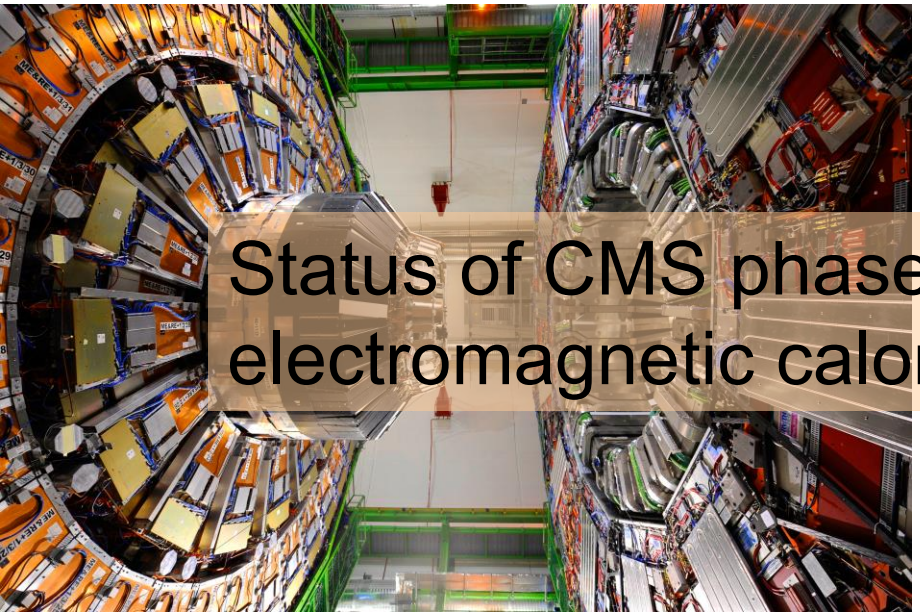
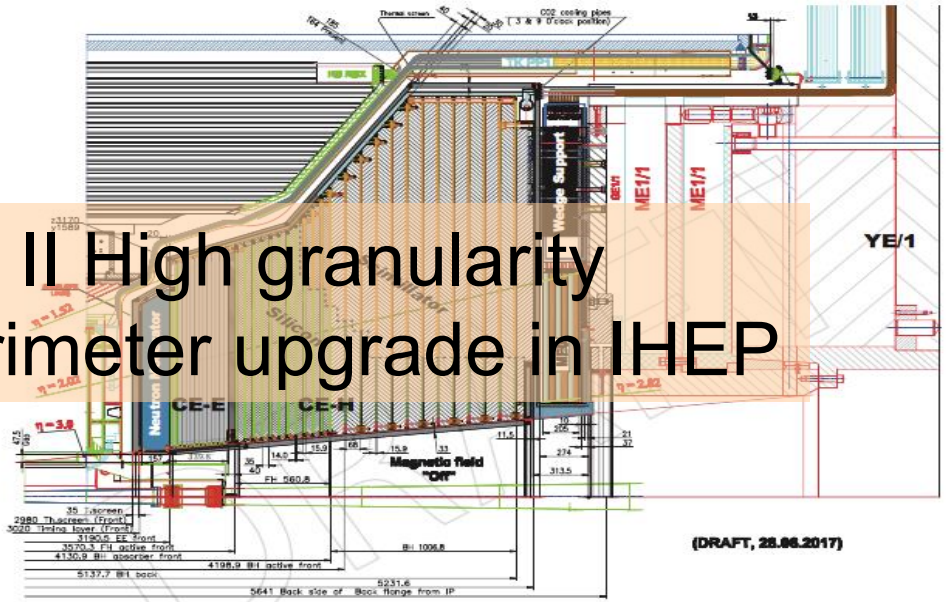
中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences
Beijing

Status of CMS phase II High granularity electromagnetic calorimeter upgrade in IHEP





Feng Wang

On behalf of the CMS collaboration

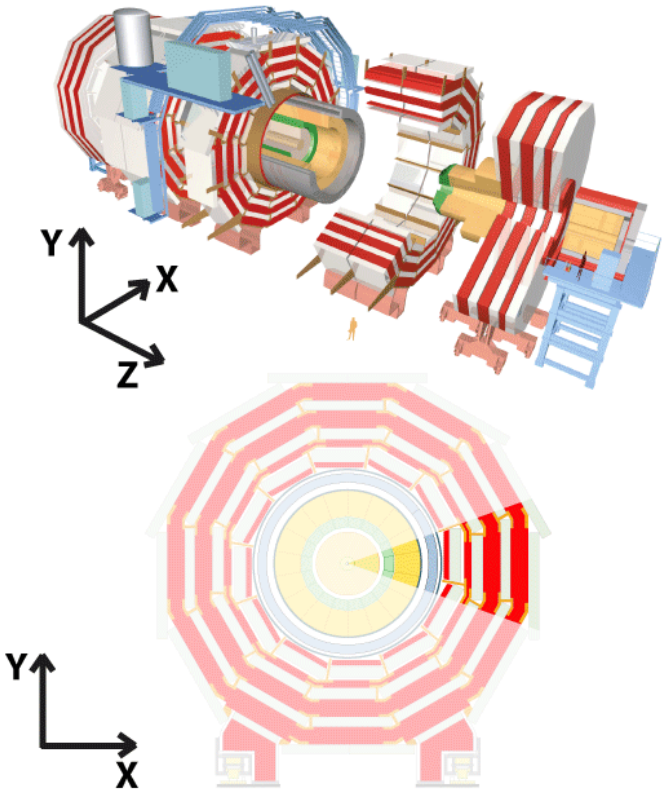
23/12/2017

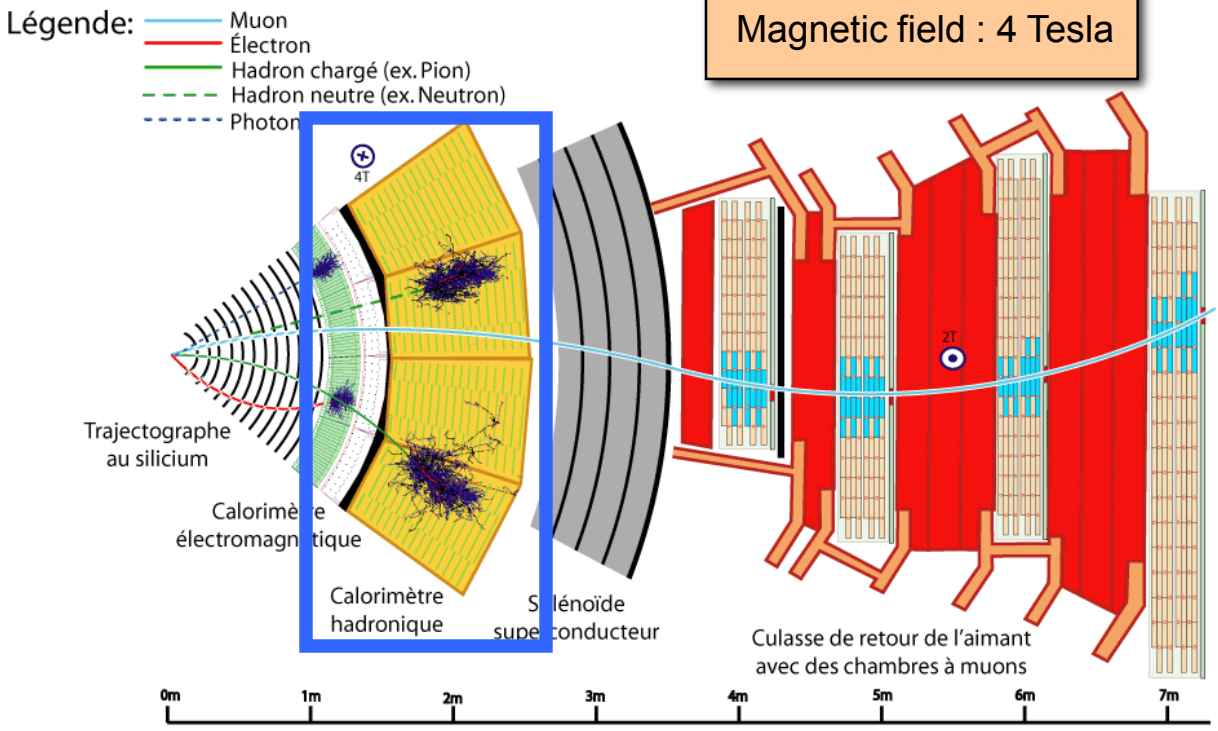
Outline

- Introduce CMS phase II HGCAL upgrade
- Status of HGCAL upgrade in IHPE
  1. HGCAL module beam test
  2. HGCAL module assembly
- Summary and next to do
  1. Building mass production center
  2. Work plan in IHEP

CMS detector

Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla





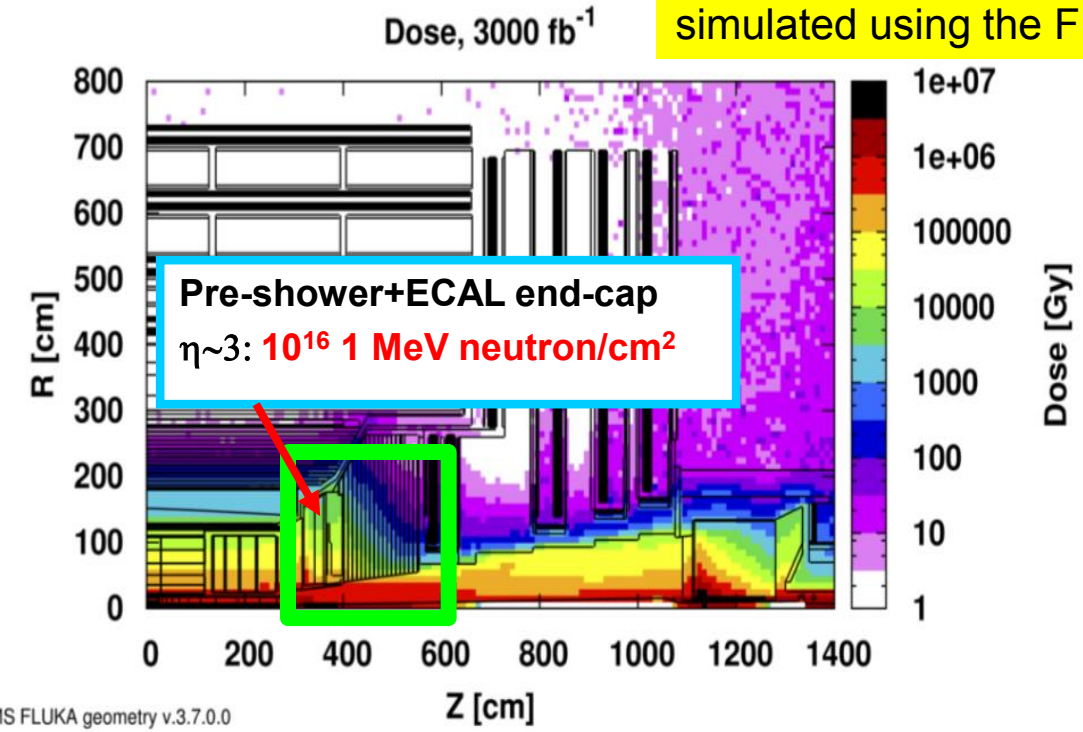
- All detectable particles can leave traces on the calorimeter
- Reconstruct photon, lepton, jet and etc. by particle follow algorithm (PFA)

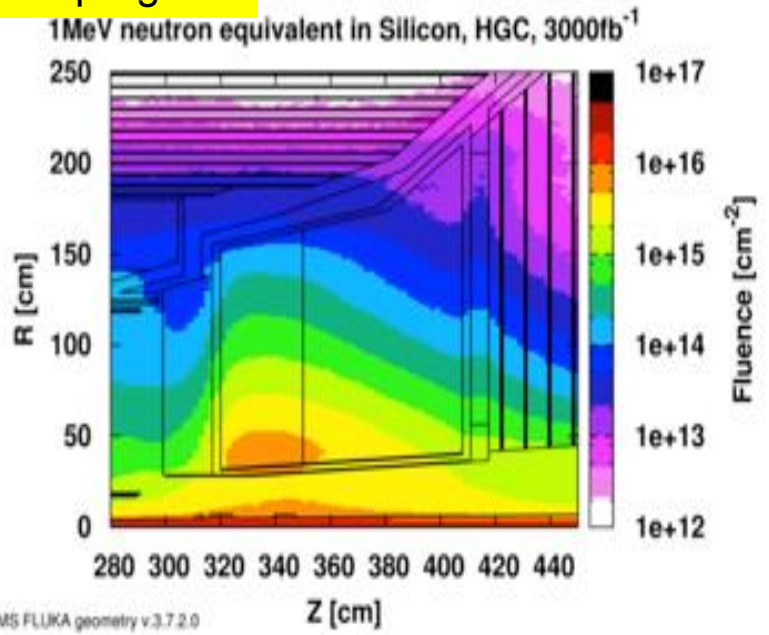
Detector is exposed to high levels of radiation, especially for forward calorimetry.

