第十三届全国粒子物理学术会议，2021年8月16-20日

NICA/MPD实验新型电磁量能器研制及生产

Yi Wang

Department of Engineering Physics, Tsinghua University

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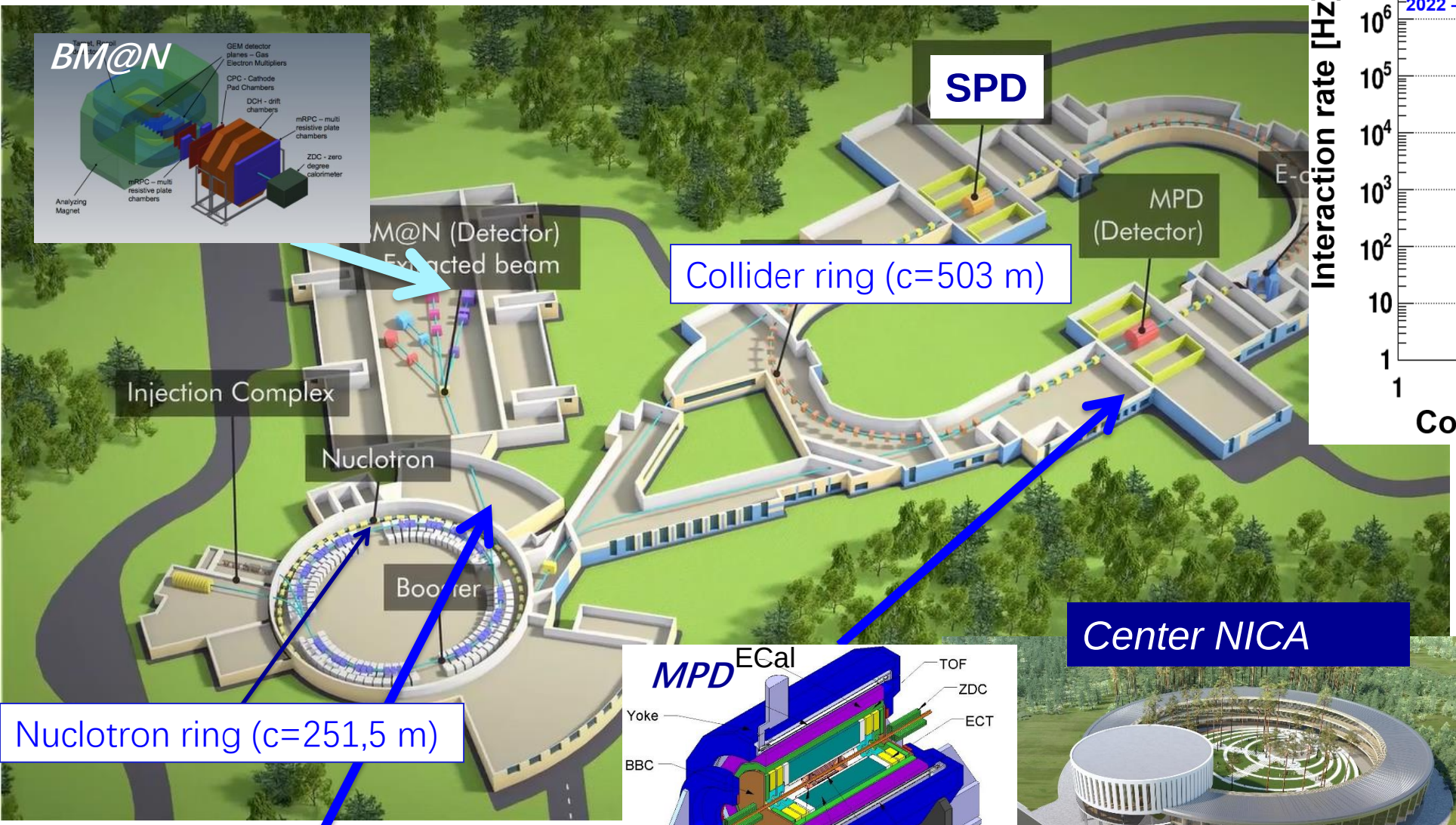
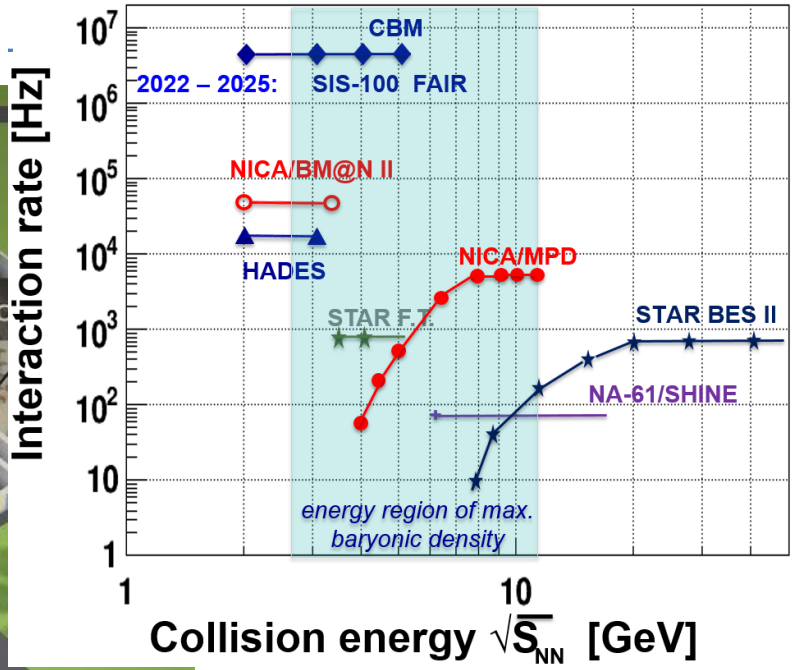
1 About MPD-ECAL





