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Calorimetry for the High Energy Frontier

# An optimized prototype of Electromagnetic Calorimeter for SOLID

*2nd conference on Calorimetry for the High Energy Frontier*

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清華大學
Tsinghua University

# *outline*

1. Introduction
2. Fiber test
3. optimized prototype
4. Cosmic test
5. Summary

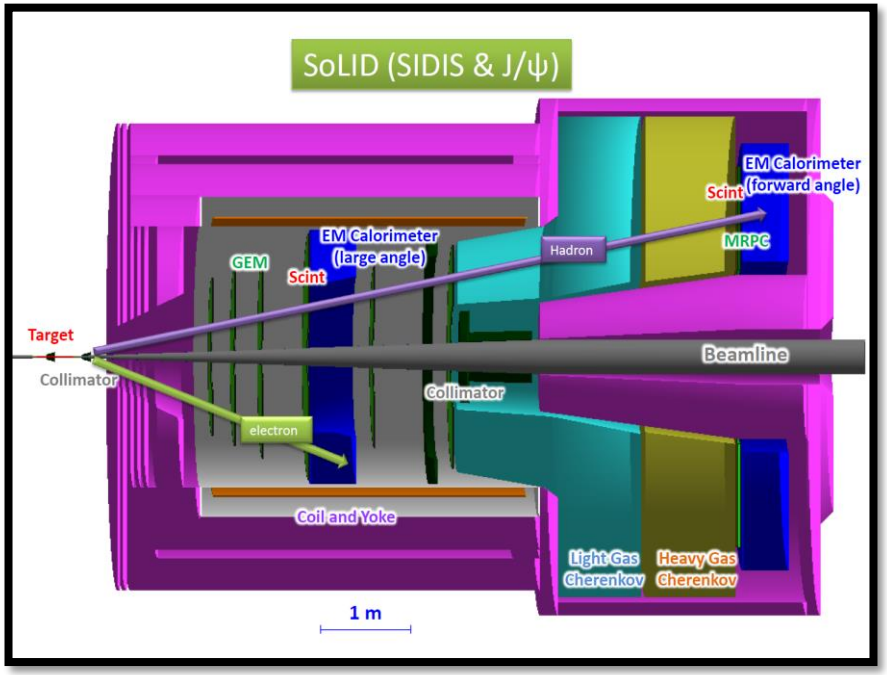
# 1 Introduction

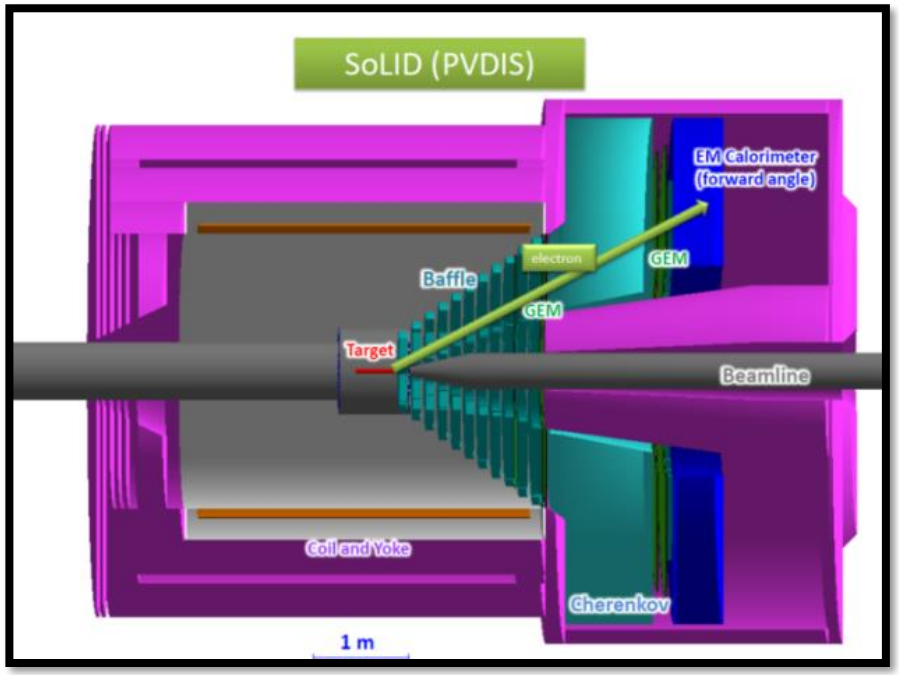
- **SoLID: Solenoidal Large Intensity Device**

  High Intensity ($10^{37}$ ~ $10^{39}$ $cm^{-2}s^{-1}$) and,

  Large Acceptance ($8<\Theta<24$, $0<\Phi<360$, $1<Pe<7GeV/c$ for SIDIS)