By the end of Run 3 (2023): Up to 300 fb^{-1}

Radiation damage

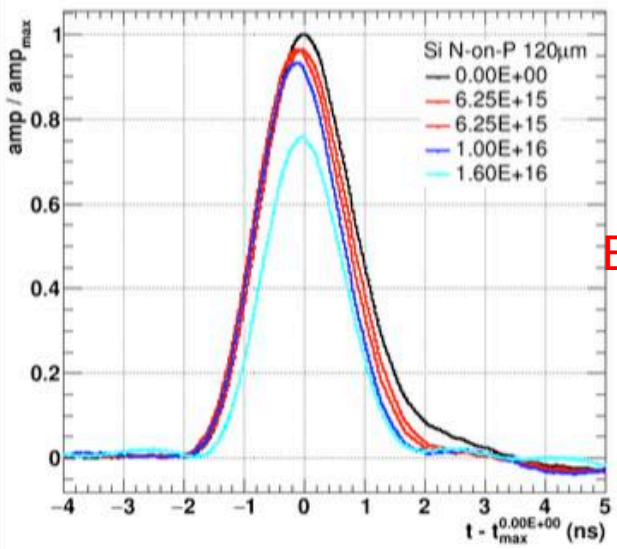
simulated using the FLUKA program

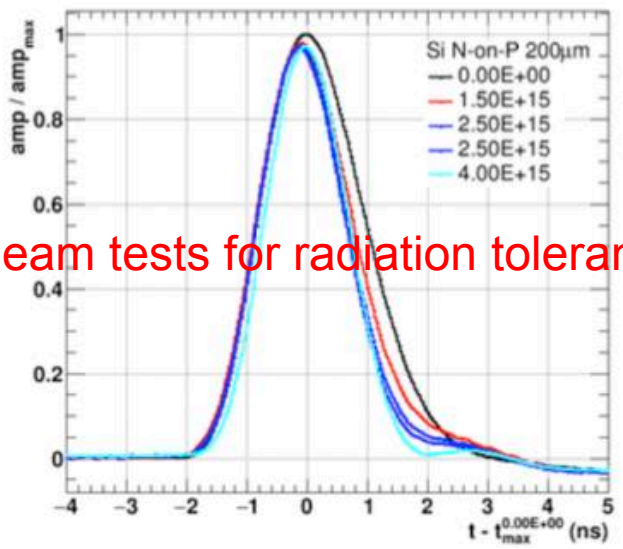


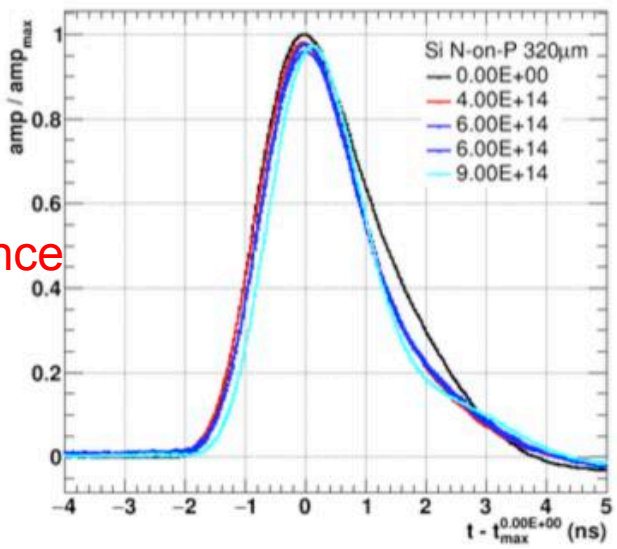


- CMS Co-operation Group Spokesperson Tizianno Camporesi:
  - We need to replace the end cap today, because we underestimated the radiation damage to the detector's sensitive materials
- 2013:
  - Proposed need to be replaced in 2013
- 2015.04：
  - Determine the HGCAL (Silicon + Tungsten) as a CMS phase II endcap upgrade proposal

IHEP was one of the first ten units to propose the HGCAL program

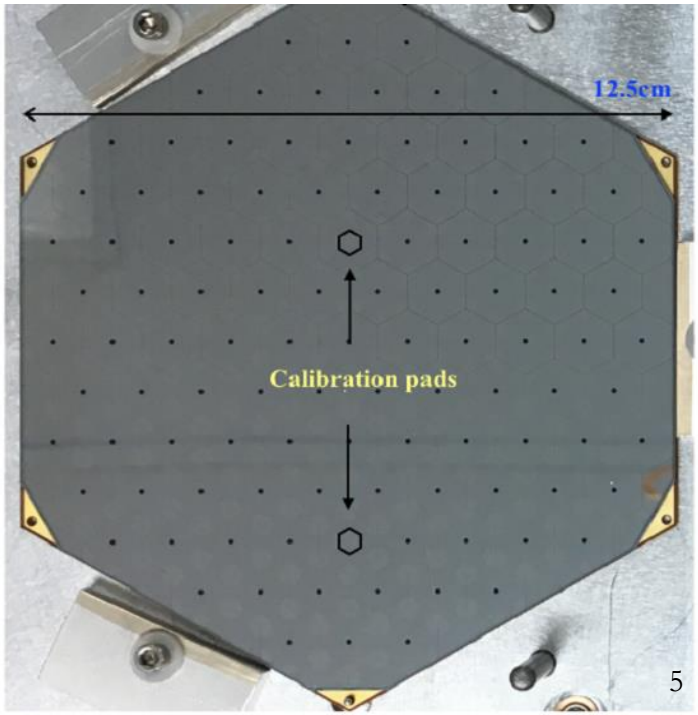






Beam tests for radiation tolerance

Thickness	300 μm	200 μm	100 μm
Maximum dose (Mrad)	3	20	100
Maximum n fluence (cm^{-2})	6×10^{14}	2.5×10^{15}	1×10^{16}
EE region	$R > 120$ cm	$120 > R > 75$ cm	$R < 75$ cm
FH region	$R > 100$ cm	$100 > R > 60$ cm	$R < 60$ cm
Si wafer area (m^2)	290	203	96
Cell size (cm^2)	1.05	1.05	0.53
Cell capacitance (pF)	40	60	60
Initial S/N for MIP	13.7	7.0	3.5
S/N after 3000 fb^{-1}	6.5	2.7	1.7



Design requirement

Energy resolution: **25%/ sqrt(E)⊕1%**

Time resolution : **50 ps**

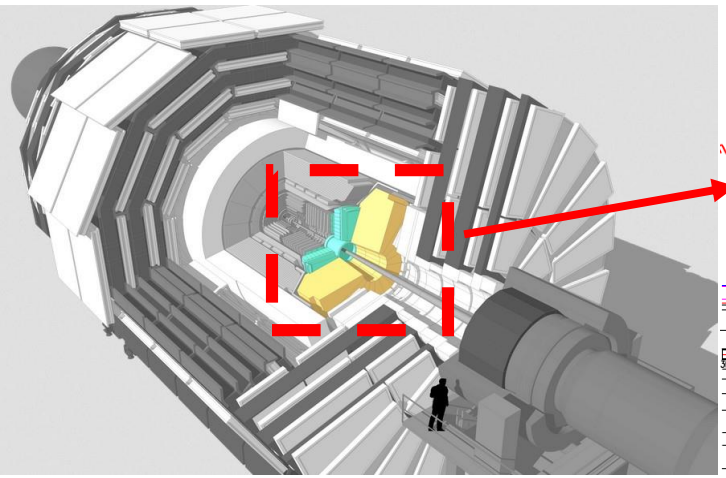
Radiation tolarence : **1×10^{16} 1MeV neq/cm^2**

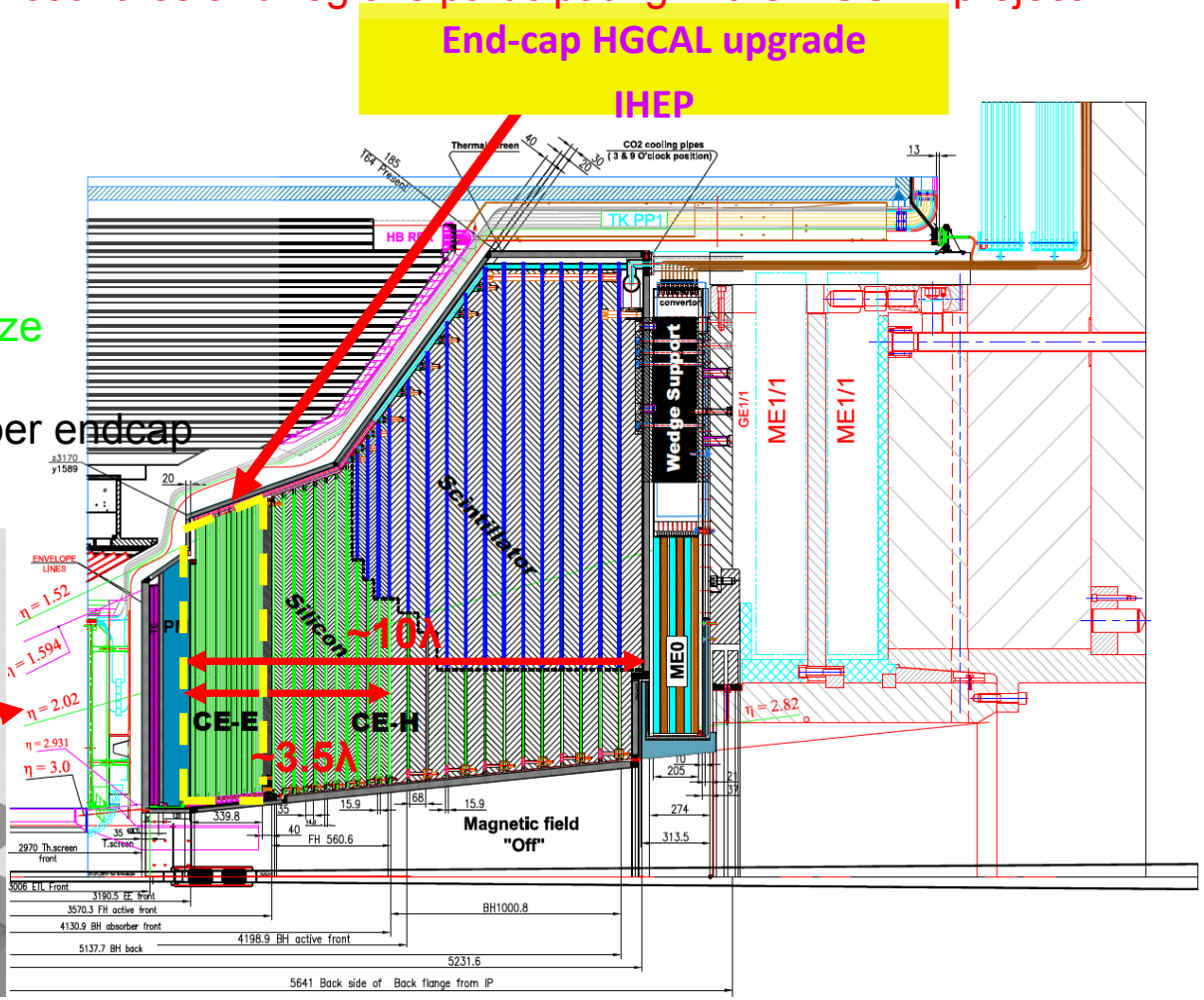
The CMS upgrade endcap calorimeter: Design

61 universities or institutes in 19 countries and regions participating in the HGCAL project

Key Parameters:

- HGCAL covers 1.5 < η < 3.0
- Full system maintained at -30°C
- ~600m² of silicon sensors
- ~500m² of scintillators
- 6M Si channels, 0.5 or 1 cm² cell size
- ~27000 Si modules (CE-E:16008)
- Power at end of HL-LHC: ~60 kW per endcap





Endcap Electromagnetic calorimeter (EE): Si, Cu & CuW & Pb absorbers, 28 layers, 25 X0 & ~1.3 λ

Front Hadronic calorimeter (FH): Si & scintillator, steel absorbers, 12 layers, ~3.5 λ

Backing Hadronic calorimeter (BH): Si & scintillator, steel absorbers, 12 layers, ~5 λ

Contribution to HGCAL in IHEP

China-IHEP_Beijing in CMS-HGCAL Phase 2 Upgrades Project

Dear Huaqiao,

CMS has undertaken to upgrade its endcap calorimetry for Phase 2 of the LHC. The Project comprises around 50 Institutes from over 15 countries. The HGCAL project shall be submitting a Technical Design Report (TDR) in November 2017 to the LHCC, the scientific peer review committee of CERN.