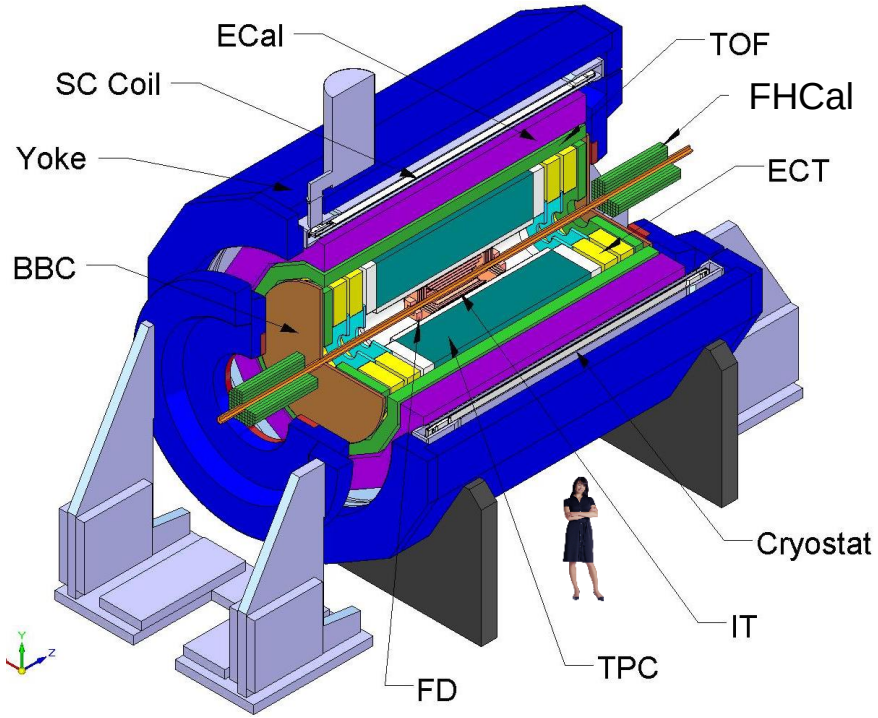
MPD aims to:

- study of hot and dense baryonic matter at the energy range of max baryonic density

- investigation of nucleon spin structure, polarization phenomena

MultiPurpose Detector (MPD) Collaboration

(not complete):



Baku State University, NNRC, ***Azerbaijan****;*
University of Plovdiv, ***Bulgaria;***
University Tecnica Federico Santa Maria, Valparaiso, ***Chili****;*
Tsinghua University, Beijing, ***China****;*
USTC, Hefei, ***China****;*
Huizhou University, Huizhou, ***China****;*
Fudan University, Shanghai, ***China****;*
Central China Normal University, ***China****;*
Shandong University, Shandong, ***China****;*

IHEP, Beijing, ***China****;*
University of South China, ***China****;*
Palacky University, Olomouc, ***Czech Republic****;*
NPI CAS, Rez, ***Czech Republic****;*
Tbilisi State University, Tbilisi, ***Georgia****;*
Tubingen University, Tubingen, ***Germany****;*
Tel Aviv University, Tel Aviv, ***Israel****;*
Joint Institute for Nuclear Research;
IPT, Almaty, ***Kazakhstan****;*
UNAM, Mexico City, ***Mexico****;*
Institute of Applied Physics, Chisinev, ***Moldova****;*
WUT, Warsaw, ***Poland****;*
NCN, Otwock – Swierk, ***Poland****;*
UW, Wroclaw, ***Poland****;*
Jan Kochanowski University, Kielce, ***Poland****;*
INR RAS, Moscow, ***Russia****;*
MEPhI, Moscow, ***Russia****;*
PNPI, Gatchina, ***Russia****;*
INP MSU, Moscow, ***Russia****;*
SPSU - Dept. of NP, ***Russia;***
St. Petersburg, ***Russia****;*
SPSU – Dept. of HEP, St. Petersburg, ***Russia****;*
KI NRS, Moscow, ***Russia****;*