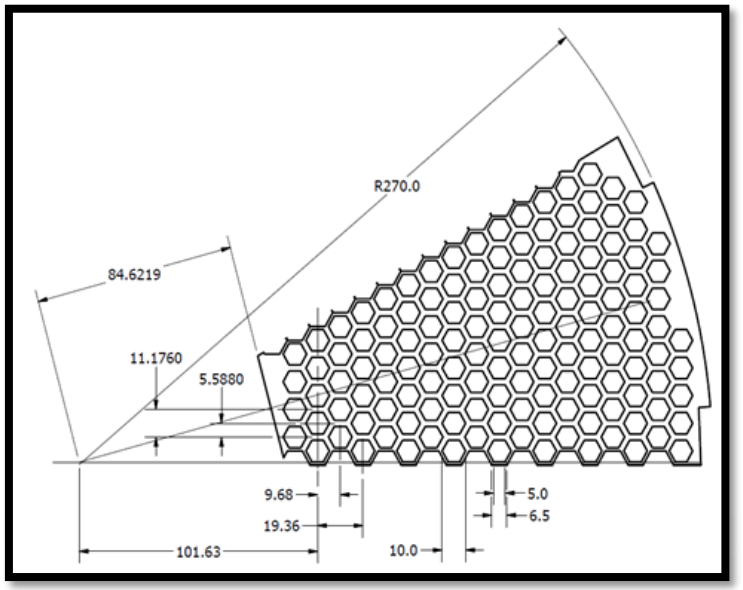
## Two Configurations

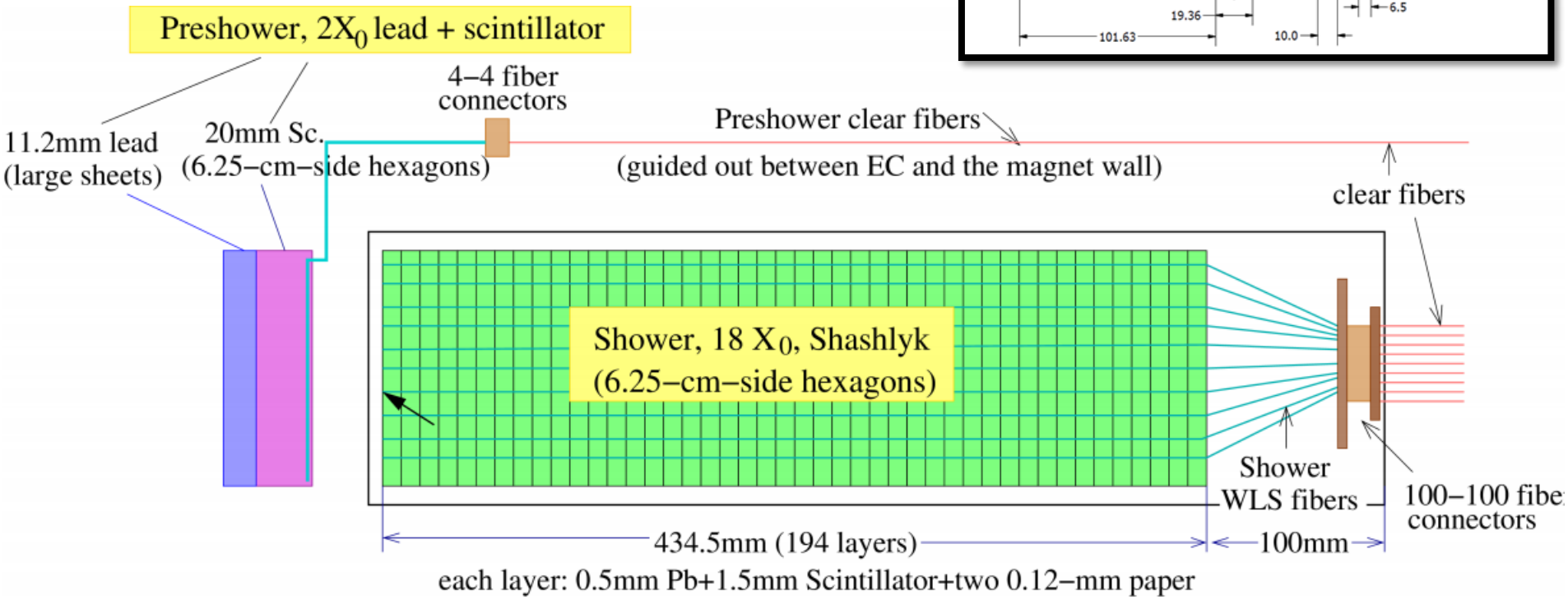


# 1 Introduction of ECal

- Preshower: $2X_0$ lead + 20mm scintillator
- Shower: 0.5mm lead / 1.5mm scintillator sampling
- Total length: $20X_0$ (< 2% leakage)

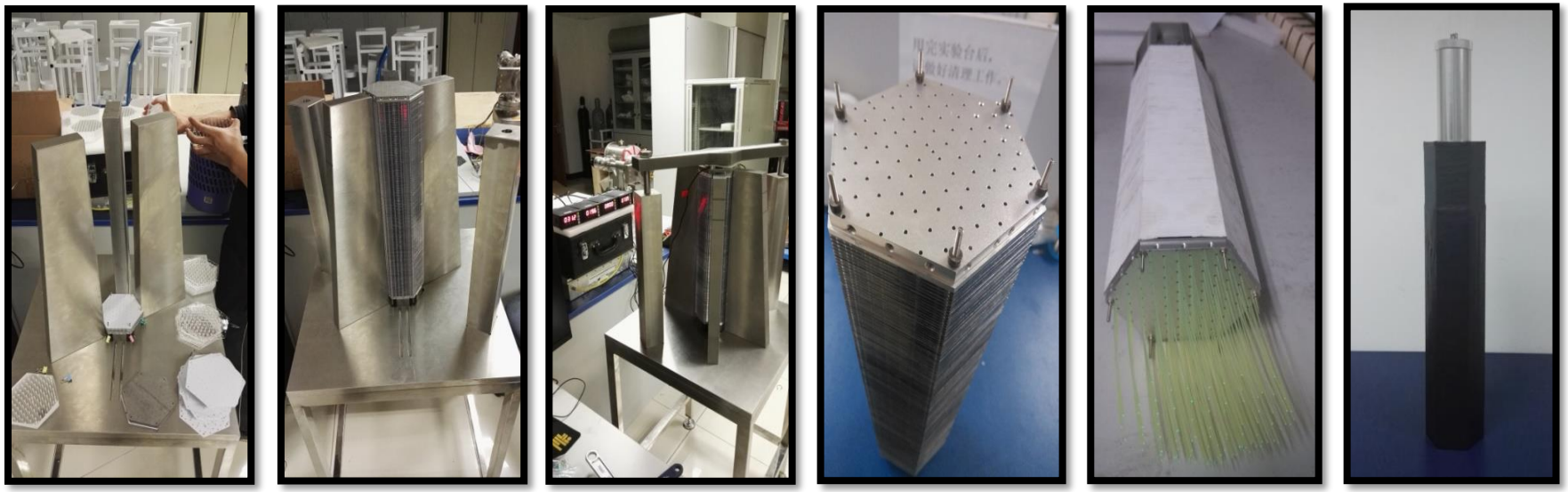


# 1 Introduction of ECal

This assembling steps:

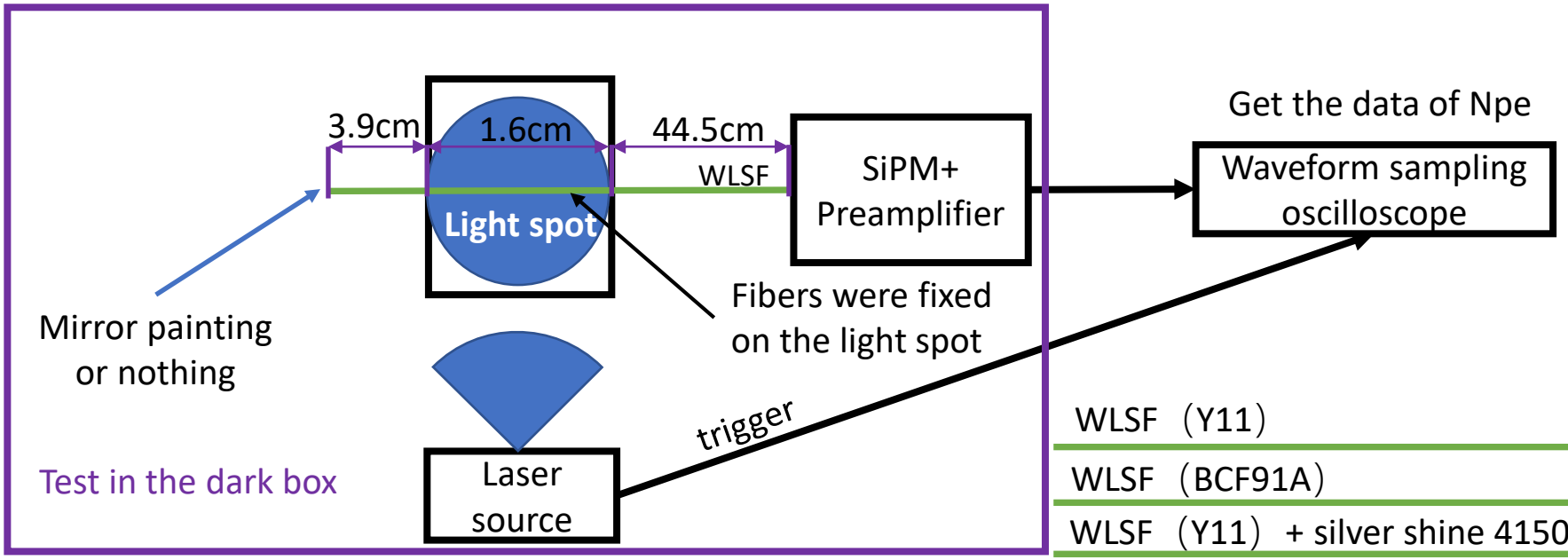
- ✓ Stack lead and scintillator accurately to ensure that every fiber can be inserted freely.
- ✓ The ECal can be pressurized by 500kg force.
- ✓ The pressure can be put under close monitor by pressure sensors.
- ✓ The pressure can be transferred from pressure bar to 6 stainless steel rods.