The HGCAL Project would like to see the following contributions from the China-IHEP_Beijing Group (with an initial CORE contribution of 1.2 MCHF):

- Pro-rata (Si+Scint cost/total cost) Contribution to Active Elements
- Contribute to sensor R&D, qualification and testing
- Contribute to fe chips testing
- Contribute to testing of on-detector electronics boards (PCBs)
- Host a silicon module assembly centre
- Contribute to EC_ECAL and EC_Hadronic assembly and test
- Contribute to 2nd cassette assembly centre at CERN (collective responsibility)
- Contribute to the installation and cabling/services in UXC
- Contribute to simulation and performance studies
- Contribute to test beam activities

Assembly HGCAL module as core contribution

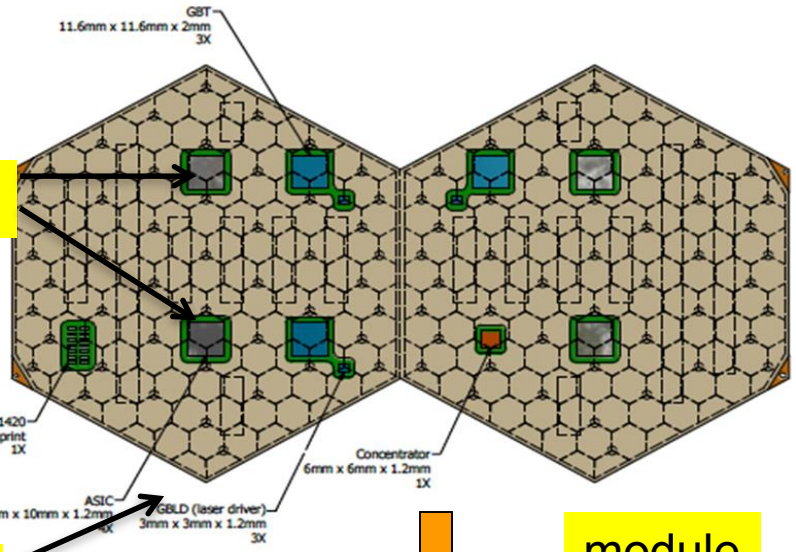
Please check that the list conforms to our mutual understanding.

Yours sincerely,

2015/01: NSFC: 0.74 M
2016/10: MOST: 2.85 M
2017/03: IHEP: 3 M
Future ~?M to apply
More?

Contracture of CMS end-cap calorimeter

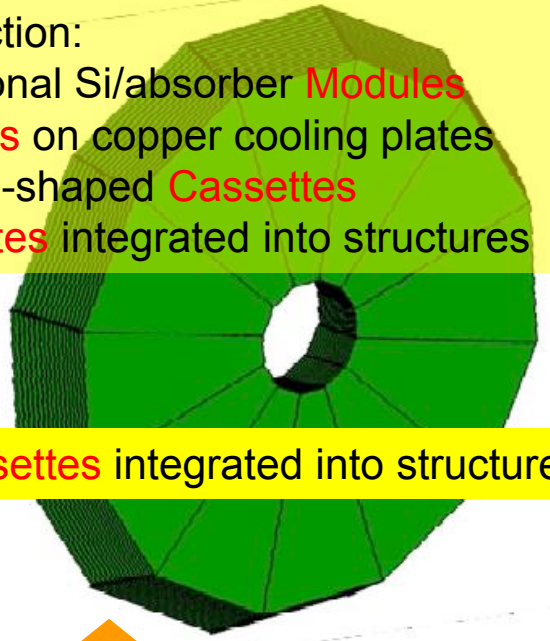
Construction:
- Hexagonal Si/absorber Modules
- Modules on copper cooling plates
- wedge-shaped Cassettes
- Cassettes integrated into structures



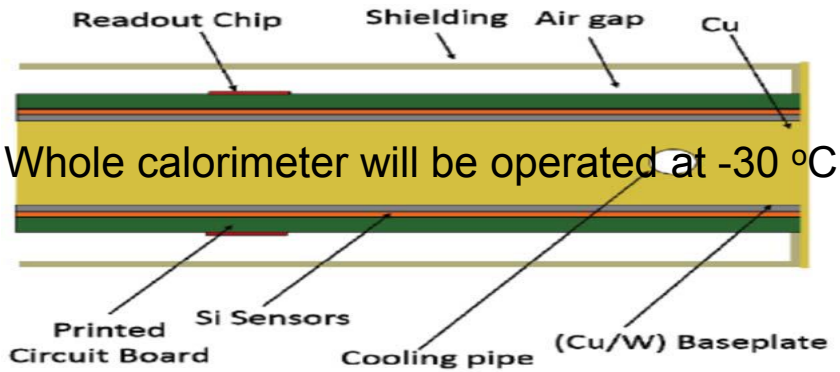
FE-ASICs

Si sensor

module

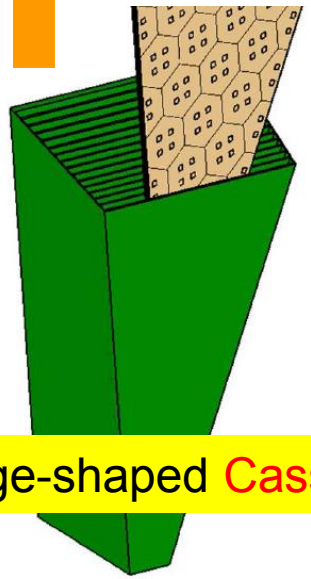


Cassettes integrated into structures



Whole calorimeter will be operated at -30 °C

Modules on Cu cooling plate

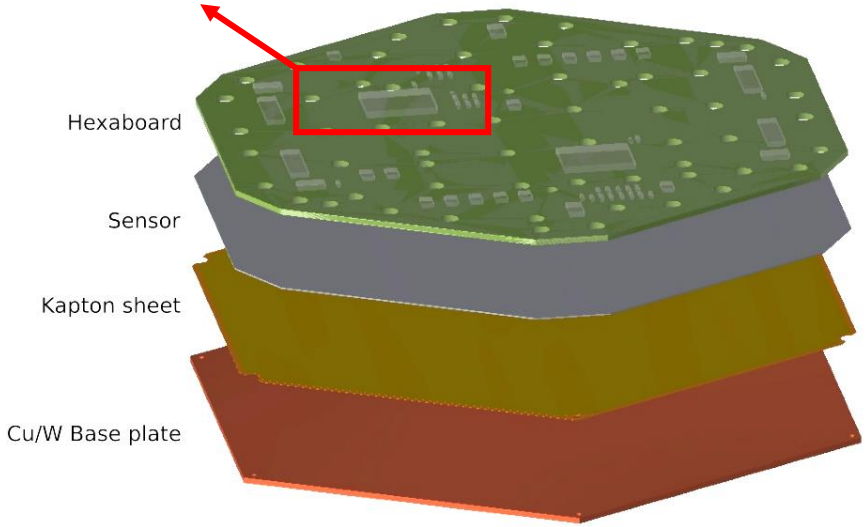


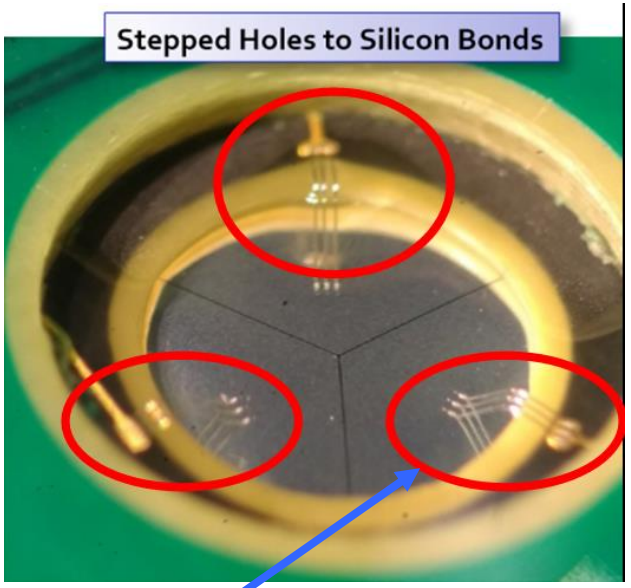
Wedge-shaped Cassette

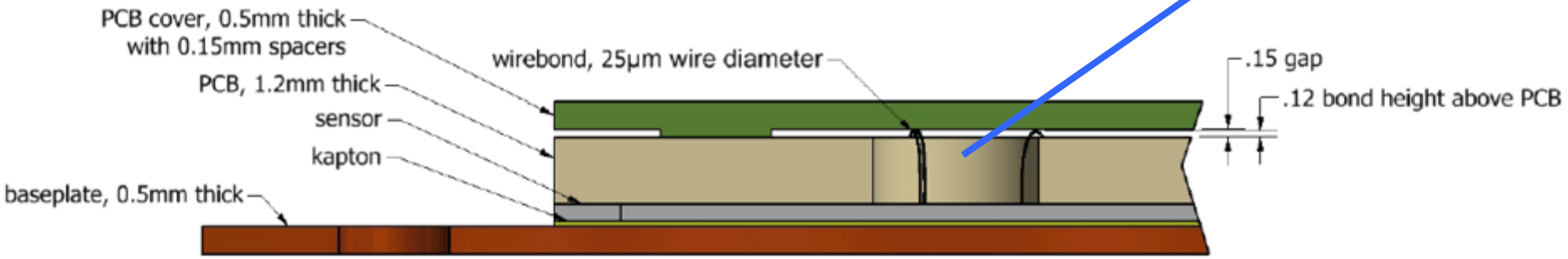
Silicon Detector Module Design of HGCAL

Assembly Center: IHEP-Beijing, BARC-Mumbai, Taiwan, USA (CMU, TTU, UCSB)

ASIC (130 nm) export license!!!







Compact detector design： The thickness of the module affects HGC Moliere radius

HGCAL ASIC export license progress

From Tejinder Virdee <tejinder.virdee@cern.ch>
Subject **Export Licence** 01/06/2017, 10:50
To huaqiao Zhang, Hesheng Chen <chenhs@ihep.ac.cn>
Cc Tejinder Virdee <tejinder.virdee@cern.ch>, Drew Baden <drew@umd.edu>, Achille P **1 more**

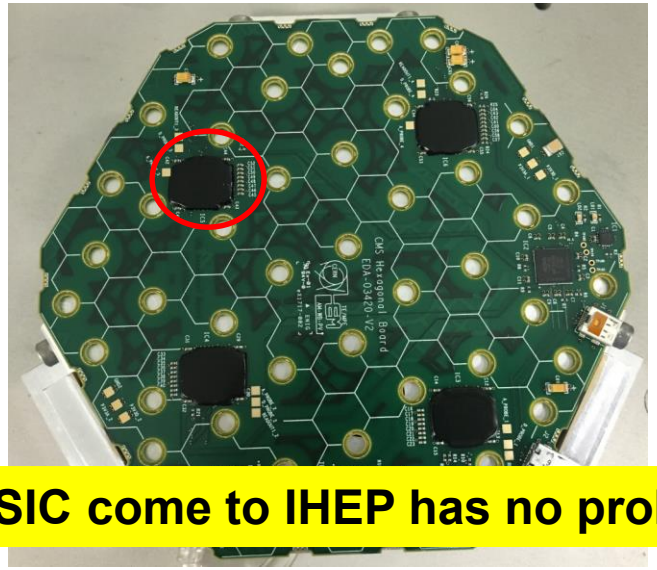
Dear Hesheng and Huaqiao,

Tiziano has now obtained very encouraging information from CERN, who are in contact with the relevant Swiss authorities, concerning the Export licence. This is summarised in the following statement:

"From the experience gained so far for temporary export licence of dual use electronics chips (for reference they are the class of devices identified by the code3A001.a.1.a of the Annex 2 OCB (Ordonnance sur le Control des Biens CH) received at CERN no problem has been encountered when dealing with Chinese institutes (including IHEP Beijing).

