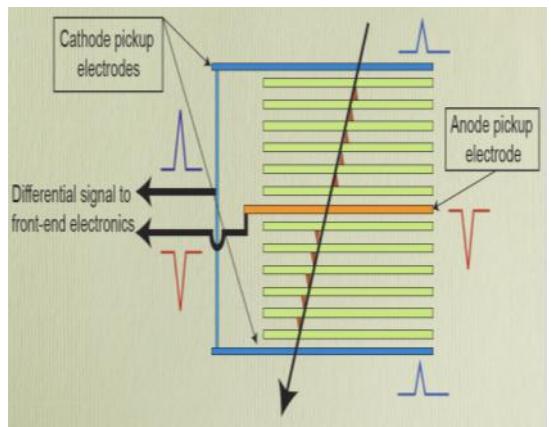


New Thin-Gap RPC

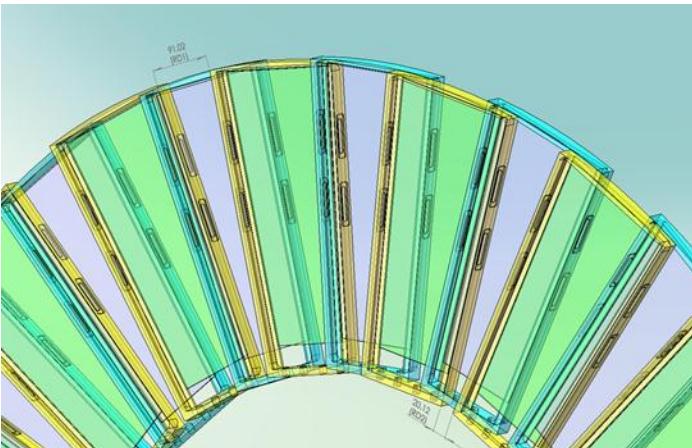
- For muon upgrade of ATLAS near beam area
- Target: 10kHz/cm², low resi. & thin gap
- Bulk resi. $10^9 \Omega\cdot\text{cm}$, uniformity: 3 times
- Beam test: SPS H8, 180GeV/c muon
- Gas recycling usage: cooperation intent with Argonne



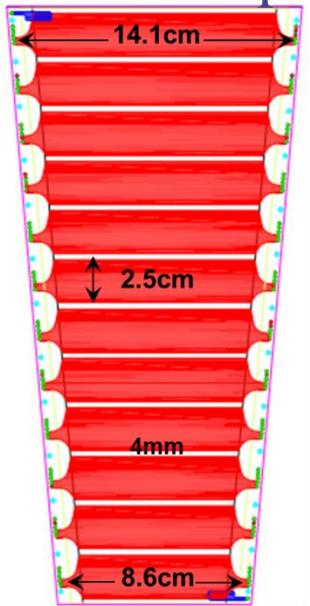
MRPC for Endcap TOF upgrade



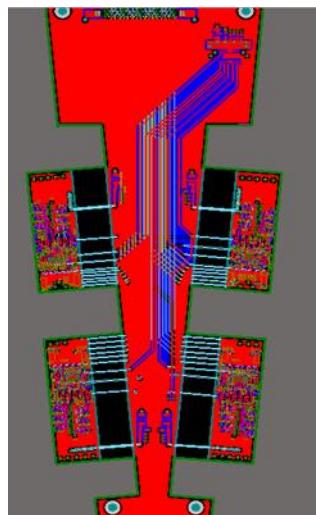
Principle



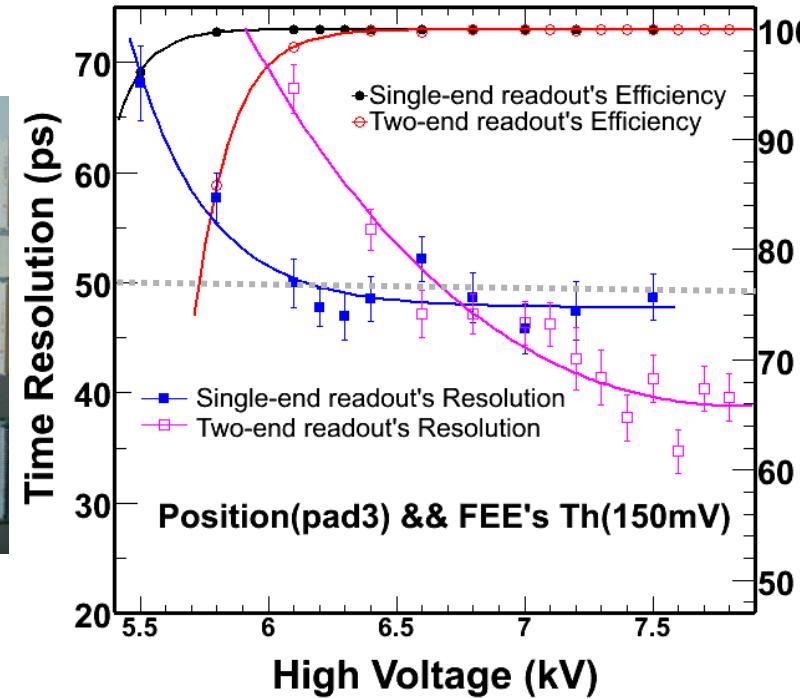
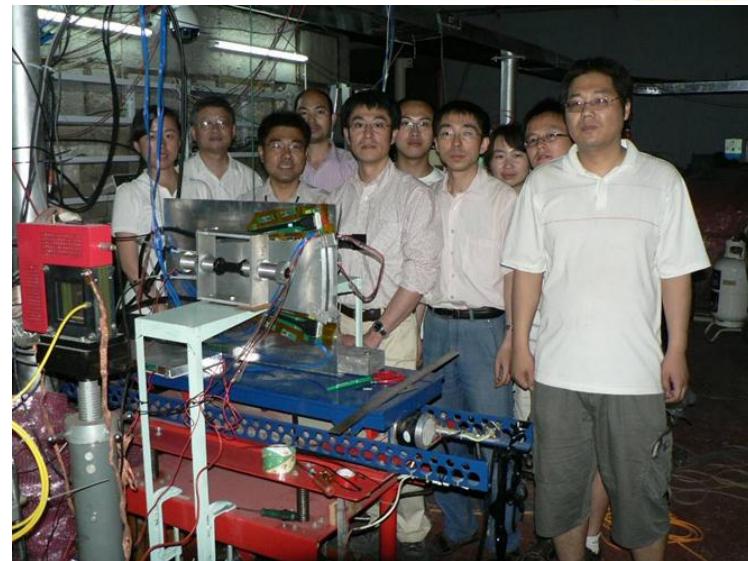
Overlapped Carbon fiber box



Readout pad



Soft PCB for FEE 25ps TDC



MWPC with ${}^3\text{He}$

- ◆ Pressure upto 8 atm ,high effi.