Step1 Step2 Step3 Step4 Step5 Step6

# 2 WLS Fiber test

## Test of two different fiber & mirror painting




Schematic diagram of vertical cosmic ray experiment setup

For laser source:
- 420 nm
- 1 MHz

For SiPM:
- Gain : $1.8 \times 10^5$
- 143.6pWb=1 pe
- Voltage=26.0 V

For the fibers:
- 50 cm
- Have been polished

WLSF （Y11）

WLSF （BCF91A）

WLSF （Y11） + silver shine 415001

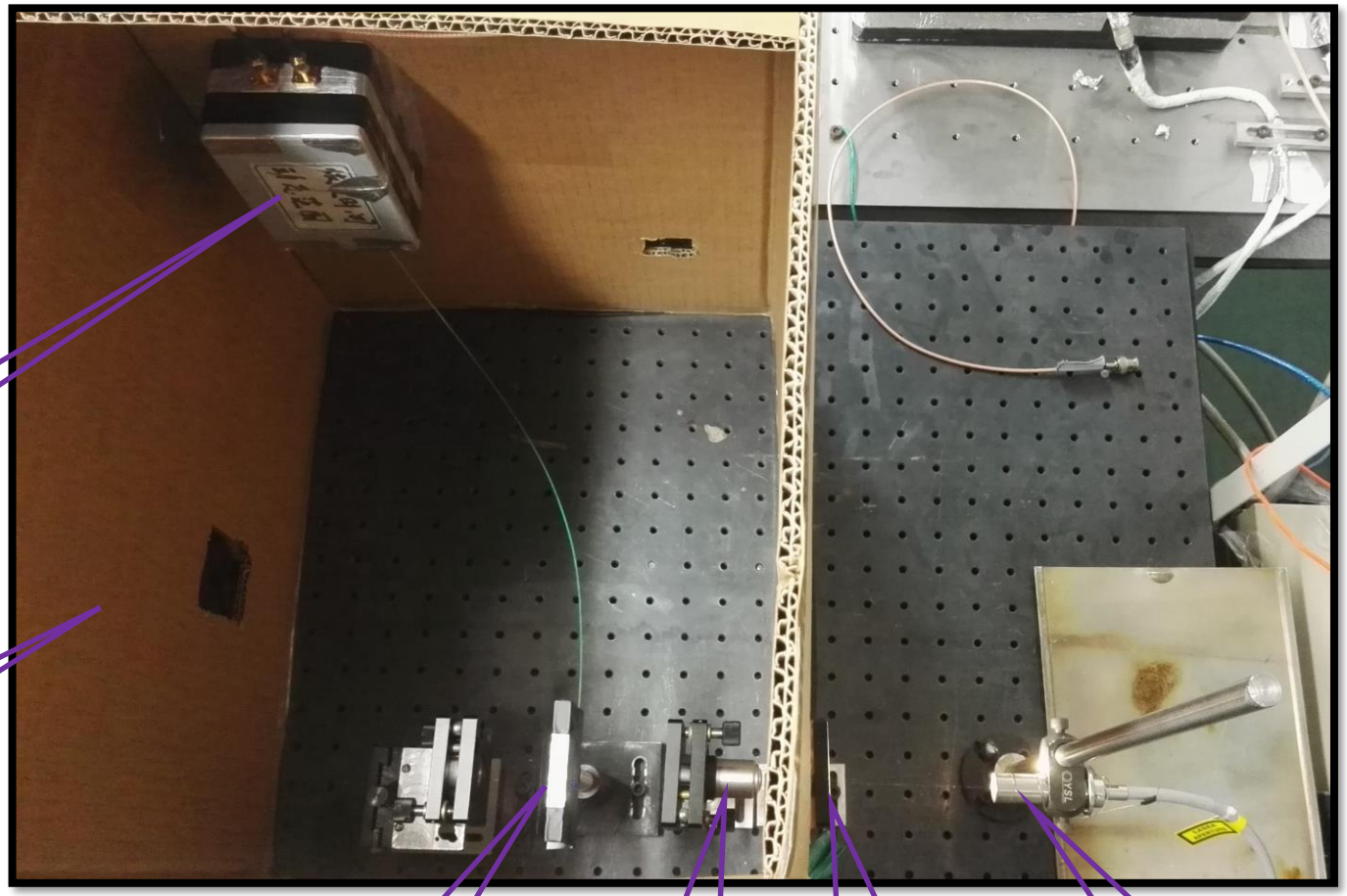
WLSF （ BCF91A ） + silver shine 415001

WLSF （Y11） + bending

WLSF (BCF91A)+ bending

# 2 WLS Fiber test

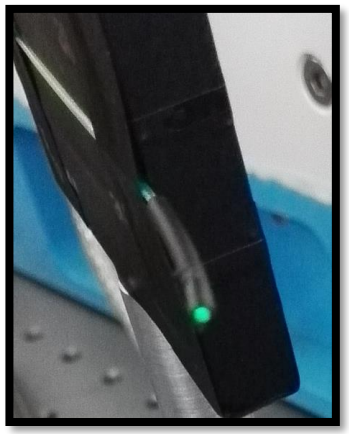
## WLS Fiber test Set up



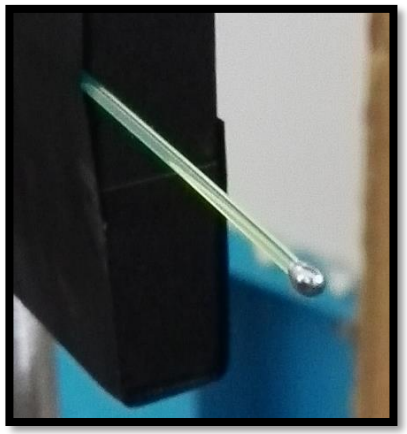
# 2 WLS Fiber test

Compared results

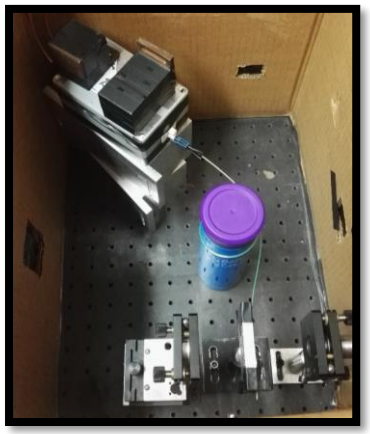
| | BCF91A | Y11 |
|---|---|---|
| No mirror painting | 14 | 13 |
| Mirror painting | 17 (+21.4%) | 17 (+30.1%) |
| Bending (ϕ6) | 4 (-71%) | 11 (-15%) |