Multi-Purpose Detector (MPD)

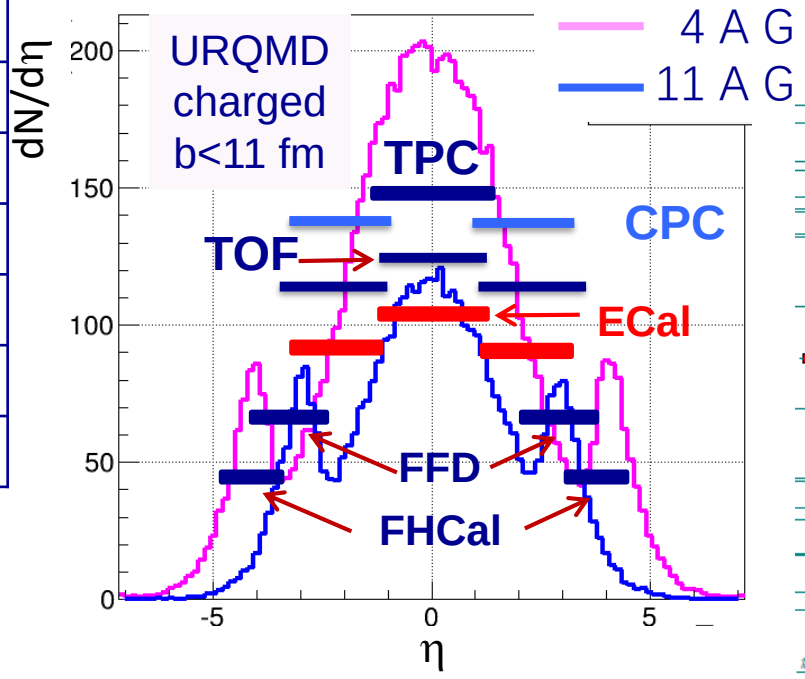
Stage I: TPC, TOF, ECAL, ZDC, FFD

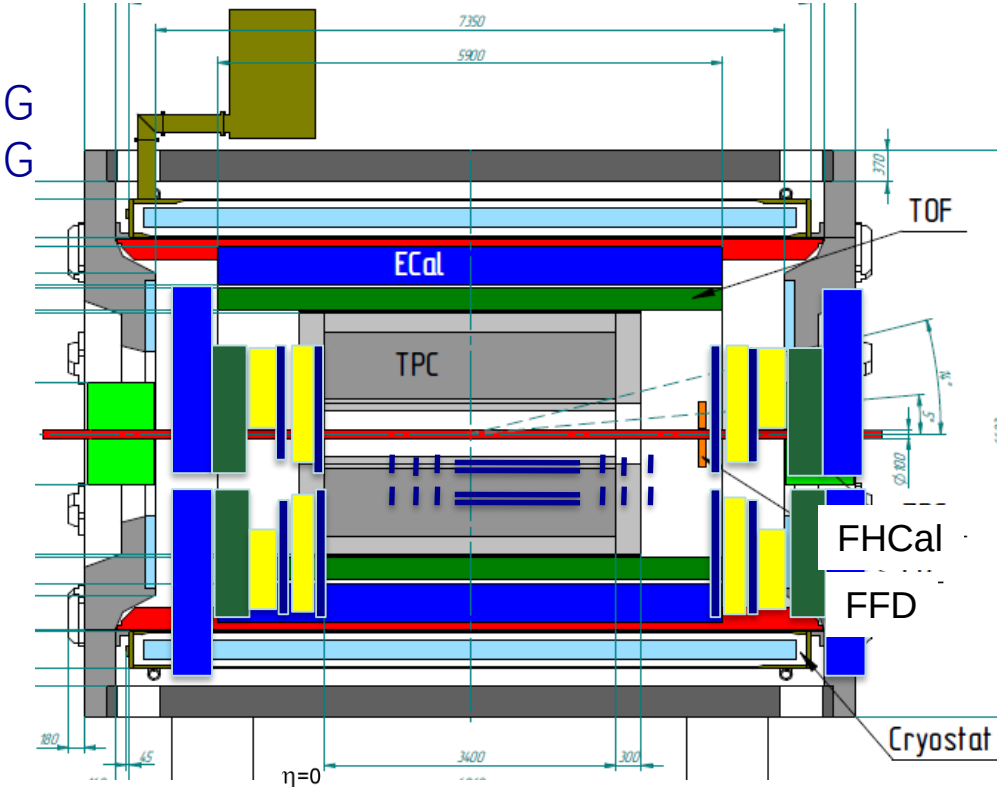
Stage II (2023): + ITS + EndCap (CPC, Straw, TOF, ECAL)