LSO and Gd-glass

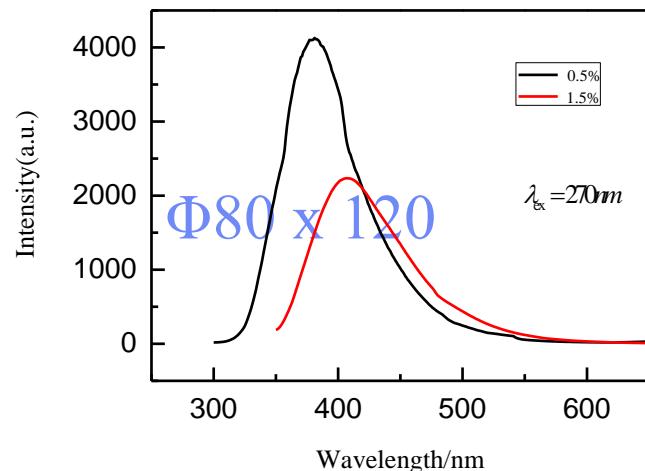
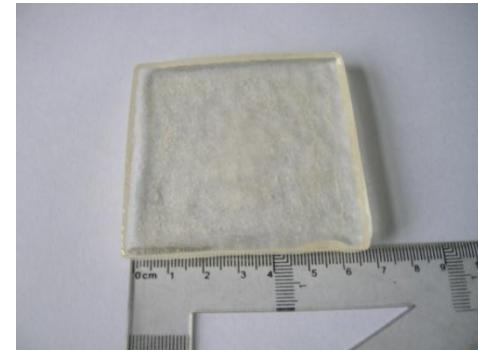
LSO ($\text{Ce:Lu}_2\text{SiO}_5$)

- Fast: 40 ns
- Dense: 7.4 g/cm³
- light yield: 70% of NaI
- Costly: 15\$/cc ?
- Noisy: ~ 1MeV



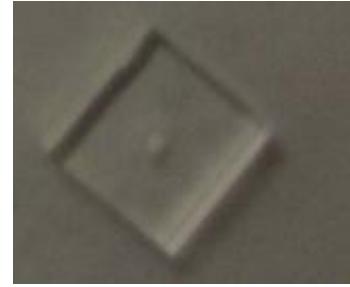
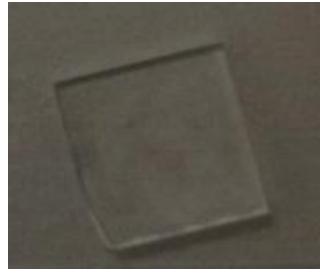
By 26th institute at Chongqing

- ◆ Gd glass: Ningbo Univ./IHEP,
 - High density: ~5 g/cm³
 - Light output: ~15% of plastic scin.

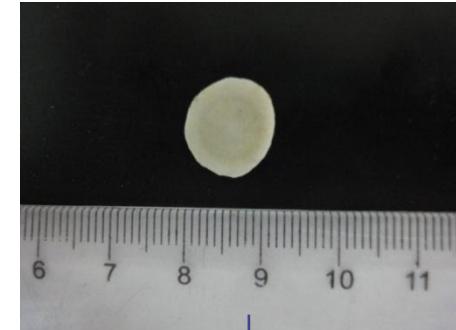


Scintillator with Li for neutron

Borate by SIC
(Shanghai Institute of Ceramics)



Silicate by SD Univ



Light output relative to plastic scintillator

Source	$\text{Li}_6\text{X}(\text{B0}_3)_3:\text{Ce}$	$\text{Li}_6\text{Lu}(\text{B0}_3)_3:\text{Ce}$	$\text{Li}_6\text{Gd}(\text{B0}_3)_3:\text{Ce}$
$^{239}\text{Pu}(\alpha)$	27%	89%	55%
^{241}Am	54%	150%	90%