We remind you that regarding electronics developed at TSMC, Taiwan, the temporary export licence will have to be requested, for each chip and for each shipment, from SECO (the swiss State Secretariat for Economic Affairs) through CERN"

Best Regards,
Jim

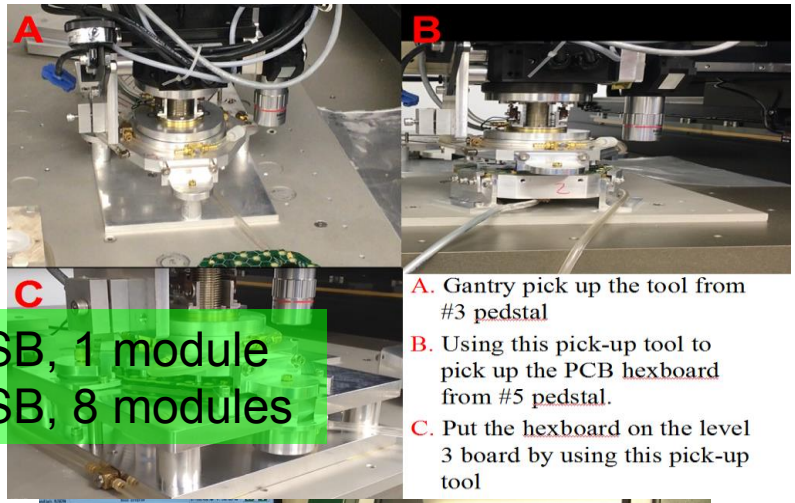


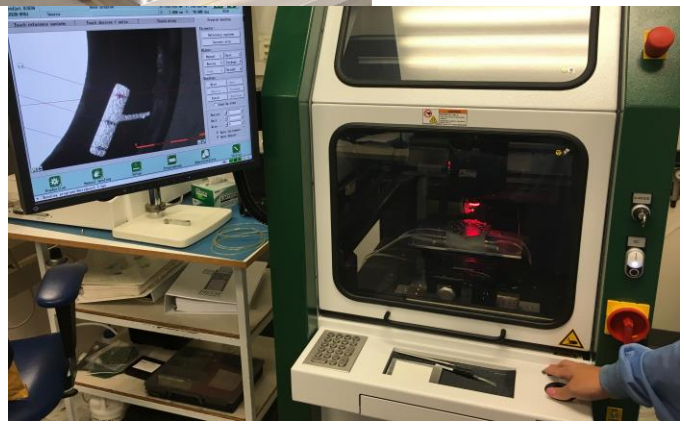
ASIC come to IHEP has no problem

Status of HGCAL in IHEP

- 1） Participate in module assembly which is for beam testing. Research and design HGCAL module assembly program which meet the requirement of thickness and quality control for mass production in the future.
  - Cooperation with UCSB

2016.3 @ UCSB, 1 module
2017.8 @ UCSB, 8 modules

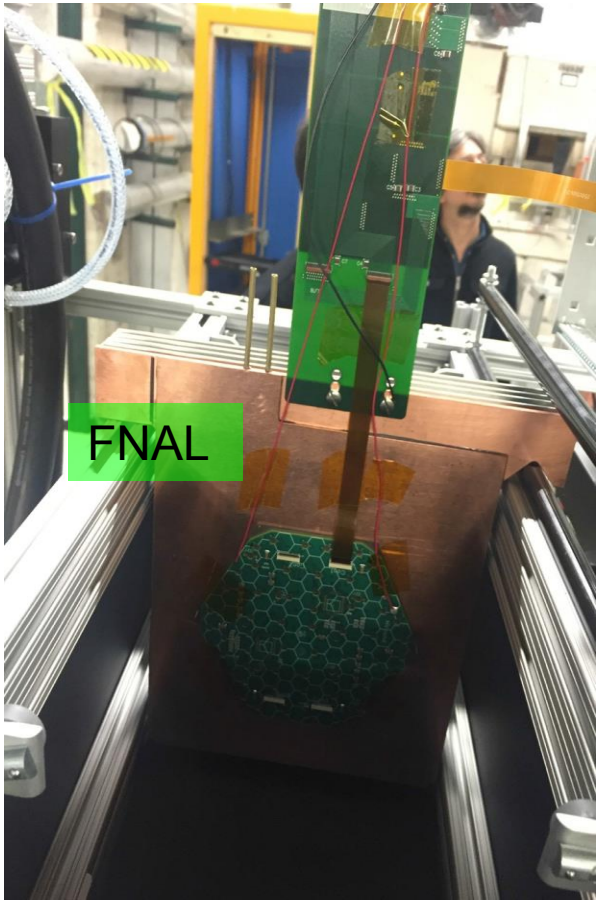




Support by Ministry of Science and Technology

Status of HGCAL in IHEP

- 2） Participate in beam test of the experimental prototype.
  - Participate in the assembly of the experimental beam device, shift, analysis of experimental beam data at Fermilab and CERN.(Huaqiao Zhang, Binghuan Li, Francesco Remo, Feng Wang)



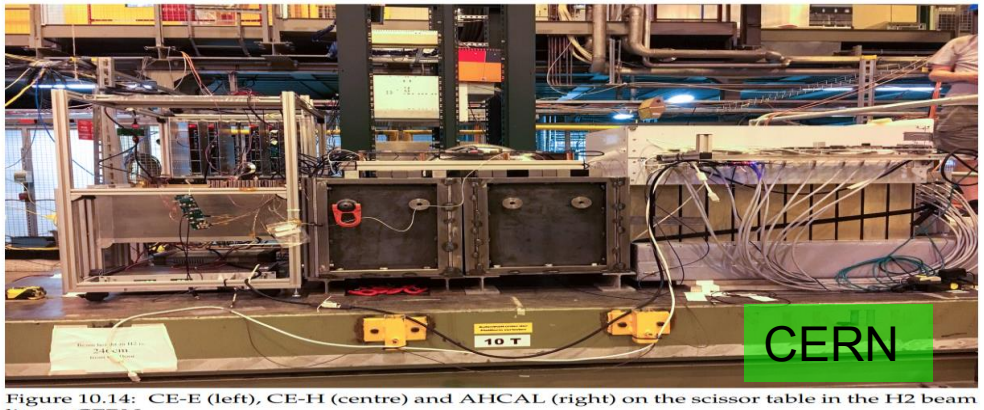


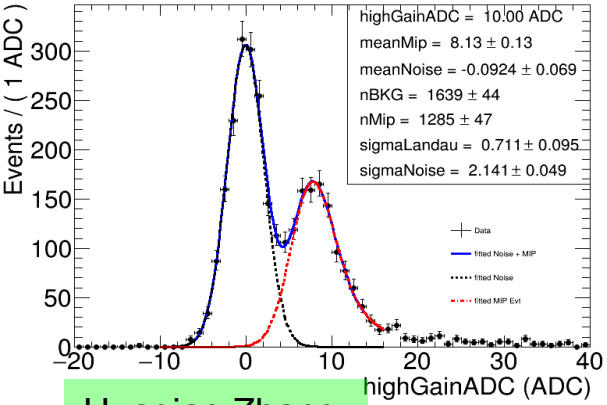
Figure 10.14: CE-E (left), CE-H (centre) and AHCAL (right) on the scissor table in the H2 beam line at CERN

HGC beam test	location	IHEP
2016/03/21-04/12	FNAL	✓
2016/04/18-27	CERN	✓
2016/08/17-24	CERN	✓
2016/08/31-09/07	CERN	✓
2016/11/09-14	CERN	✓
2017/5/8-15	CERN	✓
2017/7/12-19	CERN	✓
2017/09/29-10/02	CERN	✓
2017/10/18-23	CERN	✓

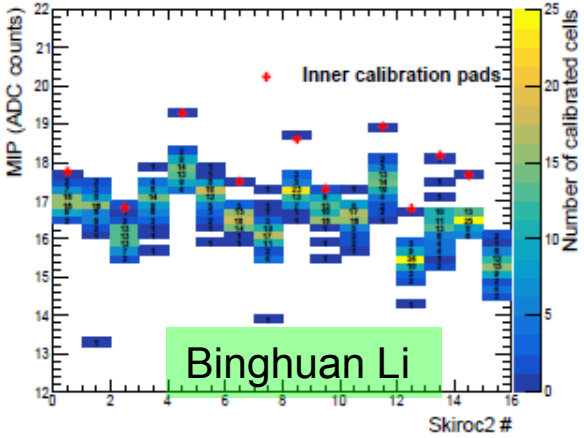
Support by Ministry of Science and Technology

China group independently analyzed the data of beam test

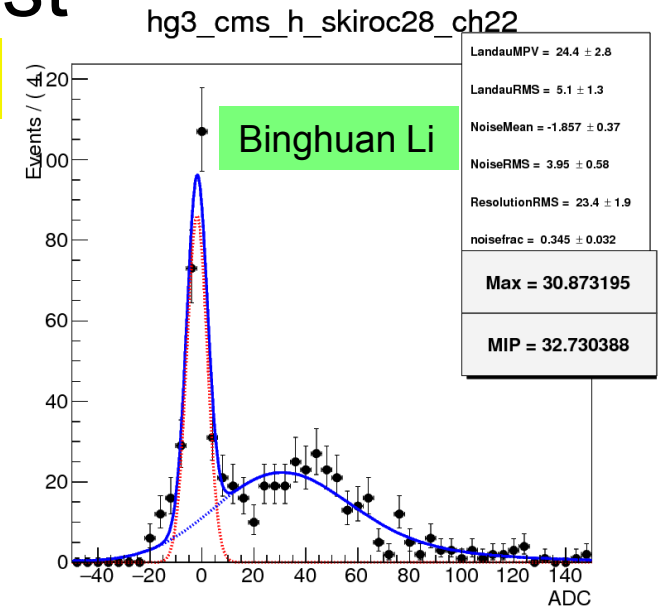
Experimental beam MIP signals were investigating



Huaqiao Zhang



Binghuan Li



Binghuan Li

Available on the CMS information server

CMS DN-17-011

The Compact Muon Solenoid Experiment

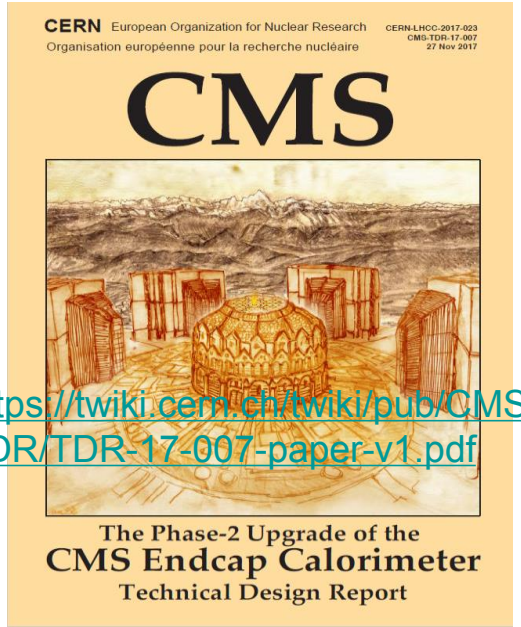
CMS Draft Note

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

2017/06/18
Head Id: 411064
Archive Id: 411057:411080
Archive Date: 2017/06/18
Archive Tag: trunk