No mirror painting



Mirror painting

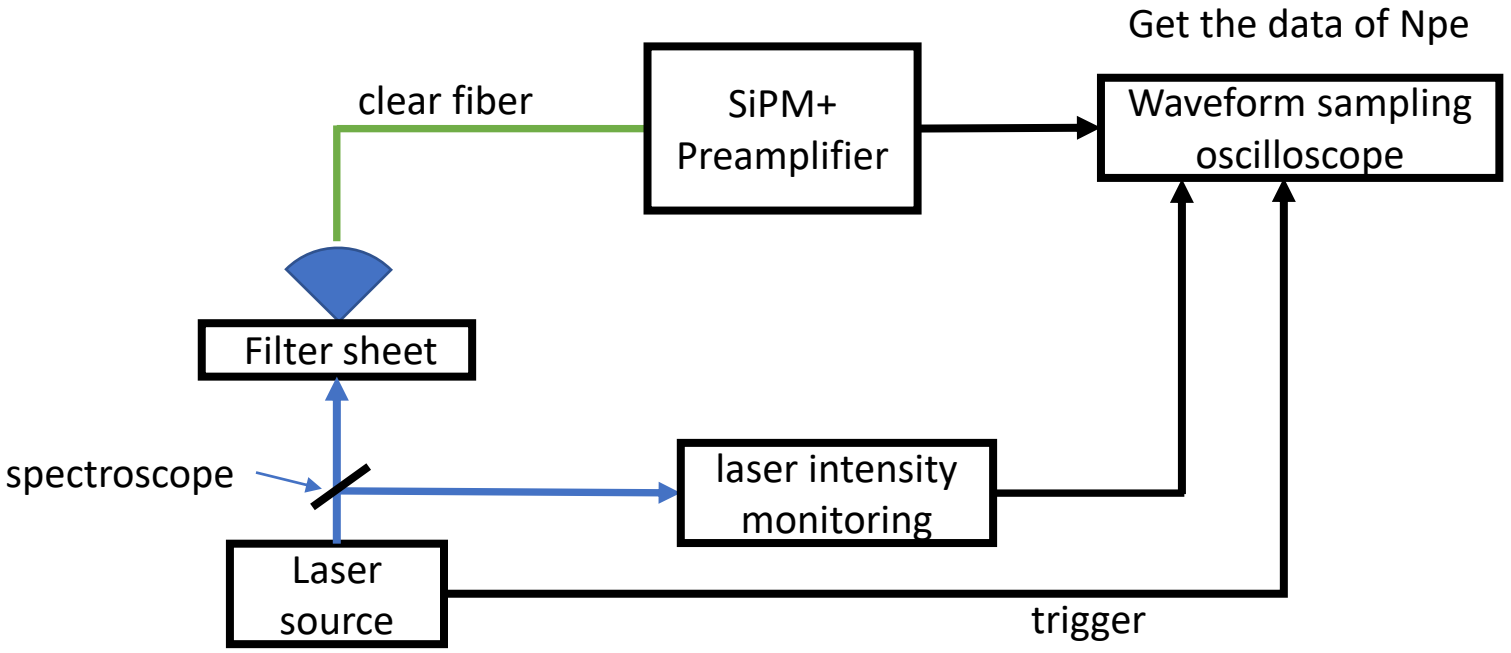


Bending

A comparison of Y11 and BCF91A multi-clad fibers has shown that Y11 double-clad S-type fiber from KURARAY and BCF91A from BICRON give about the same light yield,

but that the Y11 S-type has better mechanical properties. The BCF91A fiber has less mechanical stability against bending at small radius.