加速环参数

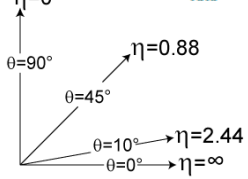
Ring circumference, m	**503,04**
Number of bunches	**22**
r.m.s. bunch length, m	**0,6**
β, m	**0,35**
max. int. Energy, Gev/u	**11,0**
r.m.s. Δp/p, 10-3	**1,6**
IBS growth time, s	**1800**
Luminosity, cm^{-2} s^{-1}	**$1x10^{27}$**

Stage II *acceptance*





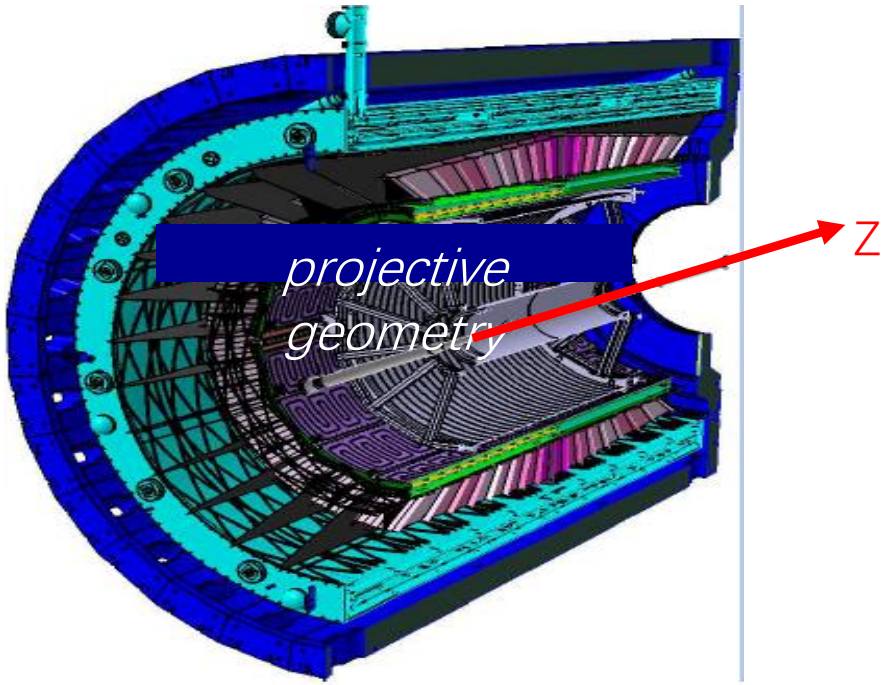
Stage I: *overall commissioning starts in* ***2022***