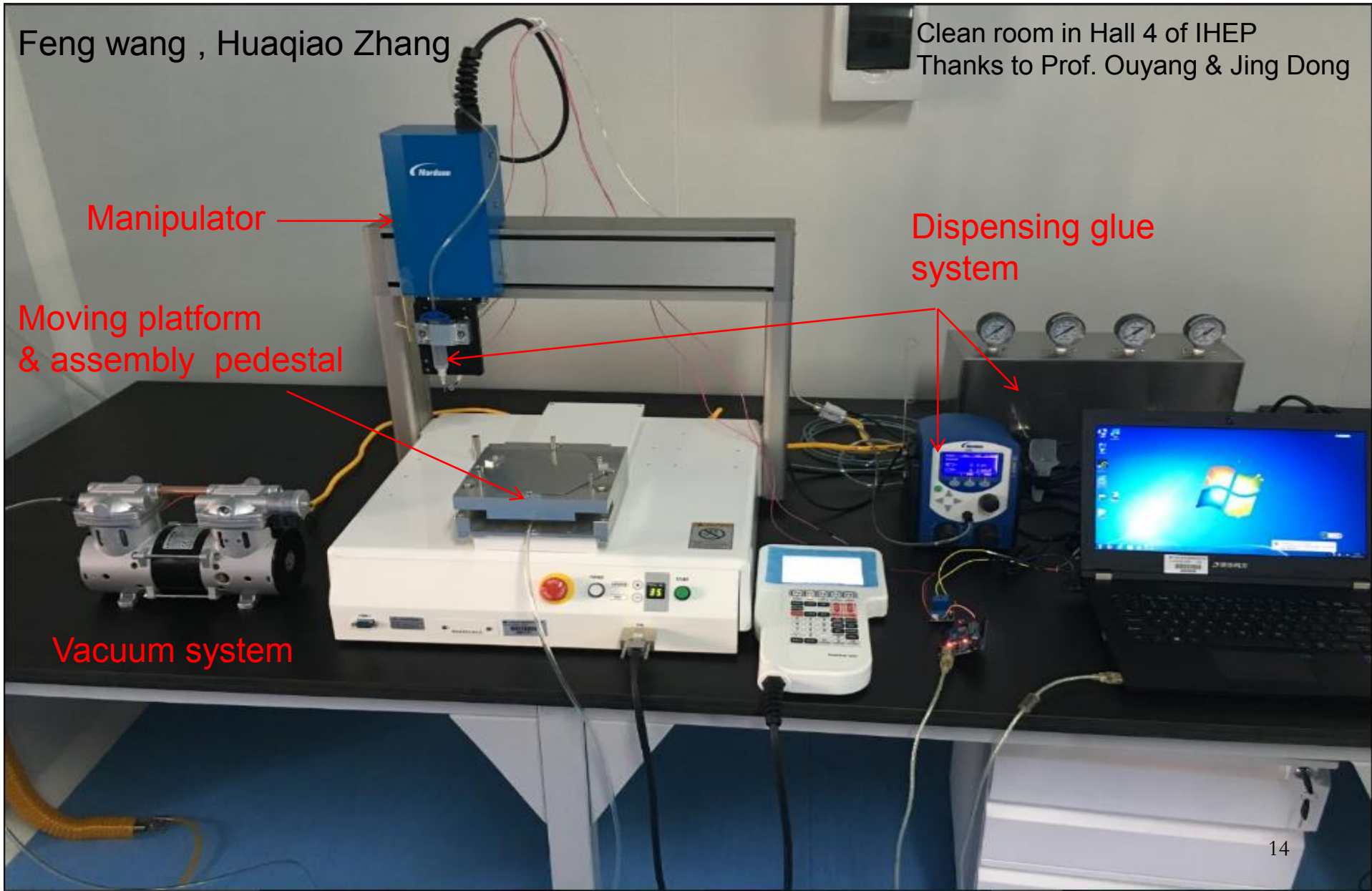
In preparation of HGCAL module beam test

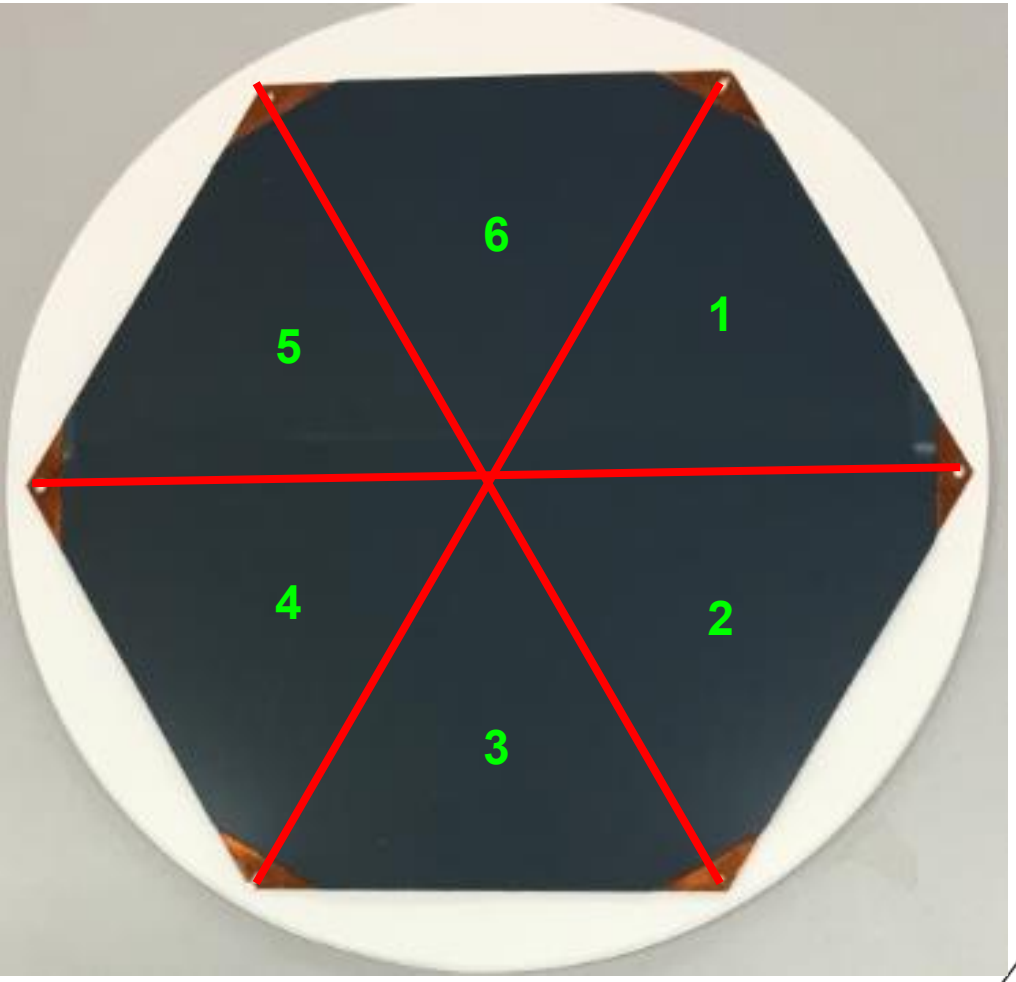
First beam tests of prototype silicon modules for the CMS High Granularity Endcap Calorimeter



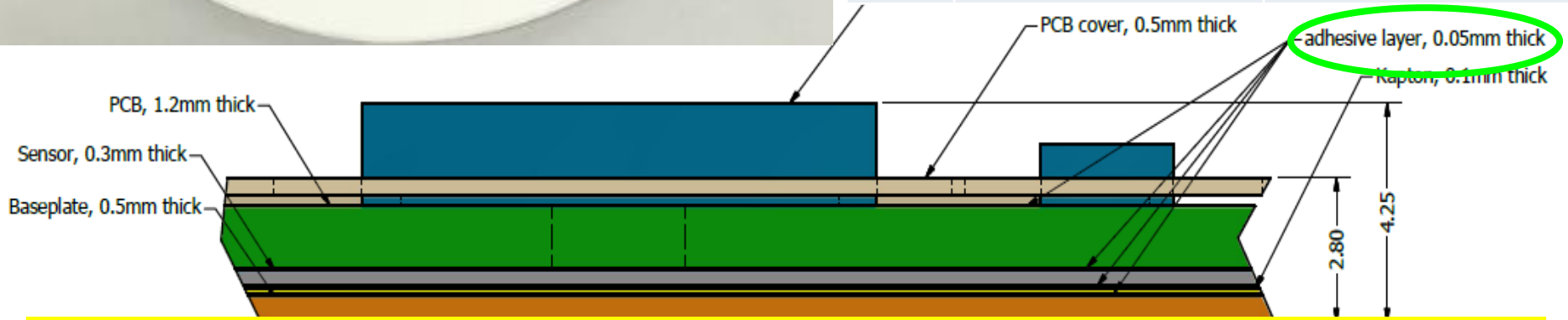
https://twiki.cern.ch/twiki/pub/CMS/EC-TDR/TDR-17-007-paper-v1.pdf

HGCAL Module assembly system in IHEP





Thickness of glue (mm)		
	Layer 1	Layer 2
1	0.049±0.003	0.047±0.004
2	0.050±0.003	0.050±0.005
3	0.050±0.004	0.055±0.004
4	0.045±0.005	0.053±0.005
5	0.046±0.003	0.046±0.004
6	0.048±0.004	0.048±0.006



The thickness of glue in the first and second layer both meet the requirement of CMS