# 2 Clear Fiber test



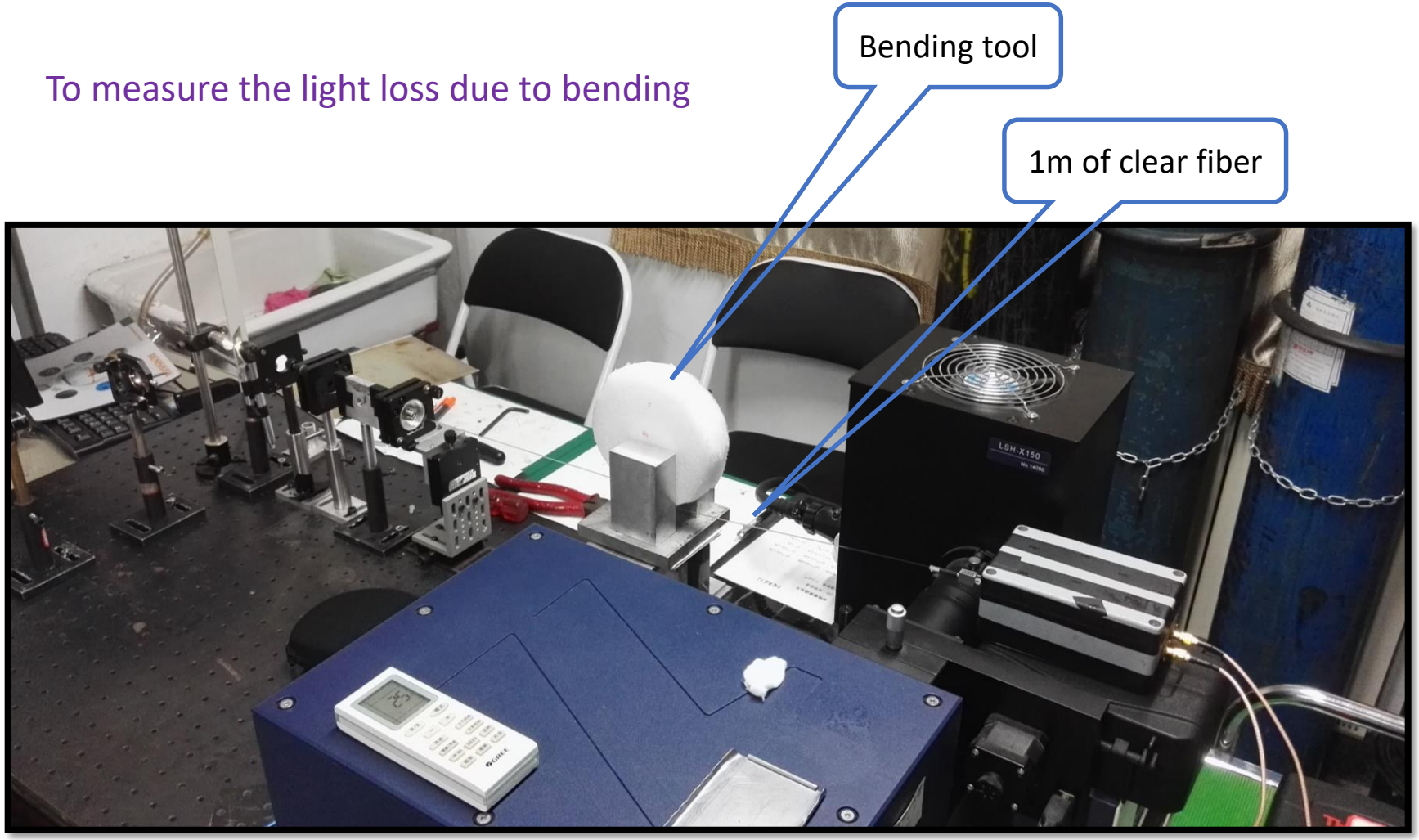

For laser source:
- 420 nm
- 1 MHz

For SiPM:
- Gain : $1.8 \times 10^5$
- 143.6pWb=1 pe
- Voltage=25.0 V

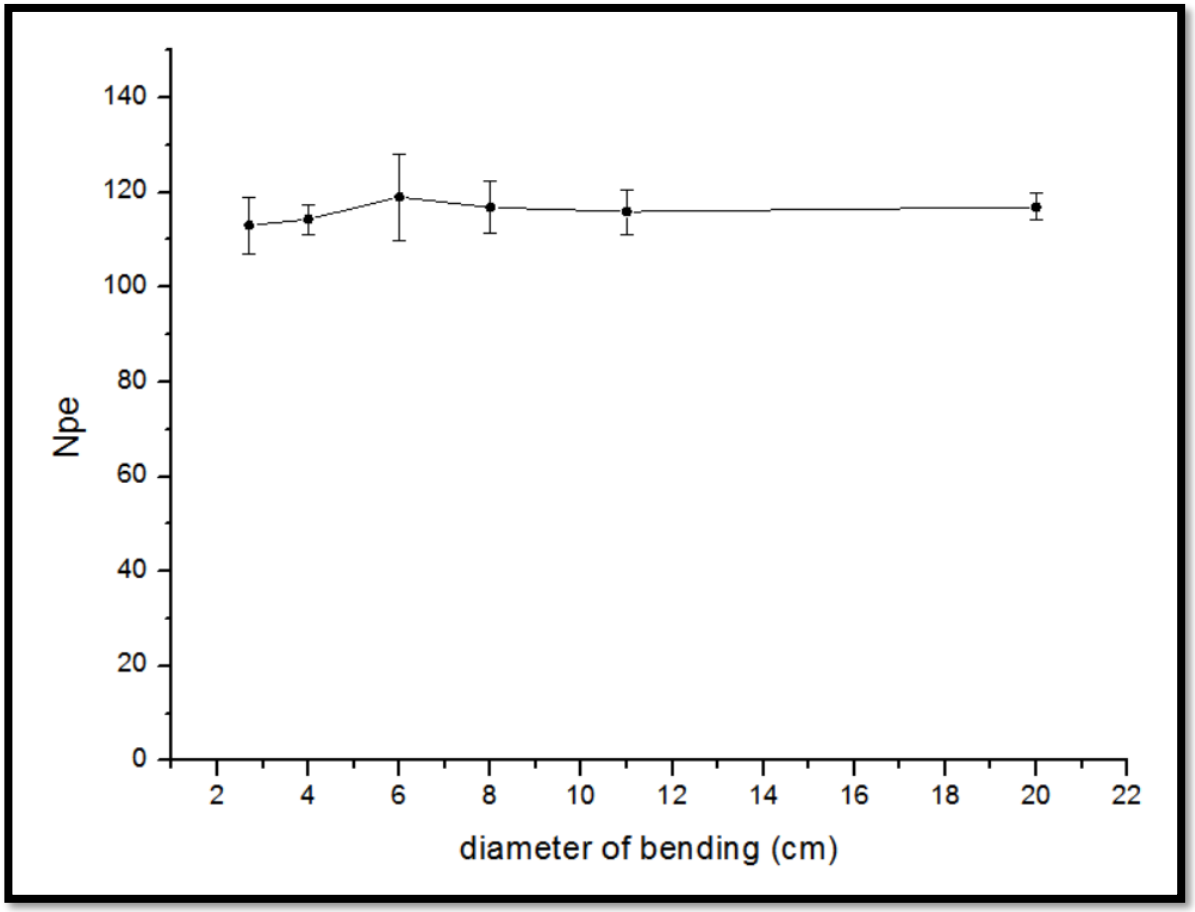
For the fibers:
- 1m, 2m, 3m, 4m, 5m, 7m and 9m
- Have been polished
- BCF98, single cladding