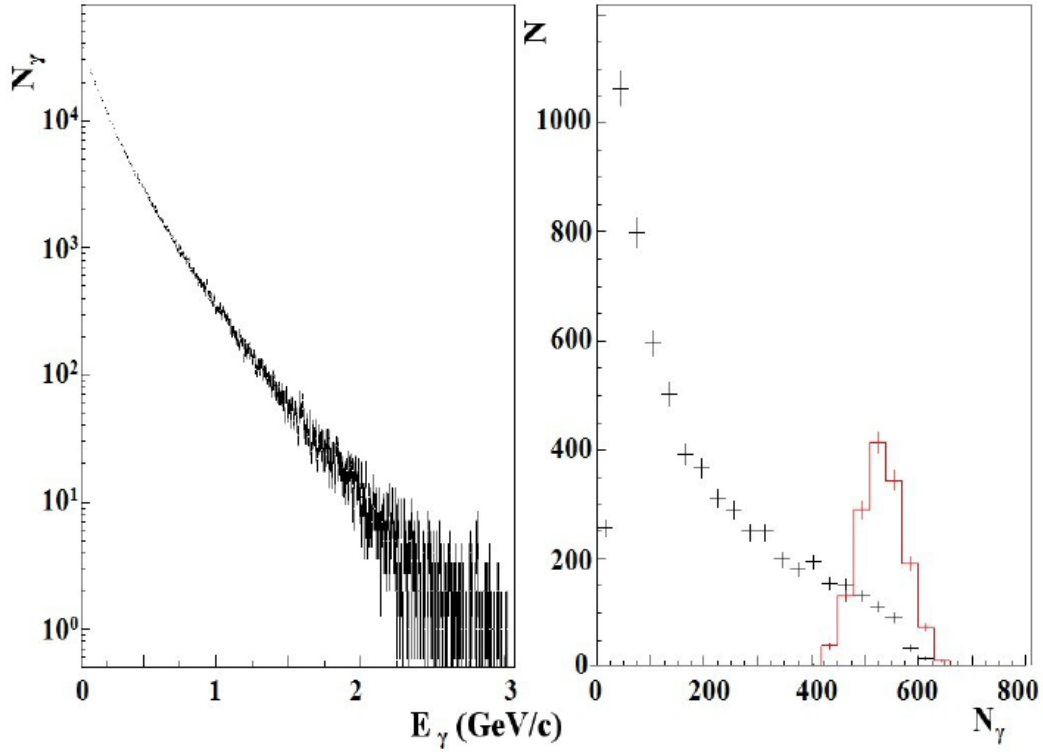


$$\eta = -\ln\left[\tan\left(\frac{\theta}{2}\right)\right],$$

MPD-Ecal requirement

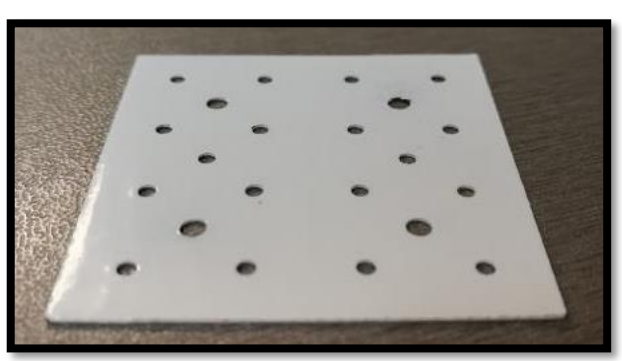
- High segmentation;
- Large enough distance to the vertex;
- Dense active medium with the small Moli'ere radius;
- Adequate space resolution;
- Energy resolution: <5%/√E
- The particle occupancy should not exceed 5%;
- Calorimeter must be able to operate in the magnetic field up to 0.5T;
- Time resolution should be at least below 1ns ;

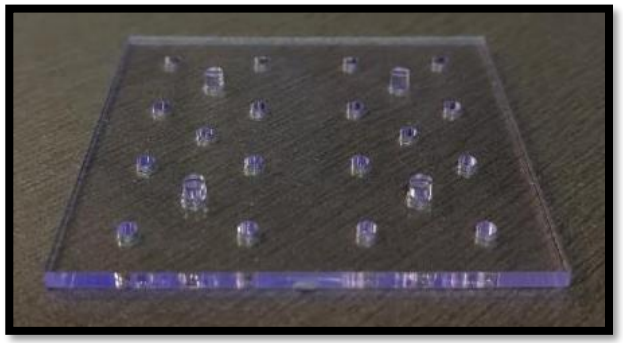


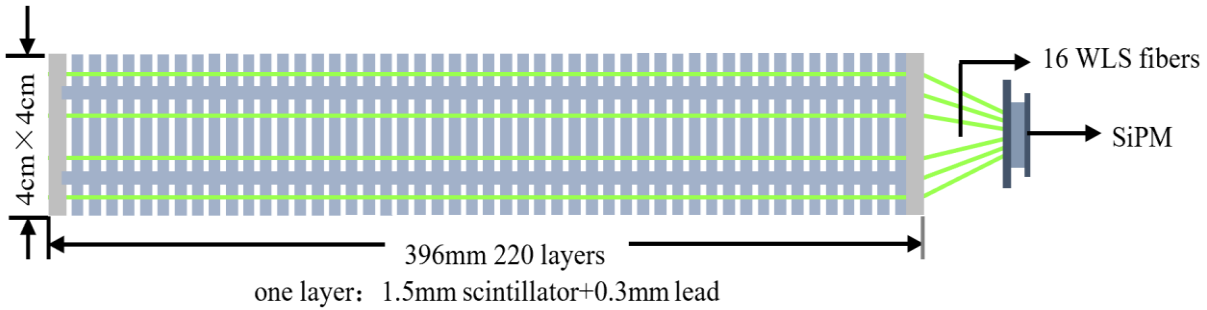


Shashlyk structure

Parameters of main module			
Transverse size, mm^2	40 x 40	Scintillator thickness, mm	1.5
WLS fibers	16	Moliere radius, mm	62
Number of layers	220	Radiation length, X_0	11.8
Lead absorber thickness, mm	0.3	Effective radiation length, mm	32.4



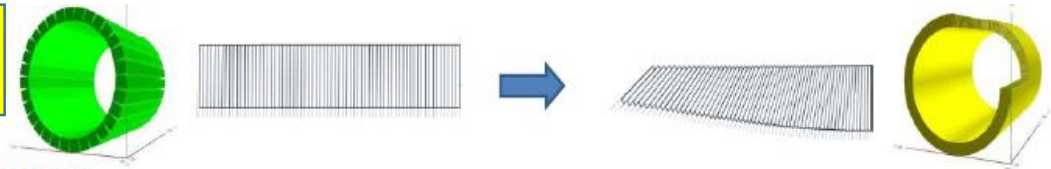




1 About MPD-ECAL

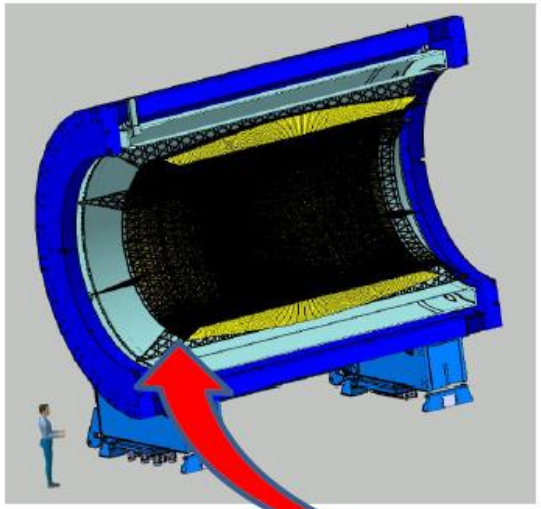
ECal is organized into 25 sectors (50 half-sectors). Each half-sector contains 48 modules.