Summary

- CMS phase II HGCAL upgrade

  1. Determine the HGCAL (Silicon + Tungsten) as a CMS phase II endcap upgrade proposal.

  2. Installation and test of detector will be completed in 2025.

- Status of HGCAL upgrade IN IHEP

  1. We have been involved in eight module assembly by cooperate with UCSB.

  2. Full participate in beam test of HGCAL module in FNAL and CERN.

  3. Analyze the MIP signal.

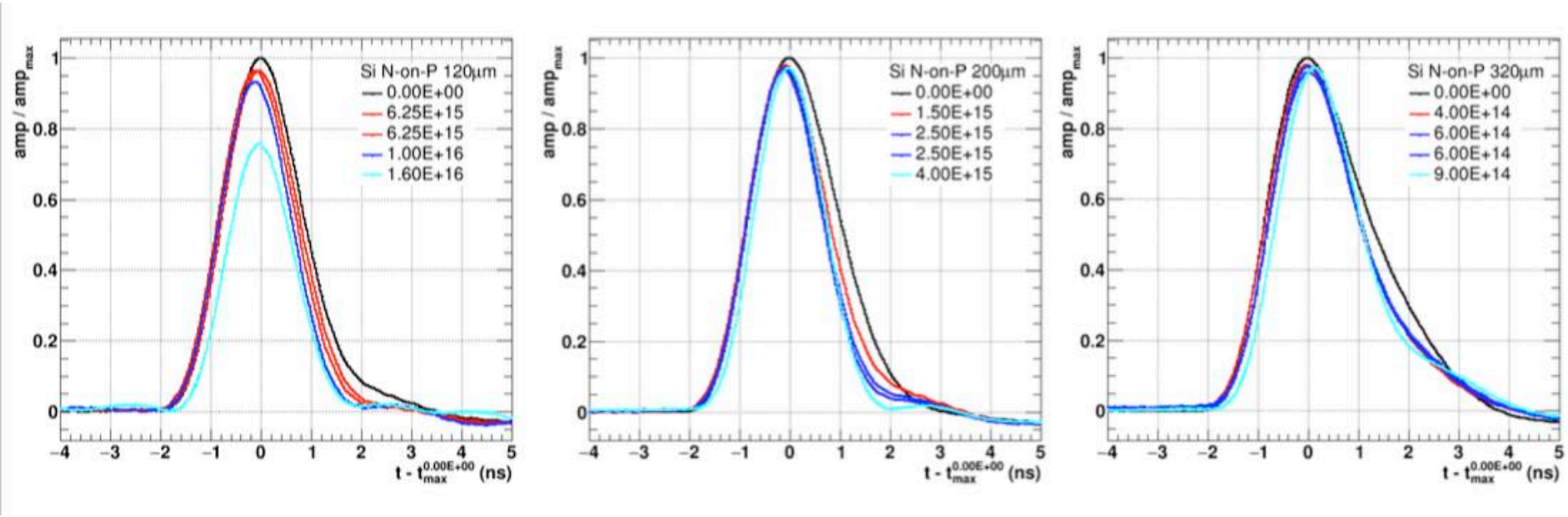
- Next to do in IHEP

  1. Trying to build the assembly lab

  2. Plan to ship a HGCAL module to do cosmic ray test in IHEP

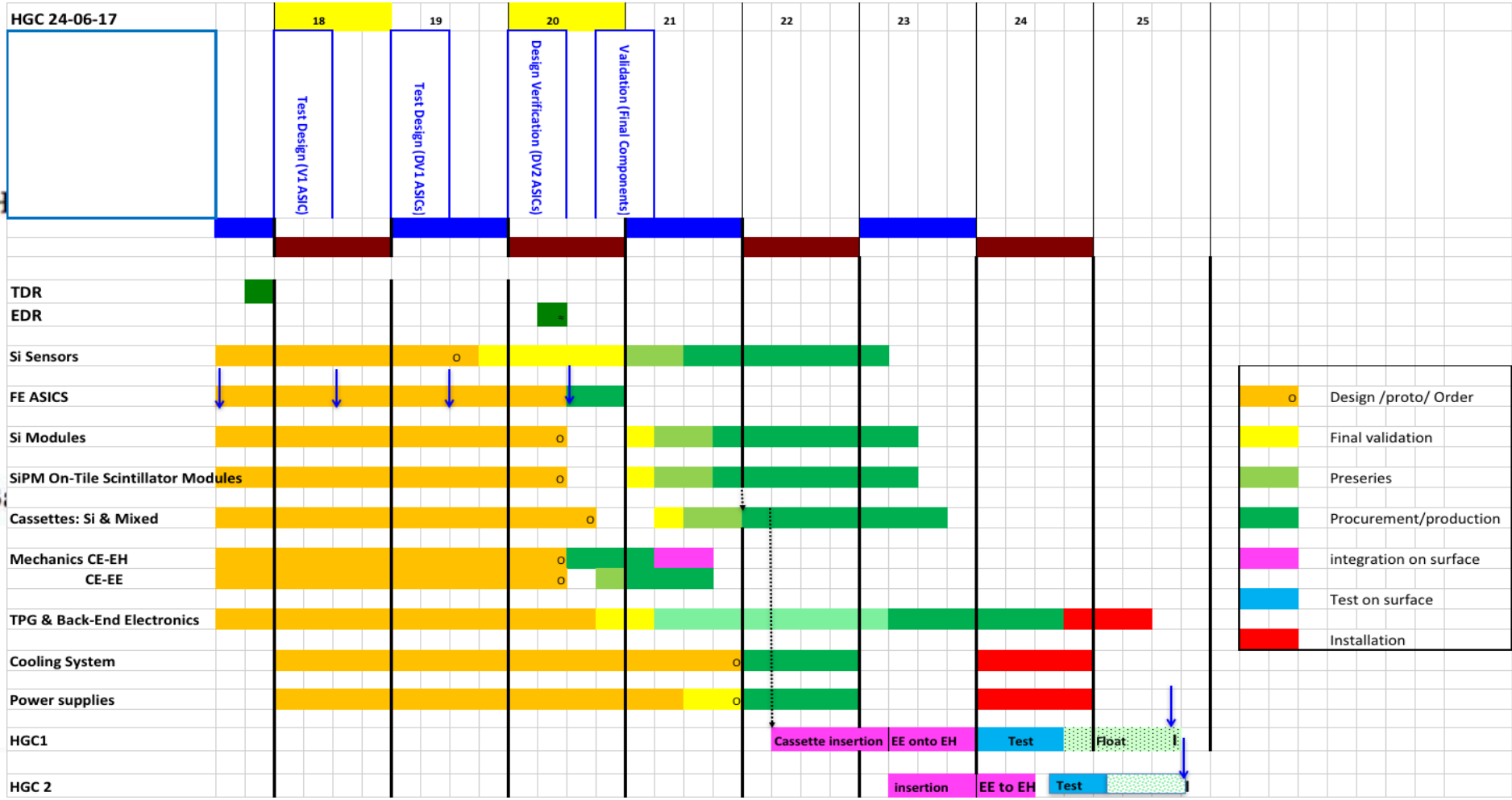

Thank you
CMS

Silicon Sensor irradiation preliminary study



- Si N-on-P sensor produced by Hamamatsu
- 120, 200, 320 um tested
- Neutron radiation up to $1.6*10^{16}$ 1MeV n/cm^2(120um)
- Beam and Sr^{90} tests give consistent results

CMS HGCAL upgrade schedule

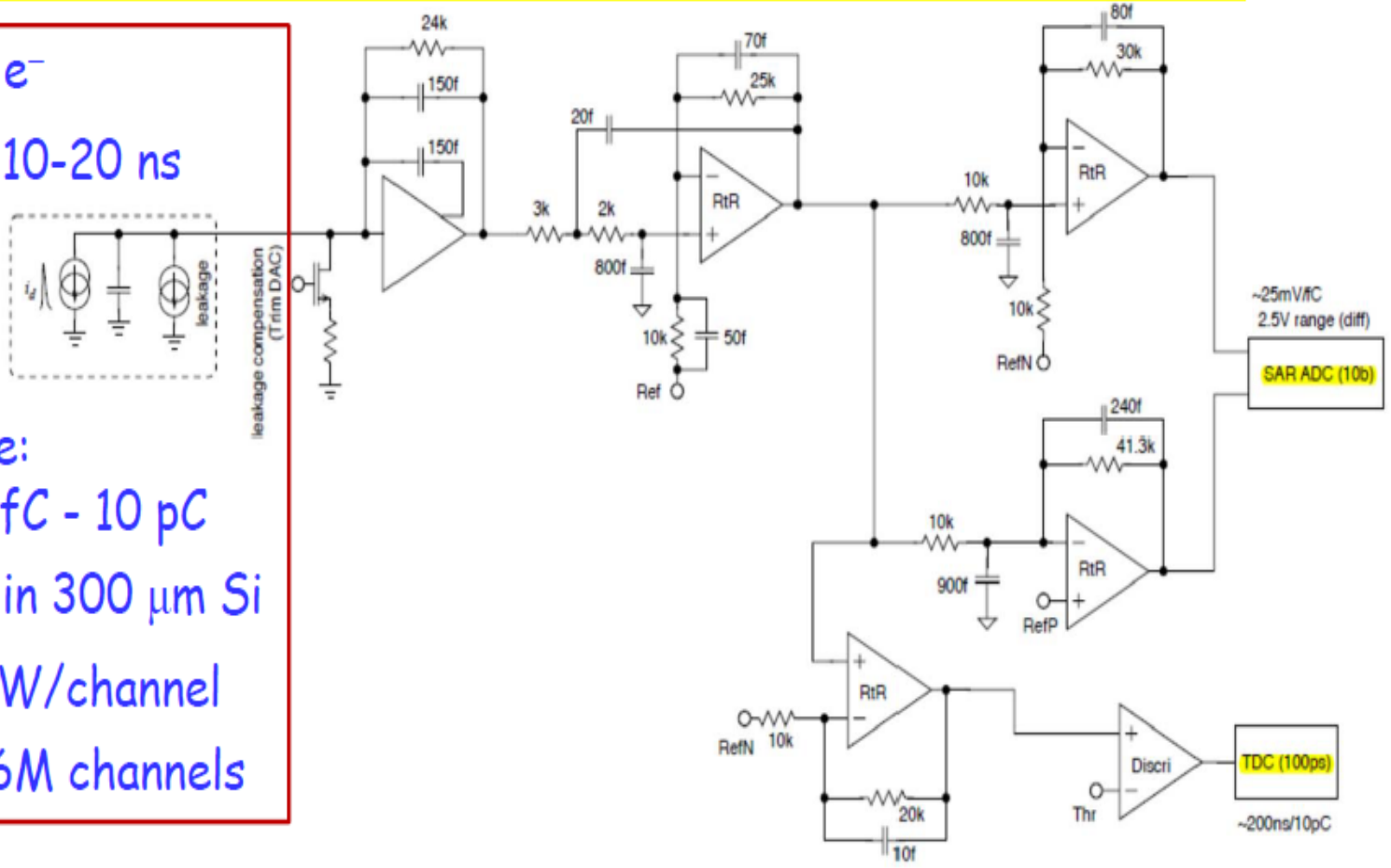


目前phaseII总体有1-2年的推迟

硅sensor的产能有限

Challenge: Large Dynamic Range @ Low Power and Low Noise

- Noise ~ 2000 e^-
- Shaping Time 10-20 ns
- Dynamic Range:
  1-100 fC & 50fC - 10 pC
  ~ 3000 MIP in 300 μm Si
- Power: ~ 10 mW/channel
  ~ 100 kW / 6M channels



Baseline:
Charge + Time-over-Threshold (ToT)
- 10-bit ADC, 12-bit TDC:
  Existing/tested design
- 20 ns peaking time

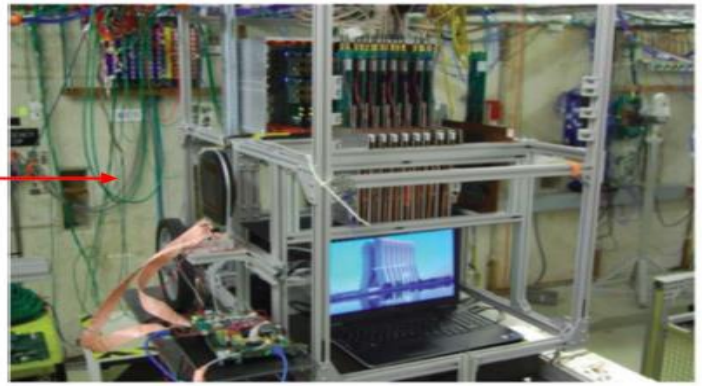
T (μm)	C (pF)	I_d (μA)	N (e^-)
300	40	≈ 0	1600
	40	3.5	1750
200	60	≈ 0	2100
	60	5.2	2250
100	60	≈ 0	2100
	60	10.5	2400