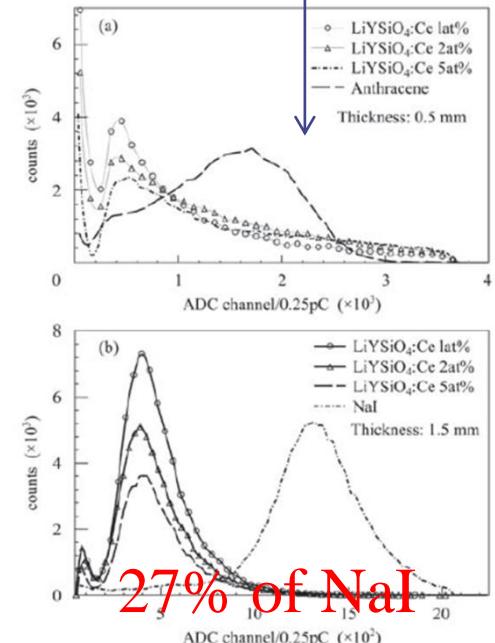
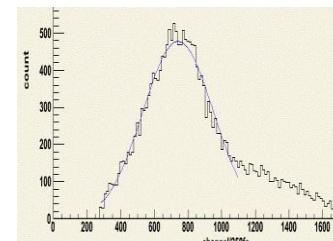
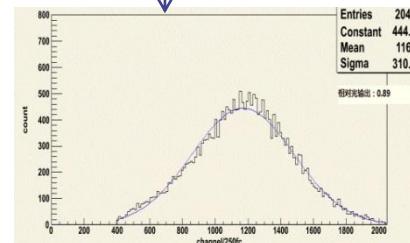
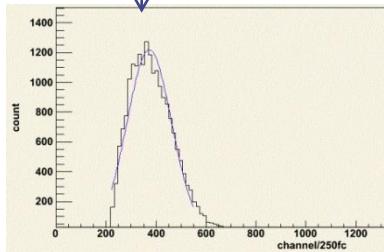
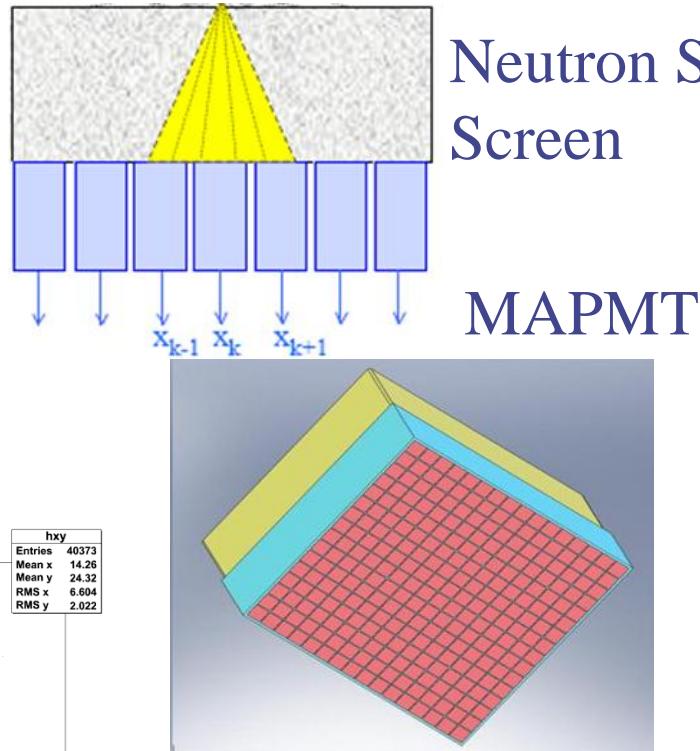
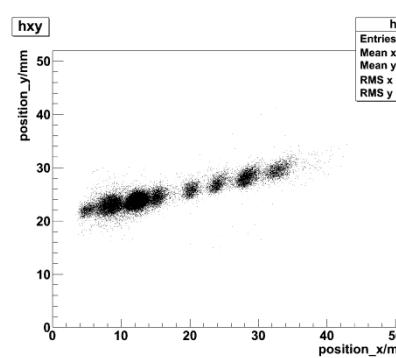
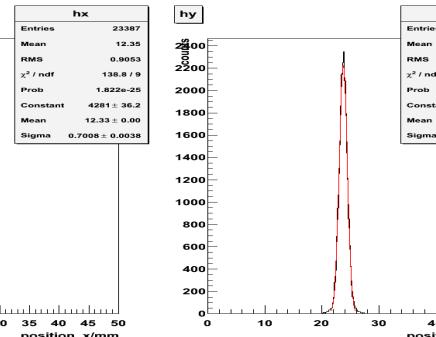
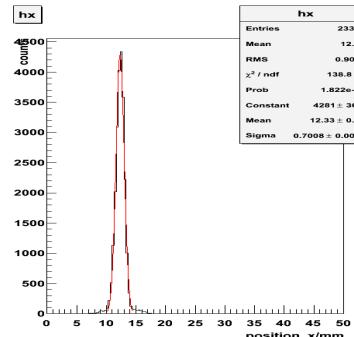


图 4.6 $\text{LiYSiO}_4:\text{Ce}$ 闪烁体在不同放射源激发下的脉冲幅度谱

Position sensitive Scin. detector for Neutron

- ◆ Principle:
 - Fluorescence disperse
 - The centre of gravity method
- ◆ Result: 0.7mm are reached.
- ◆ Effi.: 90%



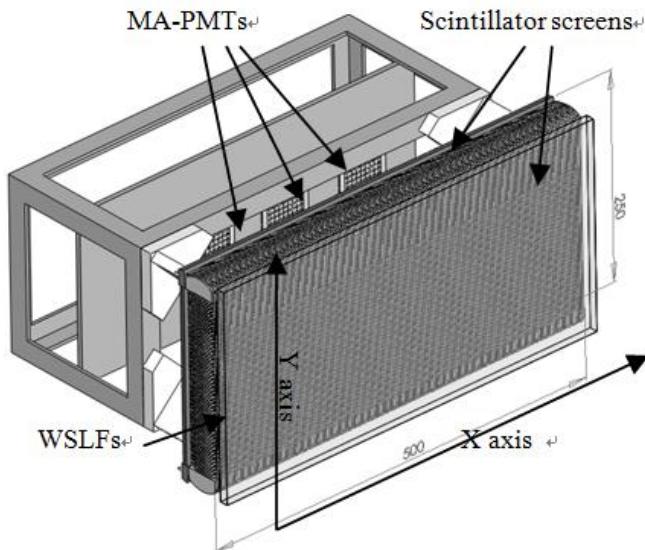
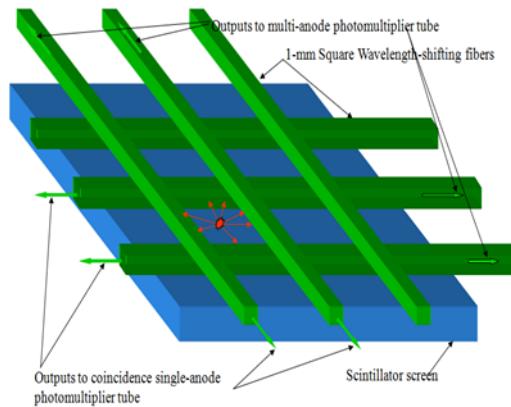
$$\sigma_x = 0.70\text{mm}$$