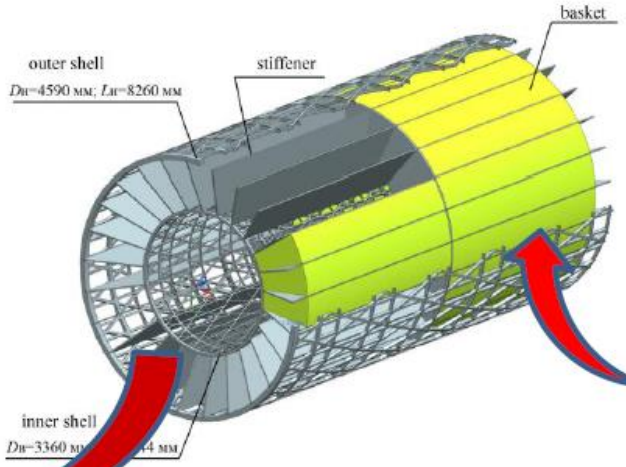
Barrel ECal ~ 38400 ECal towers

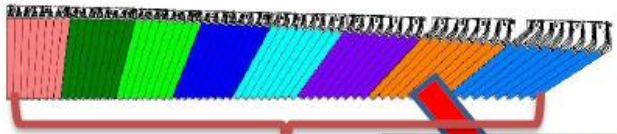


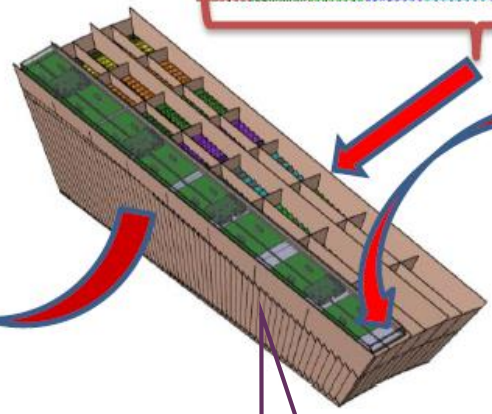
Container is made of Carbon composite

Total load of about 1.2 tons

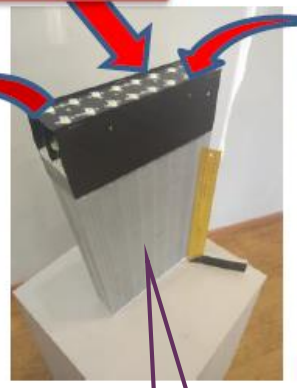








We need Containers for sectors



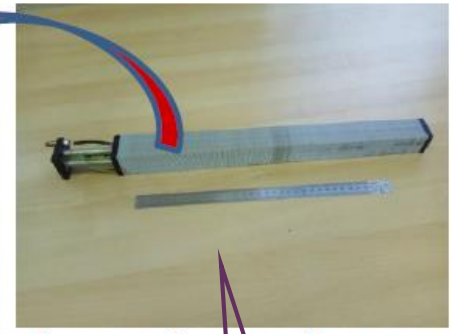


Photo of one element

1 half-sector

1 module

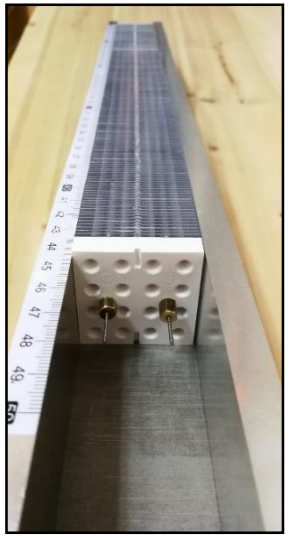
1 tower

1 China MOST MPD ECal project

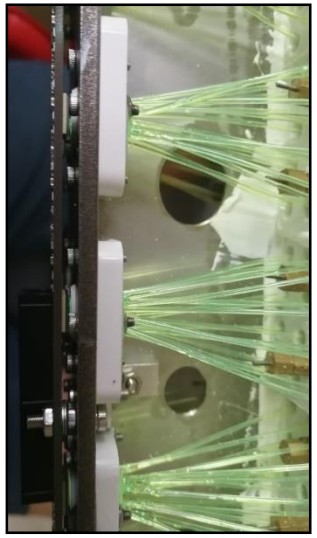
- **Hardware:**
  1) Construction of 8 sectors ECal prototype. 768 modules in total.
  2) Production of FEE PCB
  3) R&D on fast readout electronics, time resolution is less than 150ps
- **Software and simulation**
- **Schedule**: 2020.6-2024.5
- **Institutes**: Tsinghua University 60%
  Shandong University 20%
  Fudan University 10%
  University of South China 10%
  Huzhou University