	Power (mW)
Preamp.	2.0
Shaper	1.5
ADC	1.0
TDC	4.0

FNAL

- 15 X_0 with 16 layers
- e^- beam at 4-32 GeV
- p at 120 GeV

Beam

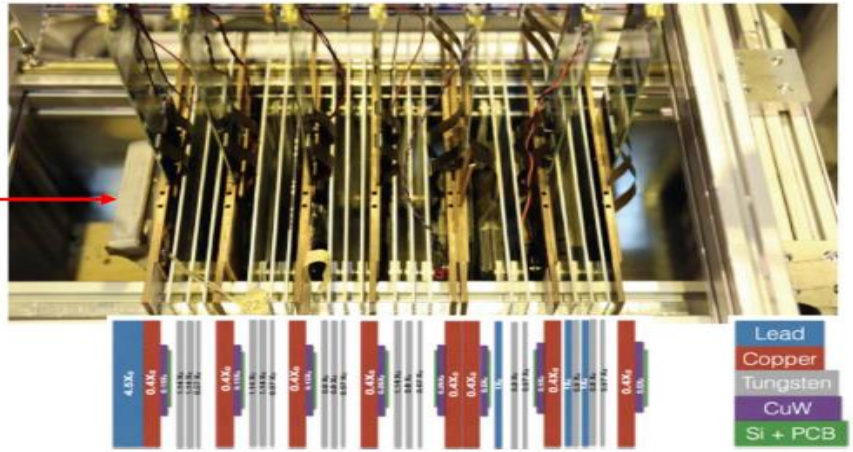


Basic double sided structure repeated eight times

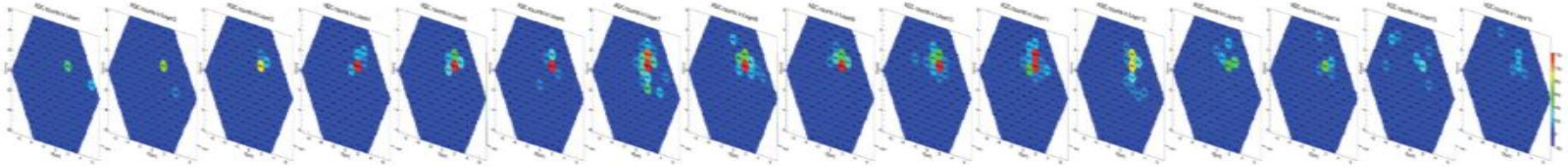
CERN

- 27 X_0 with 8 layers
- e^- beam at 25-250 GeV
- π/μ at 125 GeV
- vary # X_0's

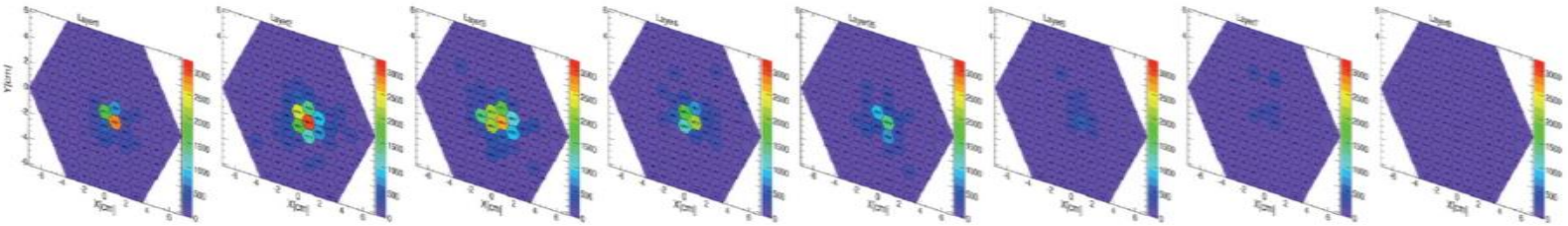
Beam

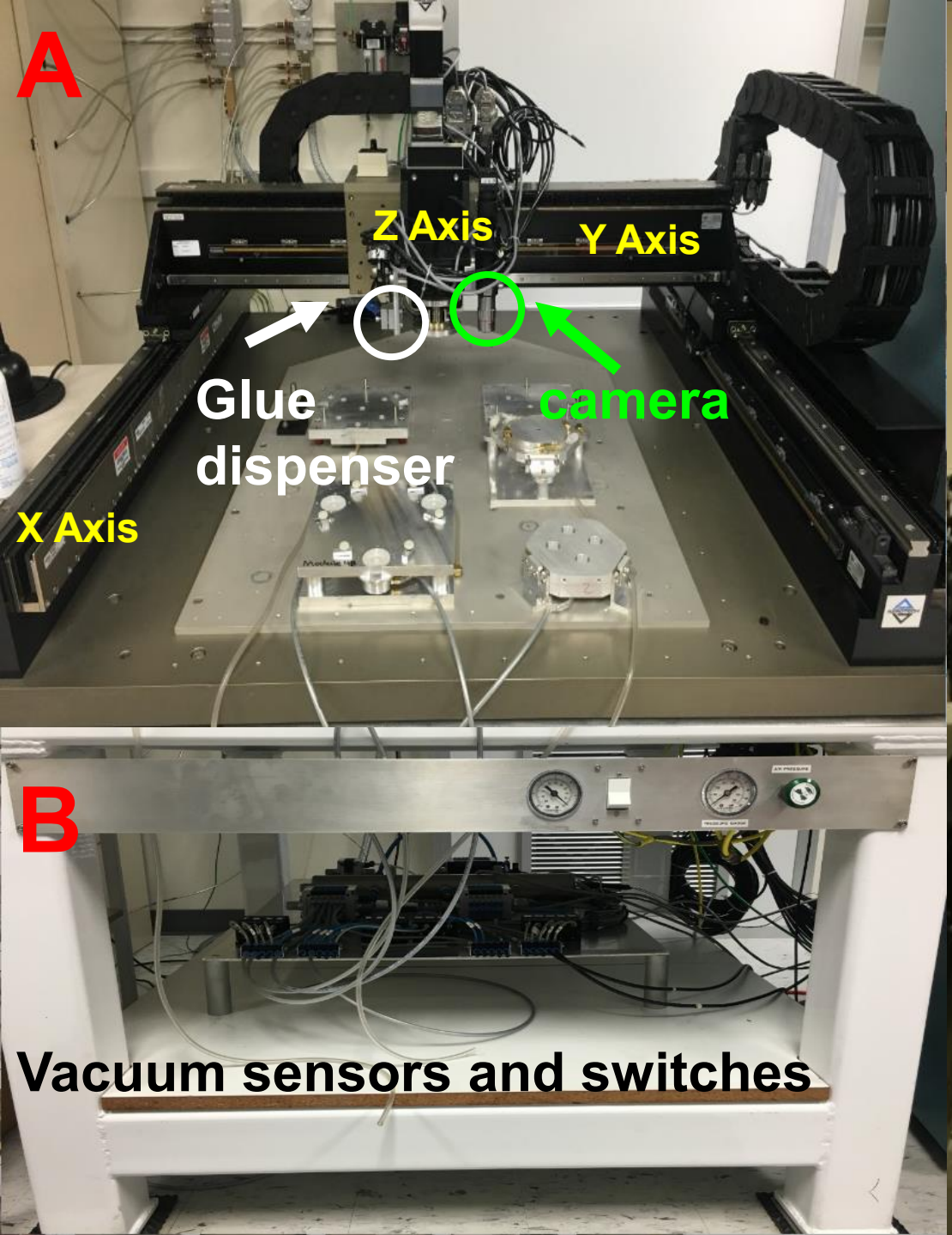


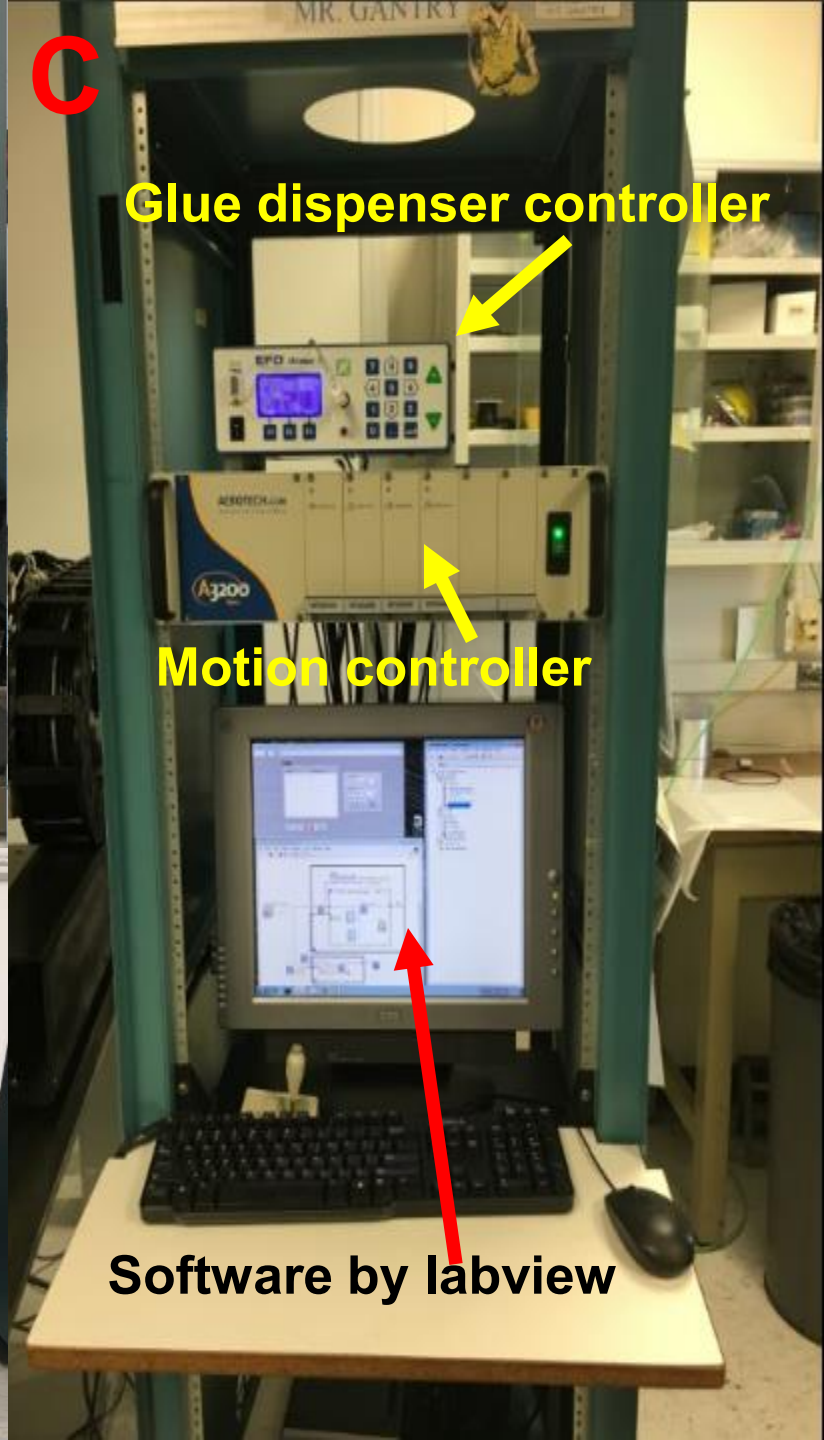
32 GeV e^-

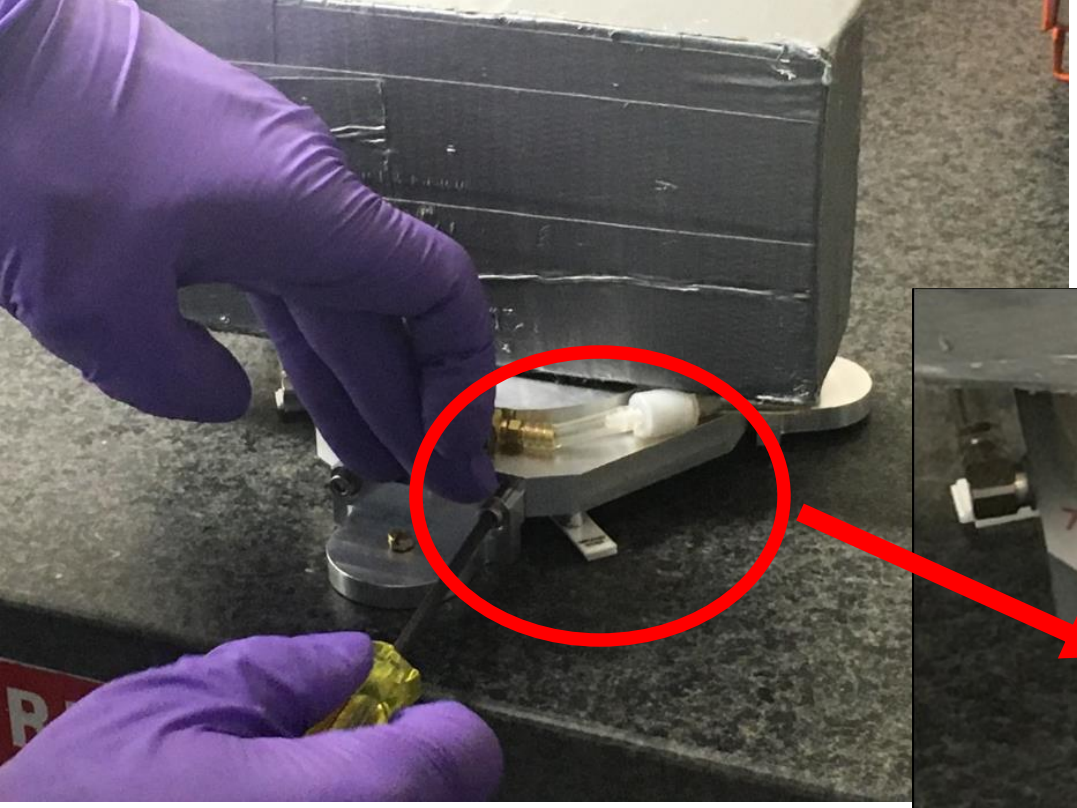


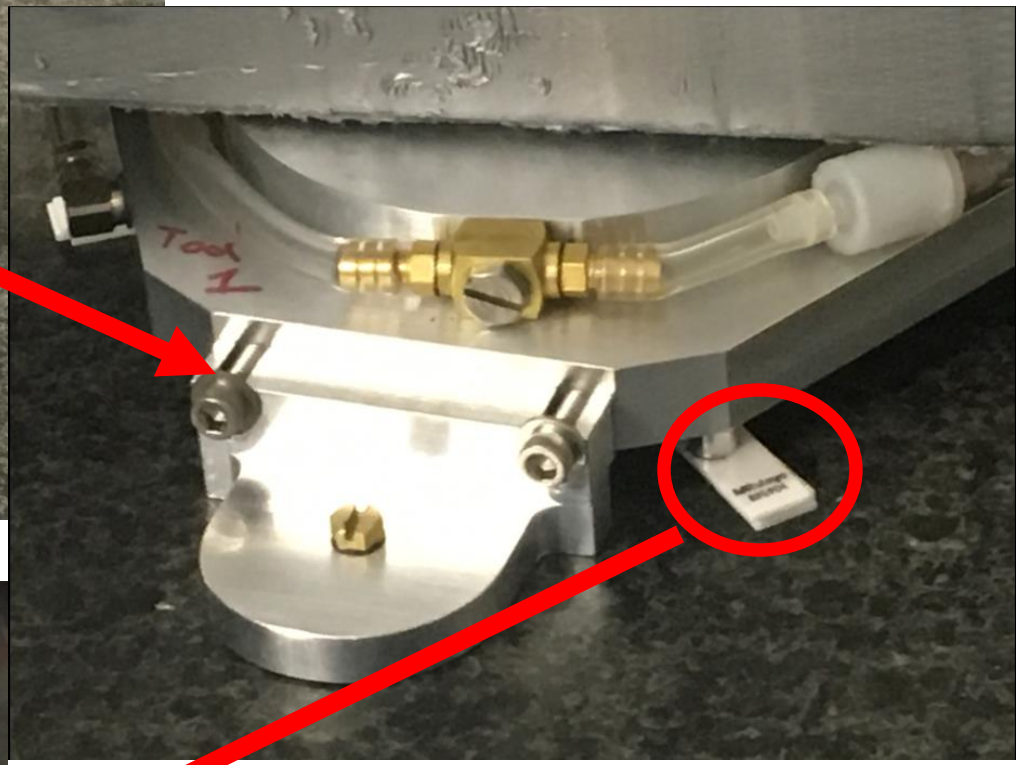
250 GeV e^-




A
Z Axis
Y Axis
Glue
dispenser
camera
X Axis
B
Vacuum sensors and switches

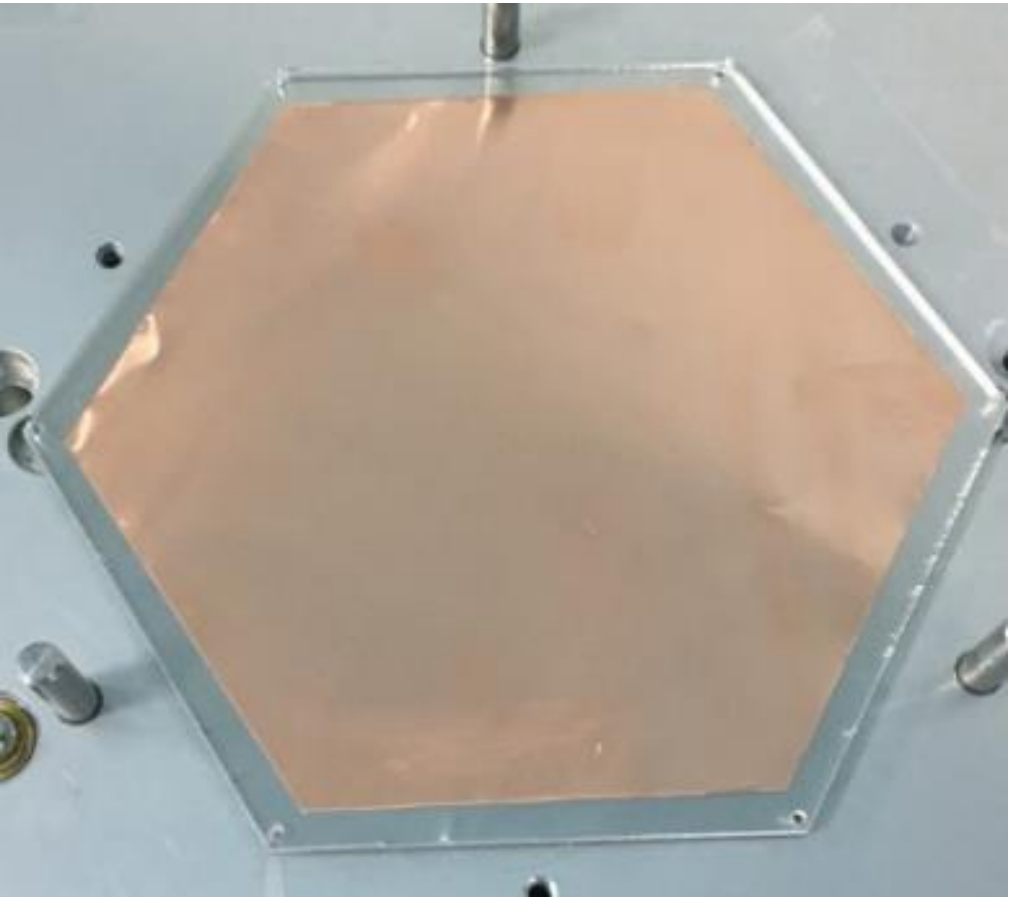

C