# 2 Clear Fiber test

To measure the light loss due to bending



# 2 Clear Fiber test



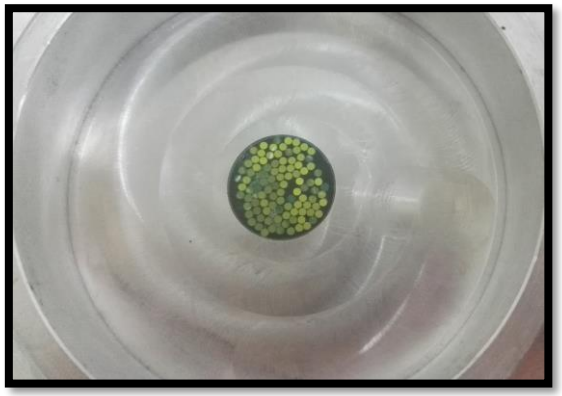

The effect of bending on the clear fiber can be ignored

no bending loss for clear PSM above a diameter of (4-5)cm

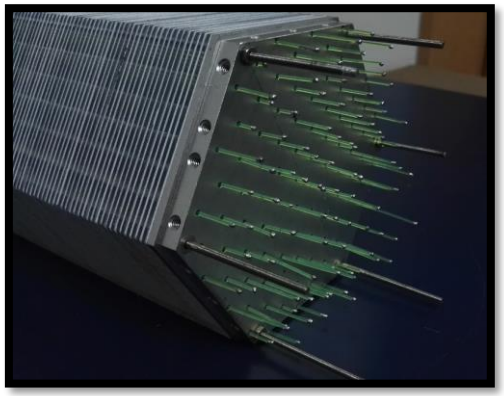
# 4 optimized prototype

materials of THU #1 and THU #2

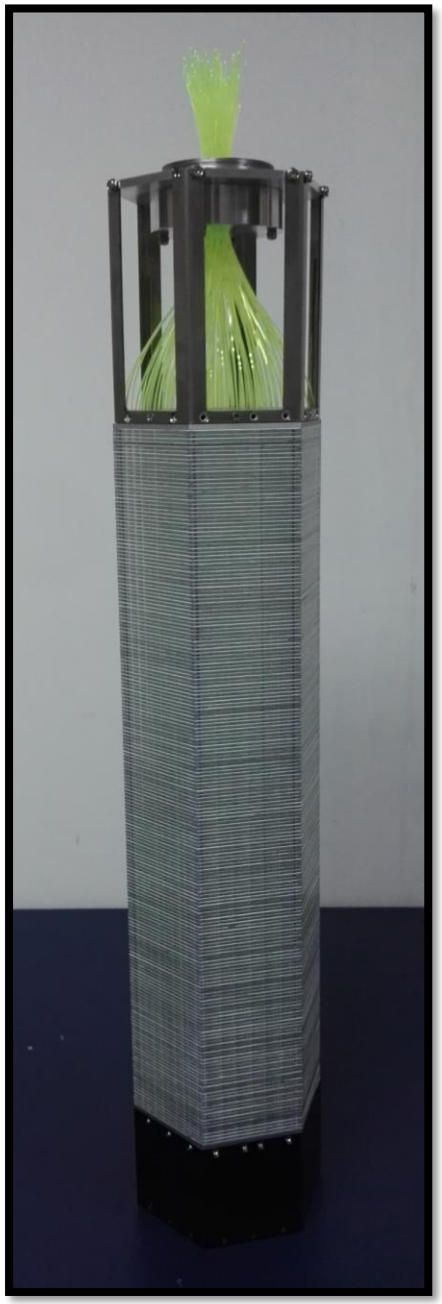
| Material | THU #1 | THU #2 |
|---|---|---|
| Lead plate | Beijing, China | |
| Reflective materials (WLS fiber) | Silver ink from Italy | |
| Scintillator plate | Kedi #1 | Kedi #2 |
| Reflective materials (between scin and lead) | Sliver paper (Mirror reflection) | Powder painting (Diffuse reflection) |
| WLS fiber | Kurrary Y11 | Saint Gobain BCF91A |



Top of the WLS fiber (connect to the PMT)

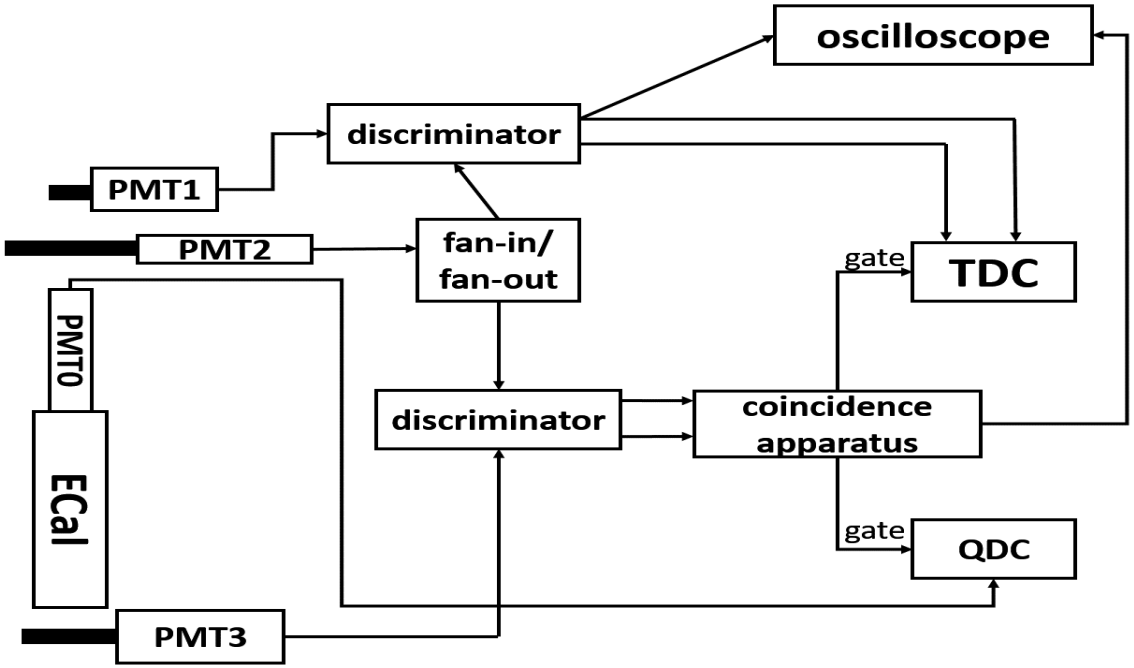


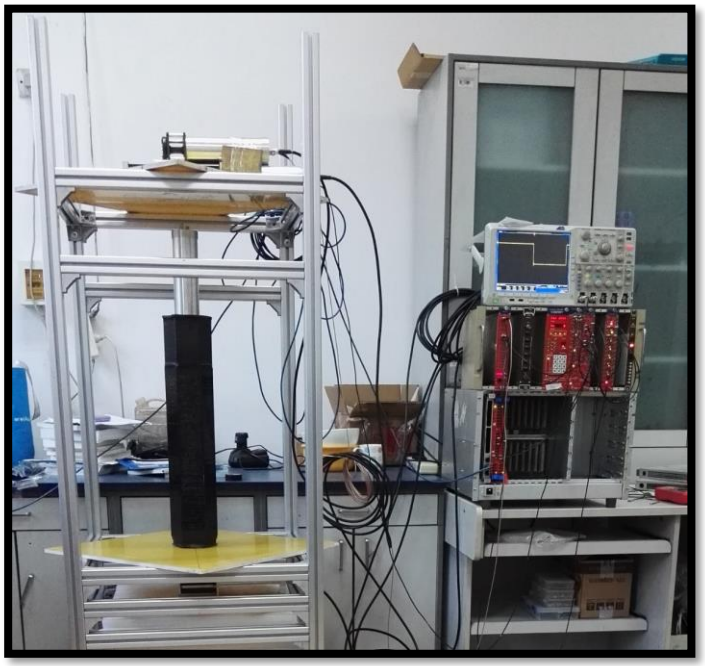
End of the WLS fiber (mirror painting)