Contents

2 Shashlyk module design



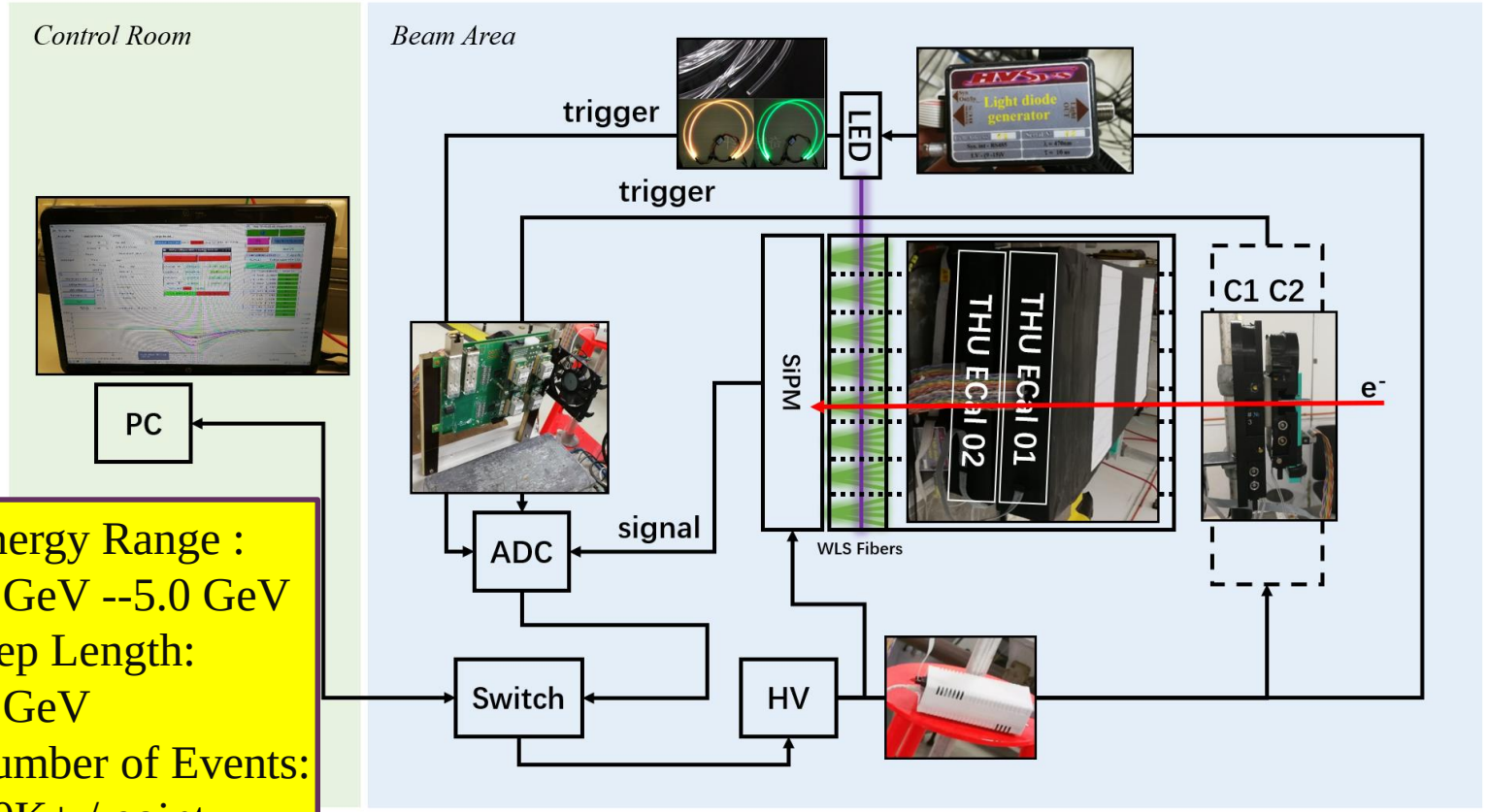




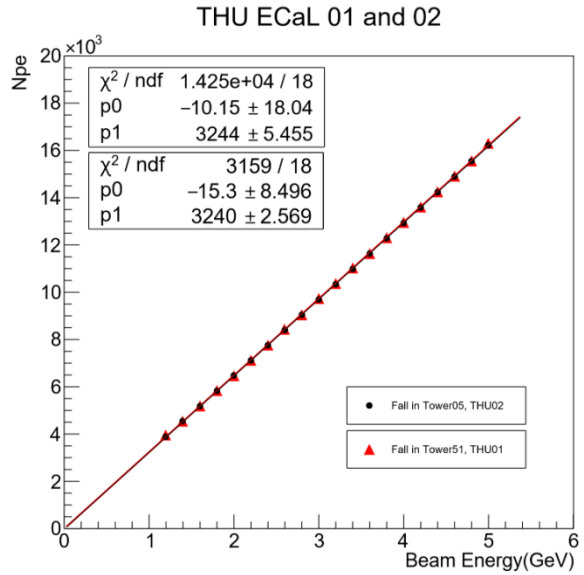

Step1 Step2 Step3 Step4 Step5 Step6

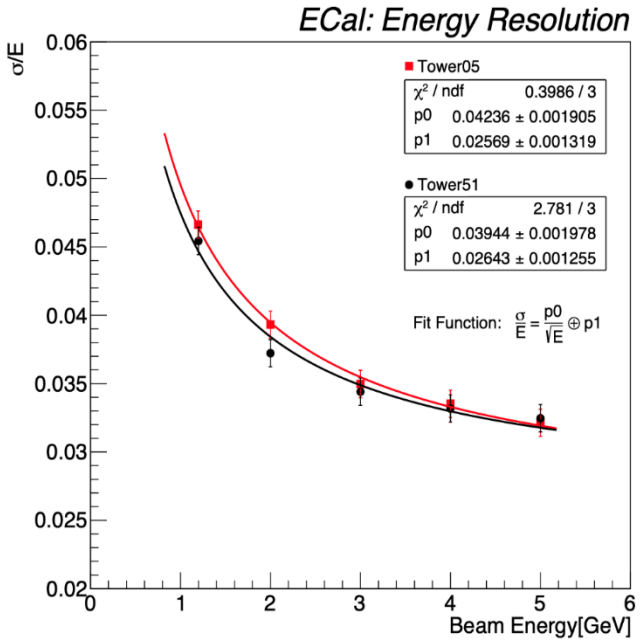
Material: Scintillator tile, lead plate, painting on lead, WLSF, SiPM,…
Material process: component of painting, painting method, polish of WLSF, wrap of tower…
Milling: tower milling, milling of half module
Installation: Plate→Tower→Half module→Module→PCB

2 Module beam test @DESY



- Energy Range : 1.0 GeV --5.0 GeV
- Step Length: 0.2 GeV
- Number of Events: 200K+ / point