Glue dispenser controller
Motion controller
Software by labview




Tool
1

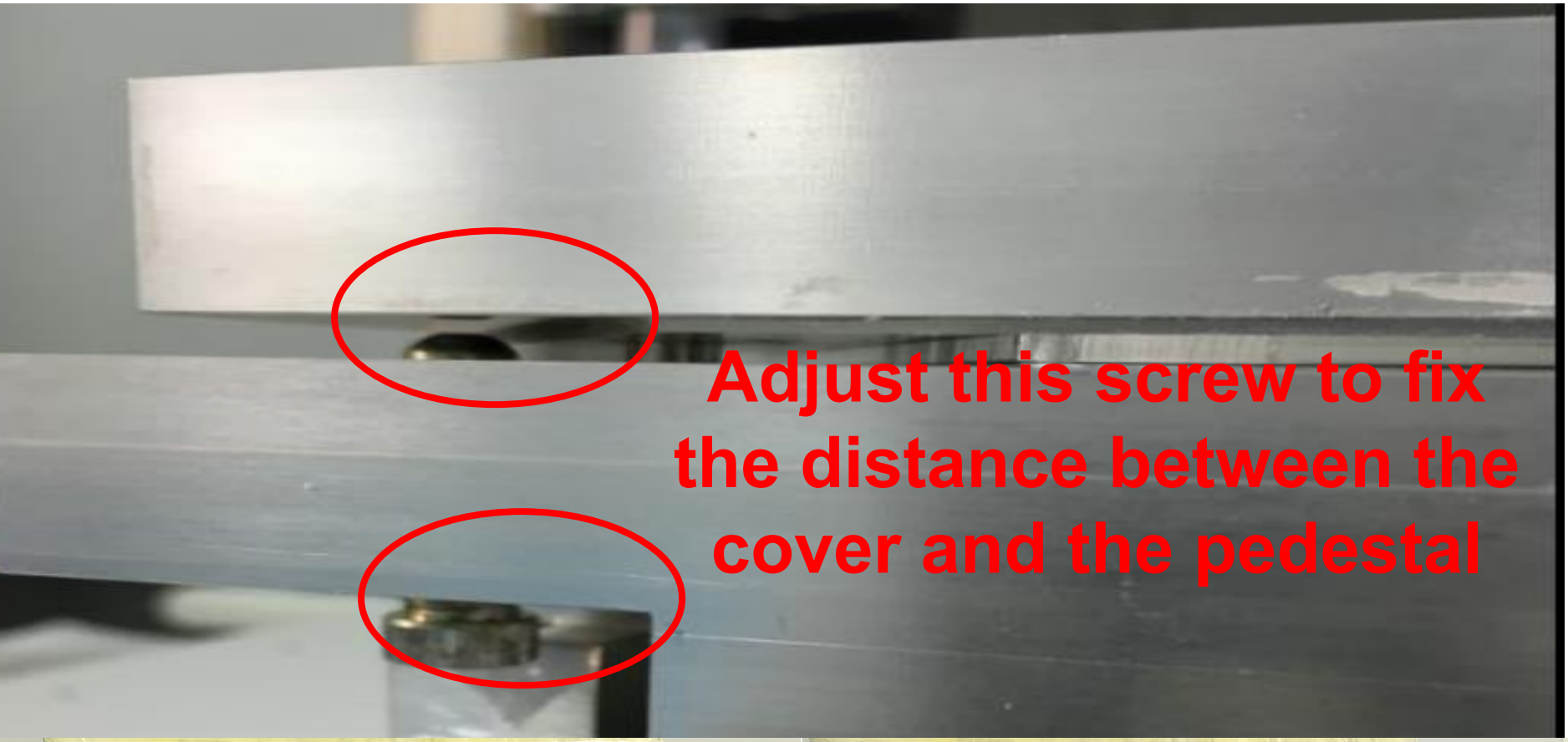

1.40
1.41
1.42
1.43
1.44
1.45
1.46
1.15
1.16
1.17
1.18
1.19
1.20
1.21
1.22
1.0005
1.001
1.002
1.003
1.004
1.005
1.006
1.007
1.008

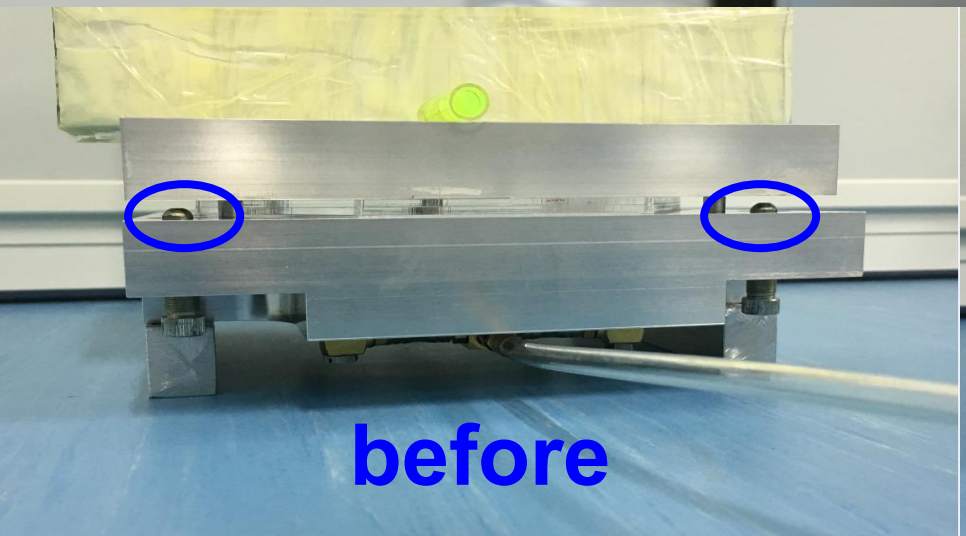
The glue area has covered more than 70% of the plate area. This parameter has meet the requirement of CMS.

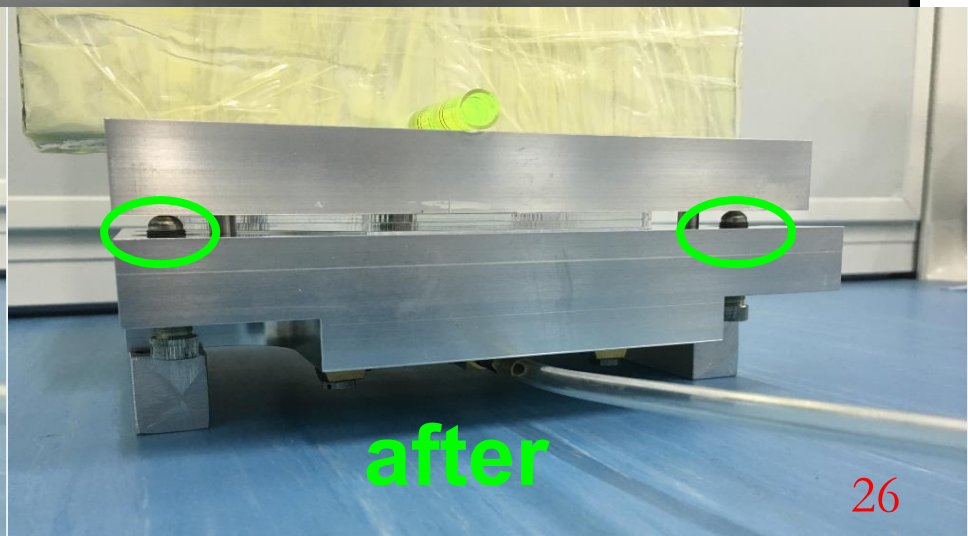


Thickness of copper foil (mm)	
0.047	0.047
0.048	0.049
0.047	0.050
0.047	0.048
0.050	0.047
0.049	0.047
0.047	0.047
0.047	0.048
0.048	0.047
0.046	0.047

The thickness of copper foil is 0.048±0.002


Adjust this screw to fix
the distance between the
cover and the pedestal


before


after