THU #2

# 2 Cosmic test

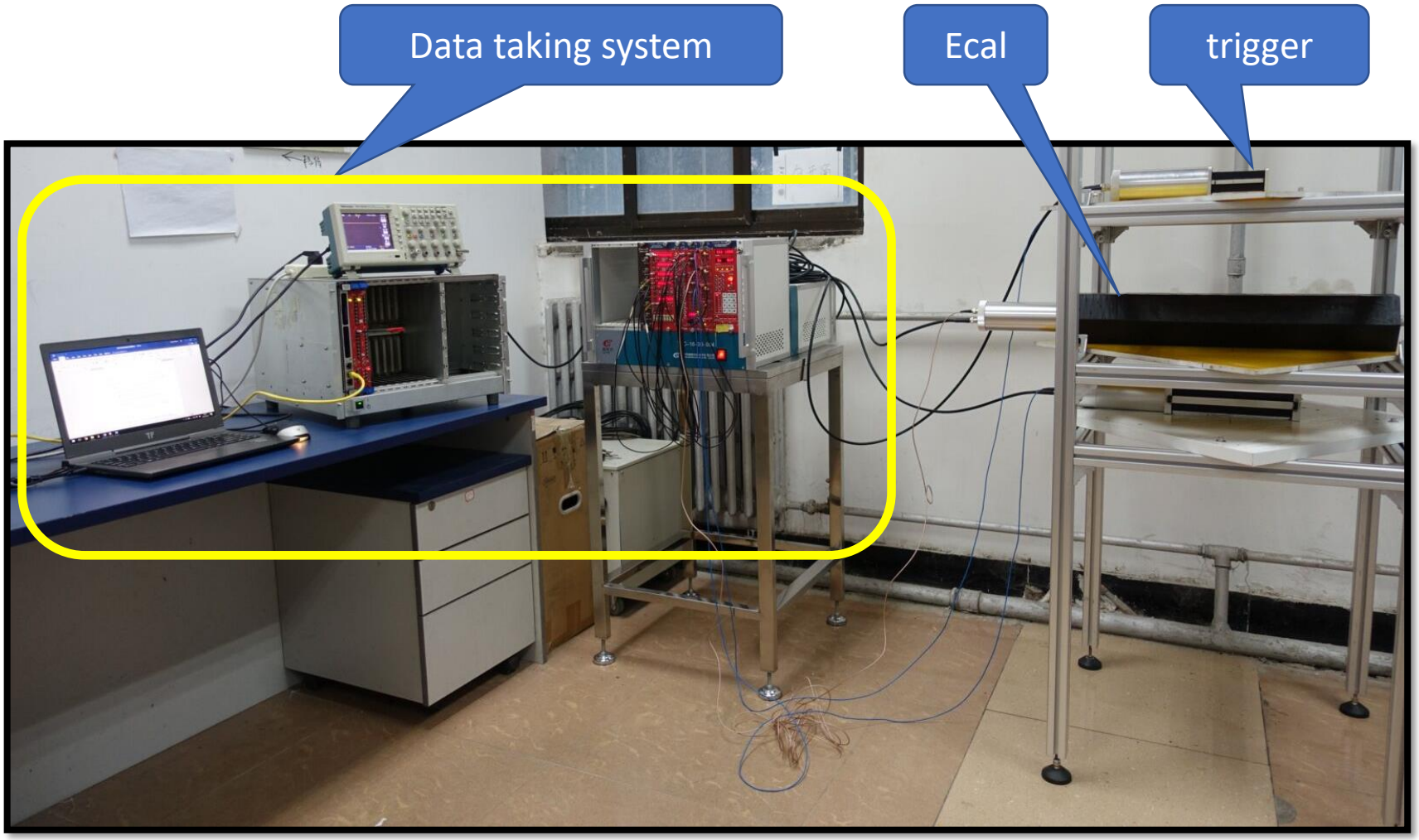


First Ecal mudule in THU (Sep 2016)

Schematic diagram of vertical cosmic ray experiment setup

# 4 optimized prototype




cosmic ray test setup

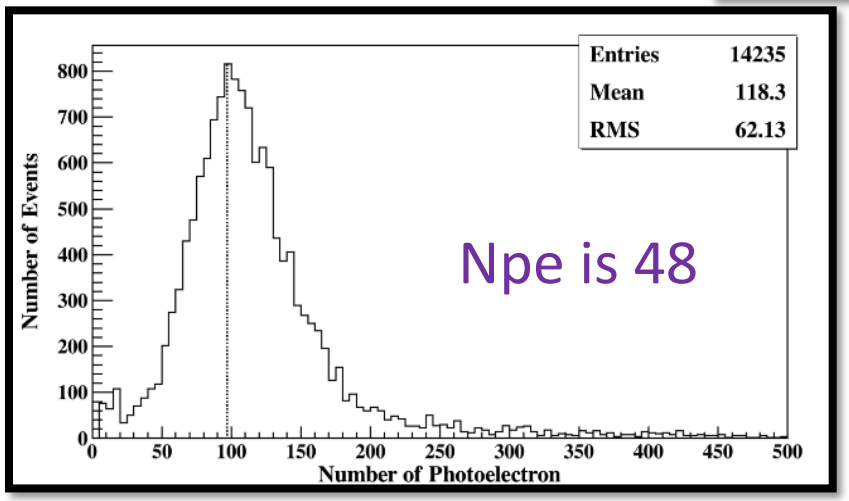
- Experimental device has been built
- Cosmic ray test is currently underway
- we will present the test results soon

# 2 Cosmic test

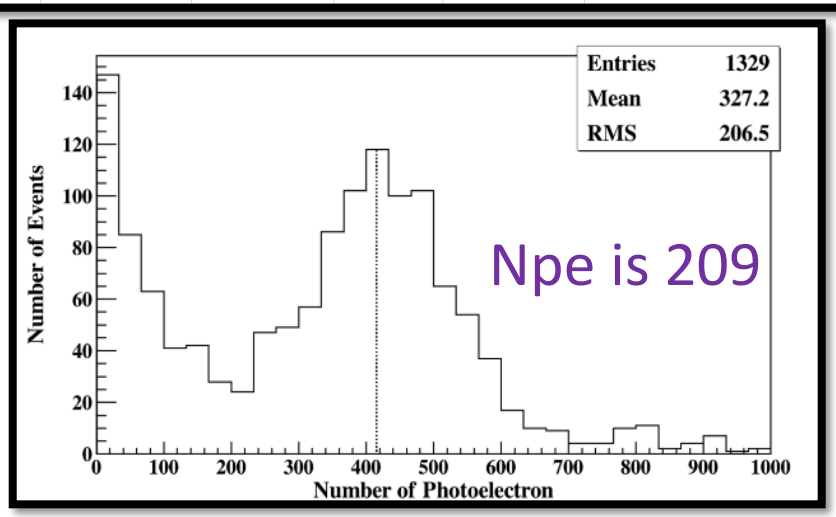
## THU#1

light yield test results in UVa

| number of p.e. per shashlyk layer, hedgehog test | # p.e. per 1 GeV electron in shashlyk module, SoLID running condition, assuming 20% sampling fraction and light yield proportional to energy deposit in scintillator | | | | | expected # of p.e. for shashlyk module cosmic horizontal test (assuming 10cm vertical thickness, 7.5cm of which is scintillator) |
|---|---|---|---|---|---|---|
| | Y11, no mirror at end of fiber, light yield directly out of WLS | if using BC91A instead of Y11 | after light loss of connectors and clear fibers (use 50%) | adding mirror to end of fiber (use +60%) | extra energy resolution due to photoelectron statistics | |
| 0.500 | 300.000 | 150.000 | 75.000 | 120.000 | 0.091 | 25.000 |
| 1.000 | 600.000 | 300.000 | 150.000 | 240.000 | 0.065 | 50.000 |
| 1.500 | 900.000 | 450.000 | 225.000 | 360.000 | 0.053 | 75.000 |
| 2.000 | 1200.000 | 600.000 | 300.000 | 480.000 | 0.046 | 100.000 |
| 2.500 | 1500.000 | 750.000 | 375.000 | 600.000 | 0.041 | 125.000 |