$$\sigma_y = 0.72\text{mm}$$

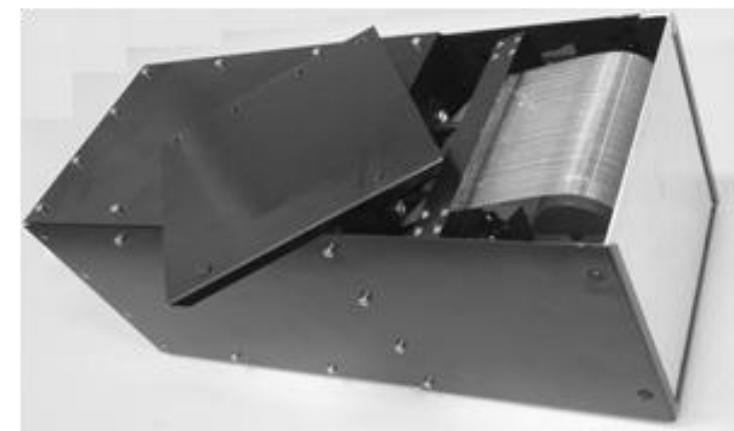
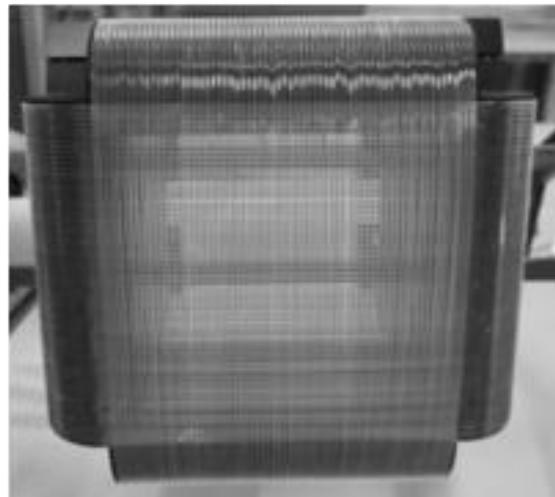


Position sensitive Scin. detector for Neutron

- Principle: ZnS(Ag) + WLSF + MAPMT
- Reso.: ~1mm
- Effi. : ~50%



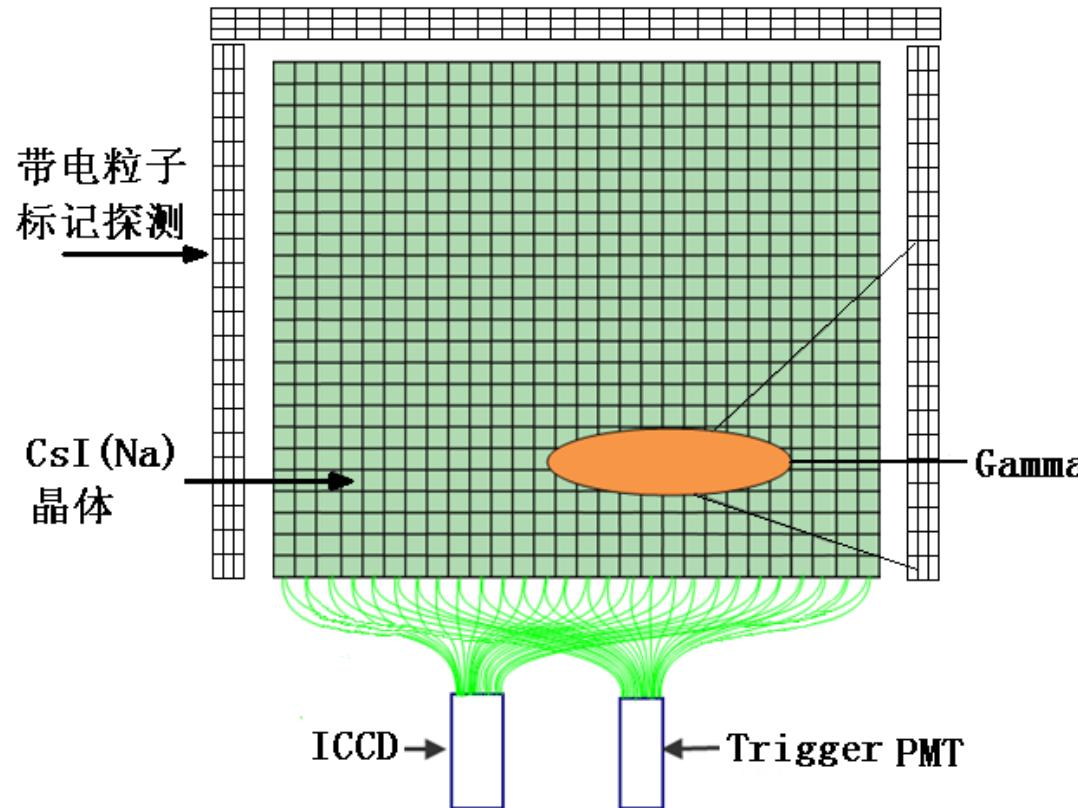
Principle



Prototype

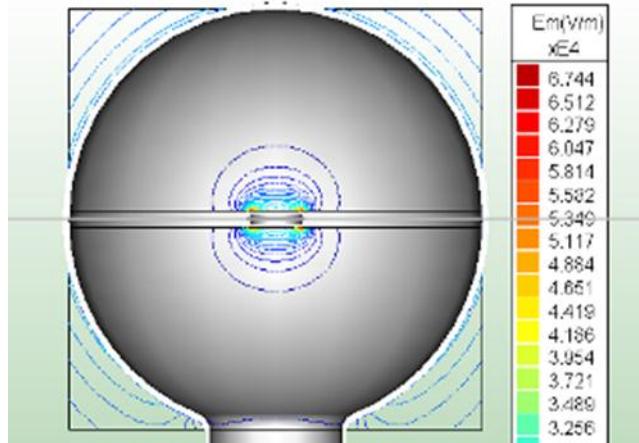
Digital Calorimeter

- ◆ CsI(Na) cell read out by fiber
- ◆ ICCD to record the fiber, 0/1 or with limited bit
- ◆ Total energy:

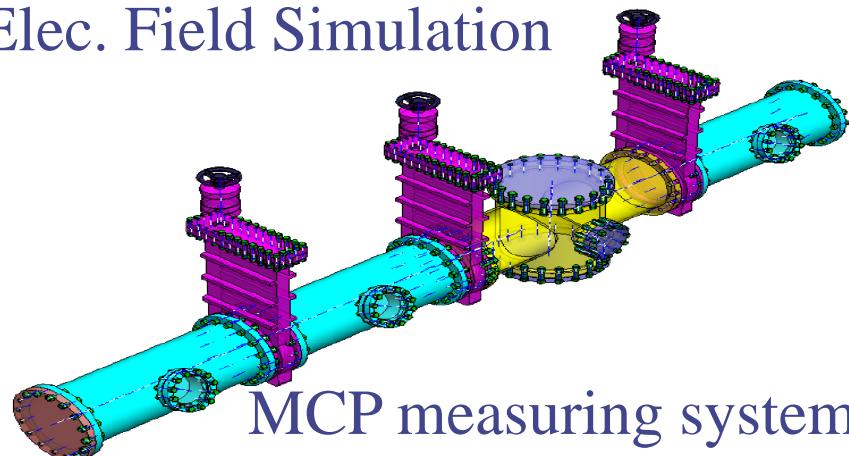


NEW LARGE AREA MCP-PMT

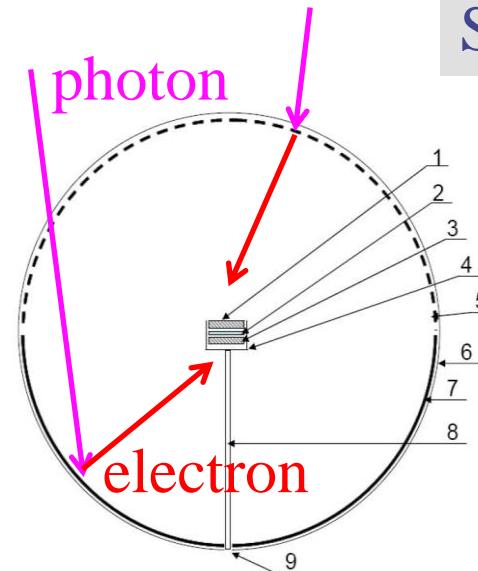
- ◆ Transparent Cathode + Reflection Cathode
- ◆ QE: $\sim 20\% + 80\% \times 20\% = 36\%$
- ◆ 5", 8"->20"



Elec. Field Simulation



MCP measuring system



Sen Qian's Talk

1. 上微通道板单元
2. 阳极读出单元
3. 上微通道板单元
4. 绝缘支架
5. 透射式光阴极
6. 特种玻璃球壳
7. 反射式光阴极
8. 高压和信号引出线, 支架
9. 玻璃熔融接口

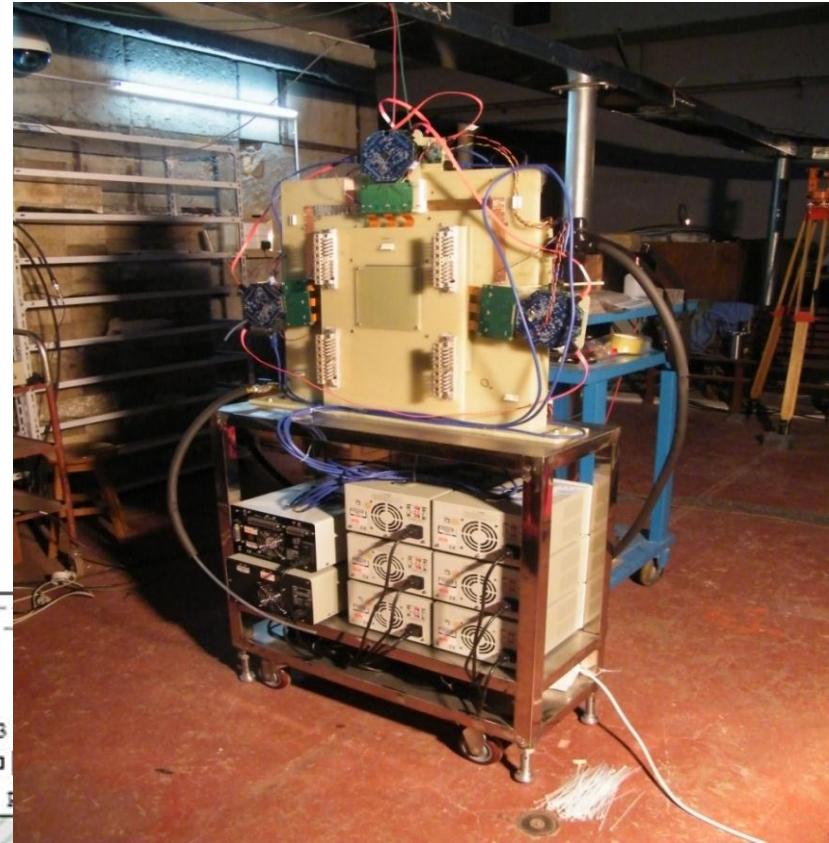
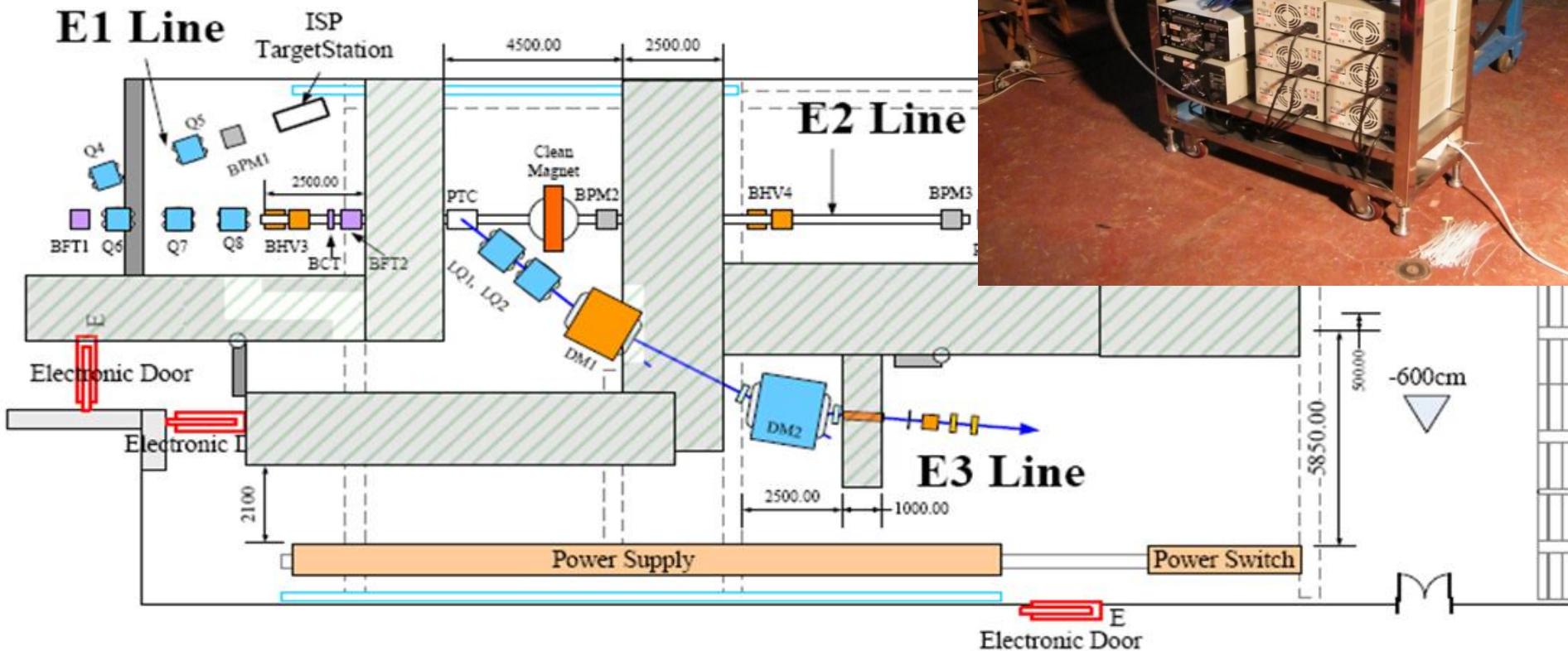
Test results:

Gain: $(1-5)10^5$
Noise: < 10 nA
QE ~ (15-20)%



Test Beam

Si strip detector From FermiLab

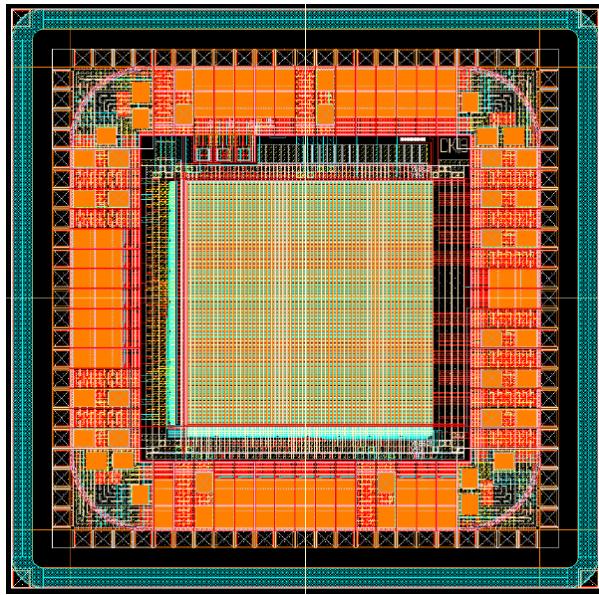


SOI Pixel Detector

Yupeng Liu's Talk

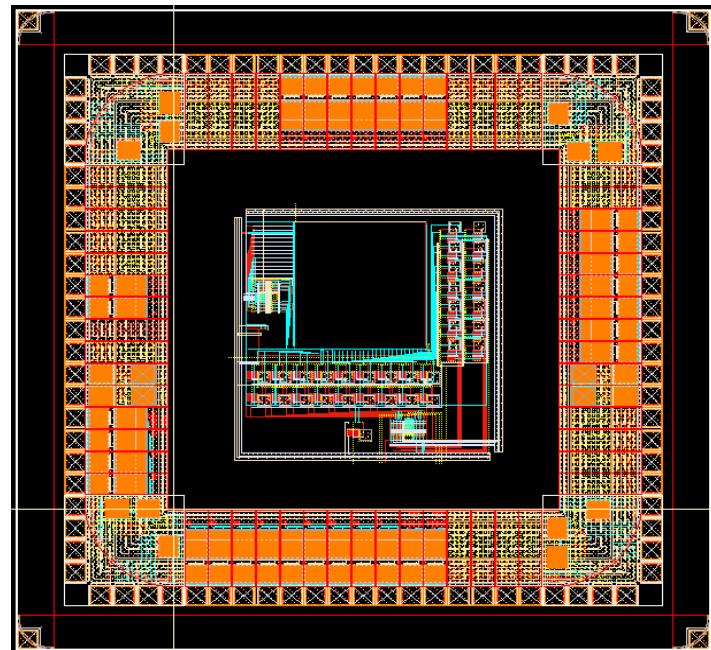
INTPIX2P5

- $2.9 \times 2.9\text{mm}^2$
- 64×64
- $19 \times 19\mu\text{m}^2$



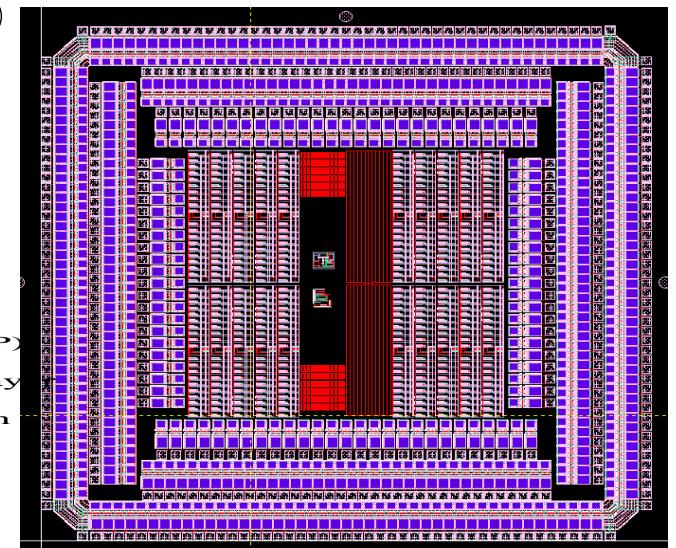
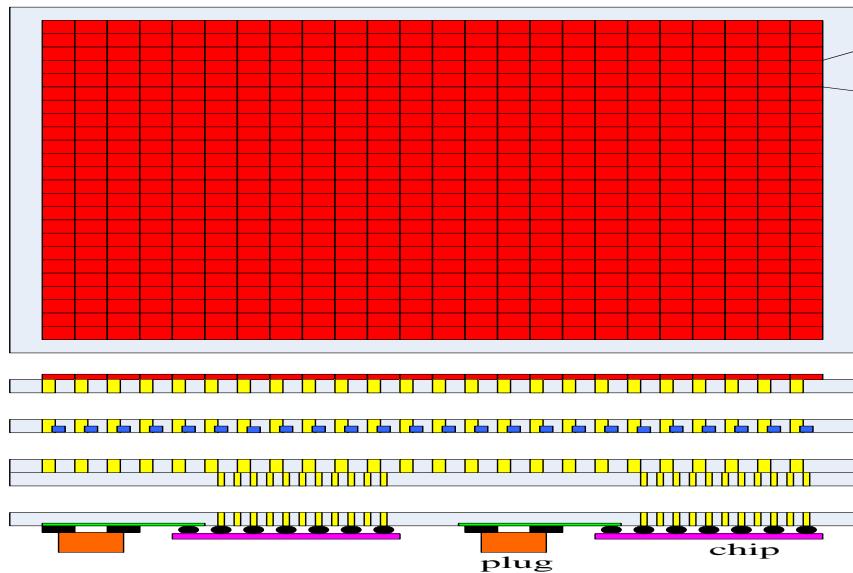
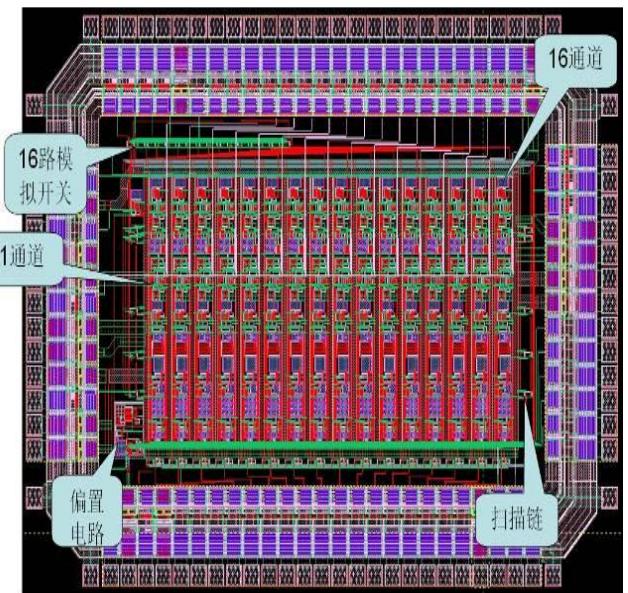
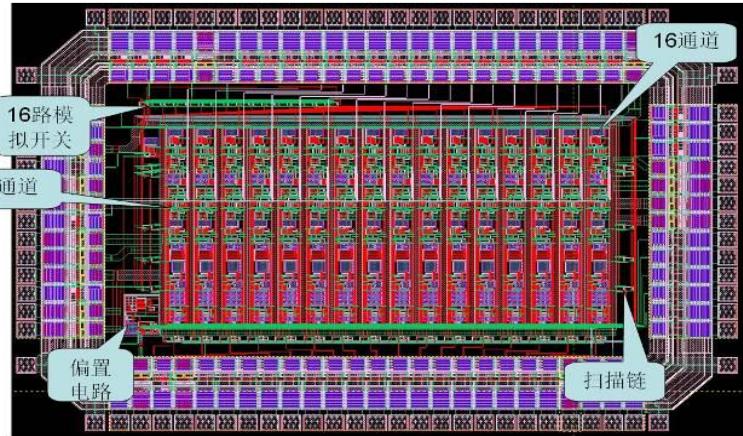
INTPIX1P8

- $2.9 \times 2.9\text{mm}^2$
- 32×32
- $18 \times 18\mu\text{m}^2$



ASIC

Wei Wei's Talk



Detectors for Nuclear Medicine



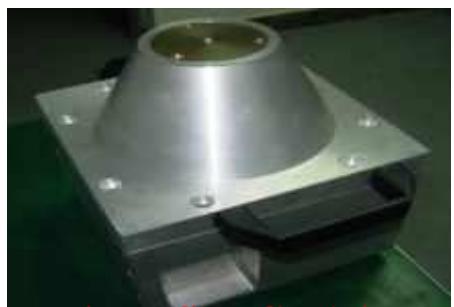
animal PET (I)



animal PET (II)



animal SPECT (parallel
hole collimator)



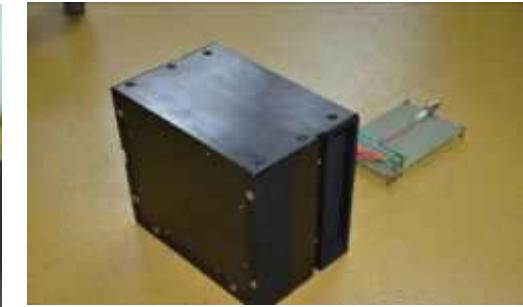
animal SPECT (pin
hole collimator)



DOI-PET



PEM



breast SPECT



whole-body PET



TOF-PET



PET-MRI

Detectors (for other applications)

Long Wei's Talk



gamma camera



X-ray backscatter imager (II)



positron annihilation
lifetime spectrometer



For ICT

Summary

- ◆ Detectors for big project
 - **BESIII、Dayabay、LHAASO**
- ◆ New detector R&D
 - **Gas detector:**
 - ◆ GEM、THGEM、Gas PMT、MicroMages、Thin gap RPC、MRPC
 - **Scintillator detector:**
 - ◆ Gd-Glasss、Borate and Silicate with Li、position sensitive scin. detector for neutron、digital calorimeter、new MCP-PMT
 - **Semiconductor detector**
 - **Medical detectors and other**

Thank you for your attention!

borate
['bɔrət]

(化)硼酸盐, 硼酸酯

lutetium [lu:tɪsiəm, -sɪəm]

Lu:

zinc D.J.[zinjk]

yttrium ['ɪtriəm]

alkyl ['alkvɪl, -kɪl]

silicate : 硅酸盐 ['sɪlɪkeɪt, -kət]

Cerium

Gd: Gadolinium

atomic number

ZnS: zinc sulfide

Pu: plutonium(Pu)

Am: Americium

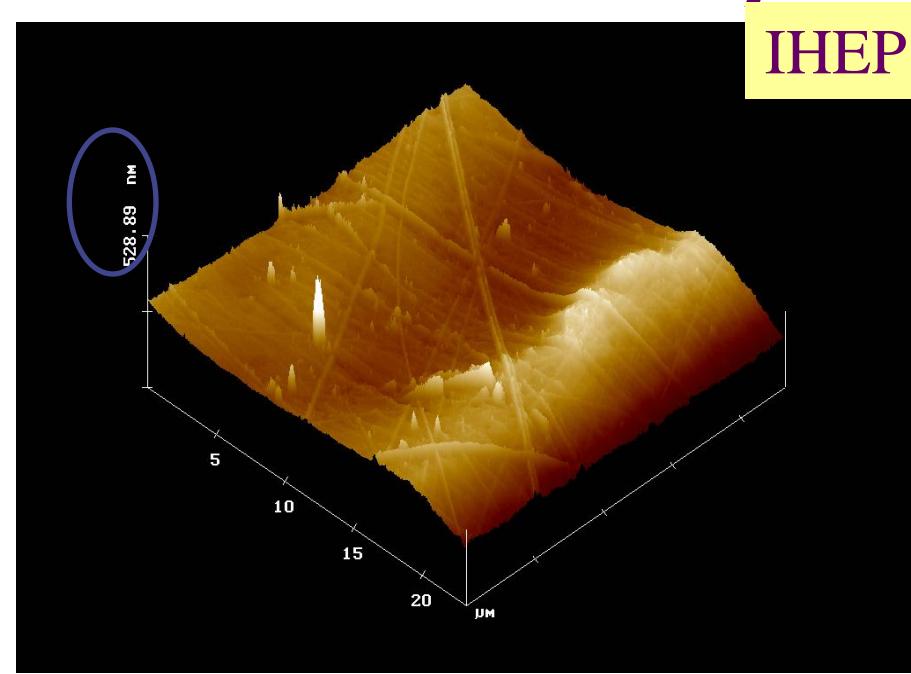
B: Boron

T: Tritium

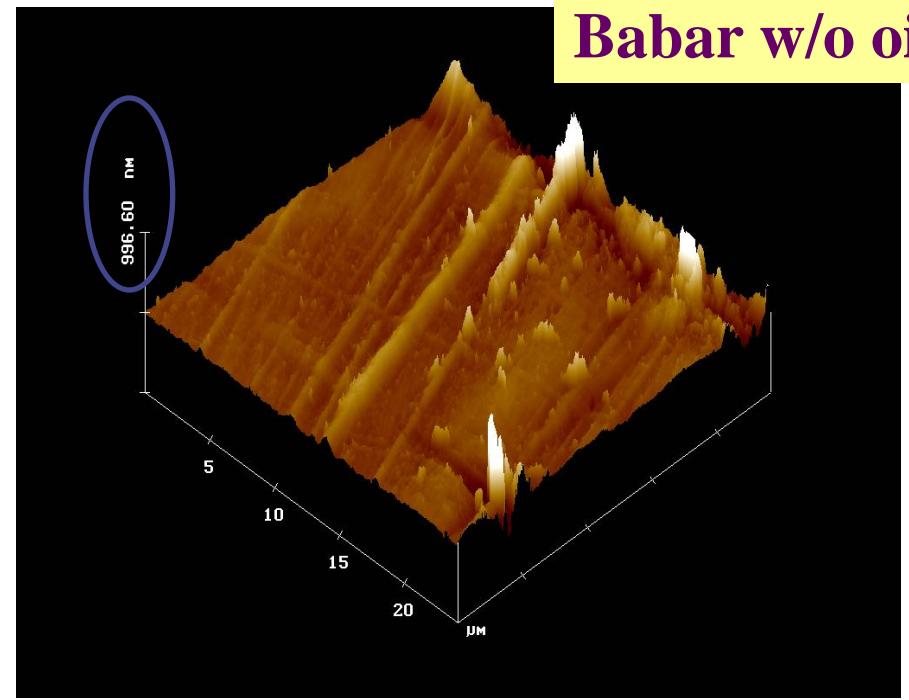
D: Deuterium

RPC surface seen by the atomic force microscope

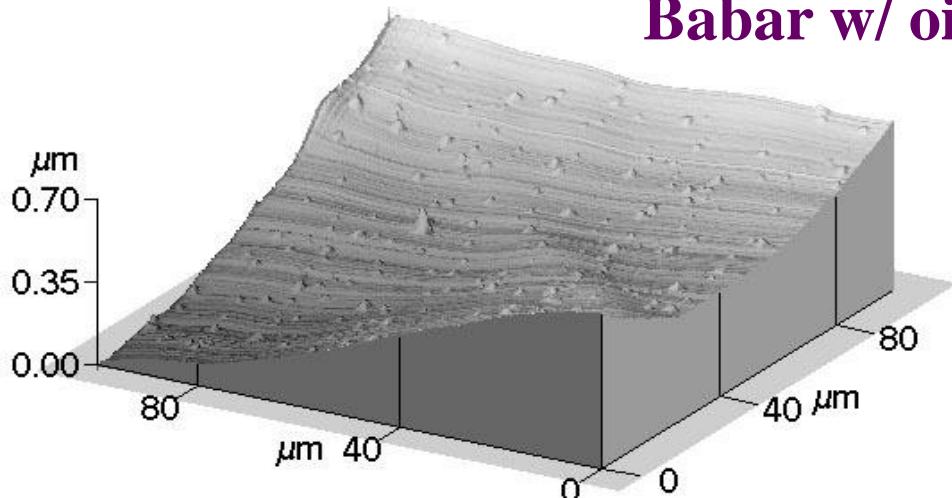
IHEP



Babar w/o oil



Babar w/ oil



Belle glass