Peak of Npe in horizontal test




Peak of Npe in vertical test

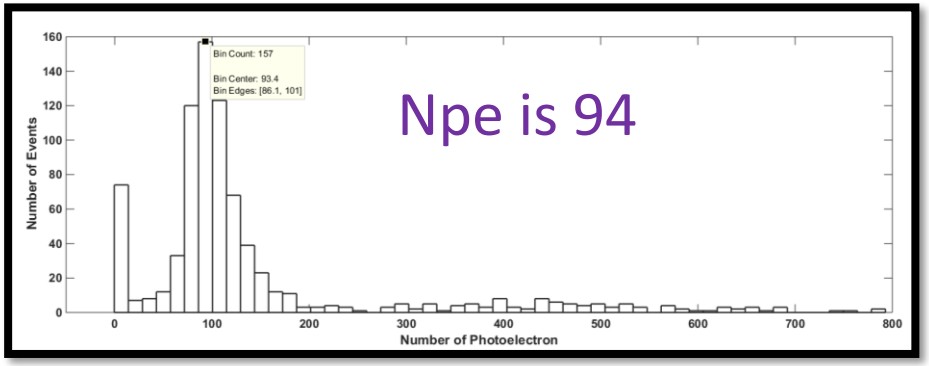
For the result, the peak of Npe in horizontal test is 48 and the peak of Npe in vertical test is 209. Through the result of the vertical and horizontal cosmic ray test, we have obtained that the prototype need to be improved to increase the light yield.

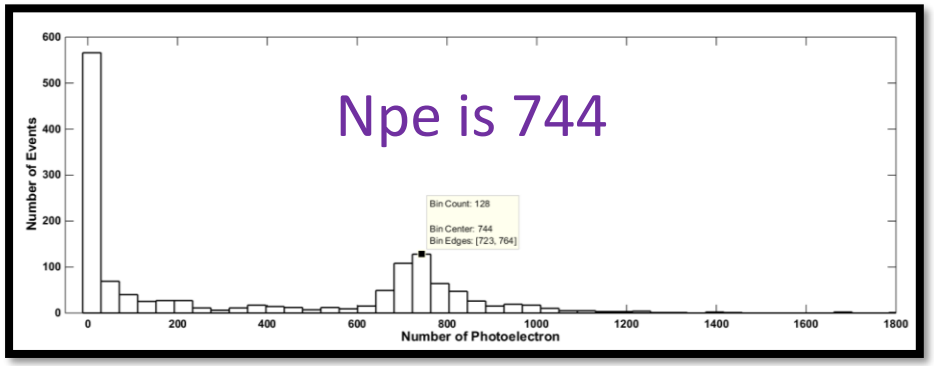
# 2 Cosmic test

## THU#2

light yield test results in UVa

| number of p.e. per shashlyk layer, hedgehog test | # p.e. per 1 GeV electron in shashlyk module, SoLID running condition, assuming 20% sampling fraction and light yield proportional to energy deposit in scintillator | | | | | expected # of p.e. for shashlyk module cosmic horizontal test (assuming 10cm vertical thickness, 7.5cm of which is scintillator) |
|---|---|---|---|---|---|---|
| | Y11, no mirror at end of fiber, light yield directly out of WLS | if using BC91A instead of Y11 | after light loss of connectors and clear fibers (use 50%) | adding mirror to end of fiber (use +60%) | extra energy resolution due to photoelectron statistics | |
| 0.500 | 300.000 | 150.000 | 75.000 | 120.000 | 0.091 | 25.000 |
| 1.000 | 600.000 | 300.000 | 150.000 | 240.000 | 0.065 | 50.000 |
| 1.500 | 900.000 | 450.000 | 225.000 | 360.000 | 0.053 | 75.000 |
| 2.000 | 1200.000 | 600.000 | 300.000 | 480.000 | 0.046 | 100.000 |
| 2.500 | 1500.000 | 750.000 | 375.000 | 600.000 | 0.041 | 125.000 |




Peak of Npe in horizontal test

Peak of Npe in vertical test

For the result, the peak of Npe in horizontal test is 94 and the peak of Npe in vertical test is 744. Through the result of the vertical and horizontal cosmic ray test, we have obtained that THU#2 has been optimized.

# 5 Summary

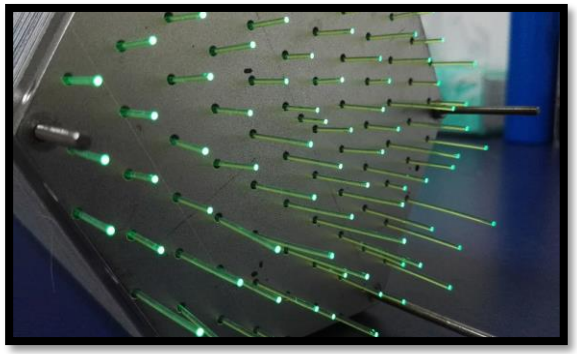
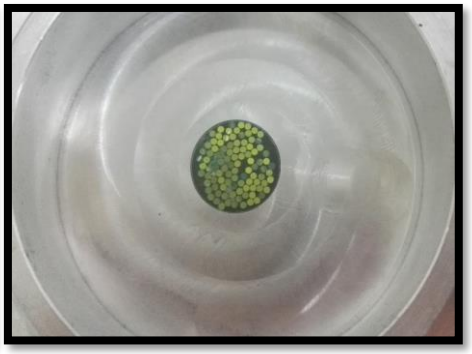
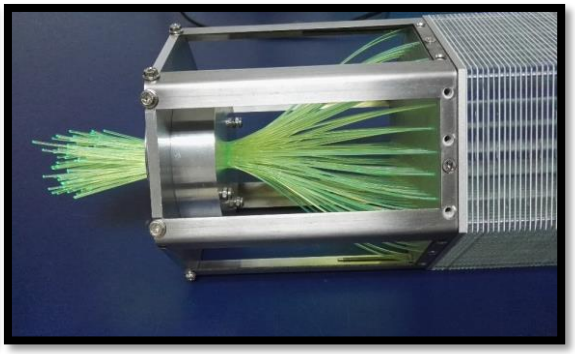
**Finished**

- The cosmic test for THU #1 has been finished, JINST 12 (2017) no.03, C03026.
- Fiber R&D
  - WLS fiber (BCF91A & Y11) test has been finished, the results show that:
    - Y11 double-clad S-type fiber from KURARAY and BCF91A from BICRON give about the same light yield without bending
    - Italian silver shine: ~30%
  - Clear fiber (BCF98, single cladding) test has been finished, the results show that:
    - no bending loss for clear PSM above a diameter of (4-5)cm
- The optimized prototype (THU #2) has been assembled and cosmic test has been finished. For horizontal test, Light yield increased by 100%. For vertical test, Light yield increased by 350%. For the results, The first reason is because the material is replaced, the second is the production process has been improved.

**Next to do**

- Re-test the BCF98 single-cladding clear fiber with 470nm lights
- Will also test BCF98 multi-cladding fiber and kurrary PSM clear fiber (bending loss, attenuation length……)
- Prepare for beam test and compare with the results of cosmic ray test.

# Thanks For your attention

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