Calibration method: 1) Saturation of SiPM
2) Energy spread of electrons
3) Position alignment

Contents

3 Module production in China

Tsinghua University (60%)

Shandong University (20%)

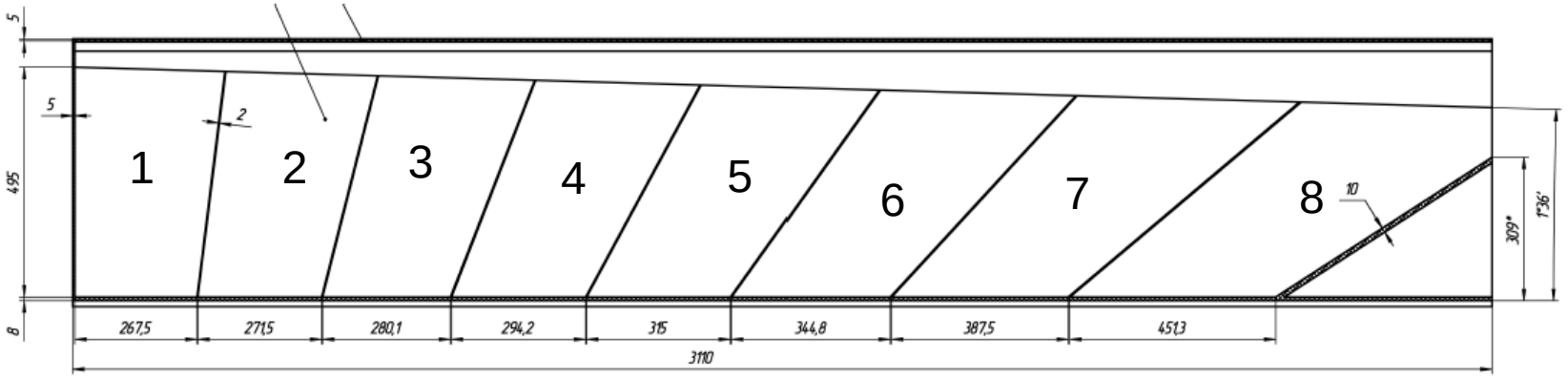
Fudan University (10%)

University of South China (10%)

3 Module production in China

- In the first stage (2020.6-2022.6), 8 sectors will be produced in China

8 sectors=16 half sectors=768 modules=12288 towers



Modules produced in each institutes

	1	2	3	4	5	6	7	8	Total
THU	19	19		38	96	96	96	96	460
SDU			96	58					154
FDU		77							77
USC	77								77

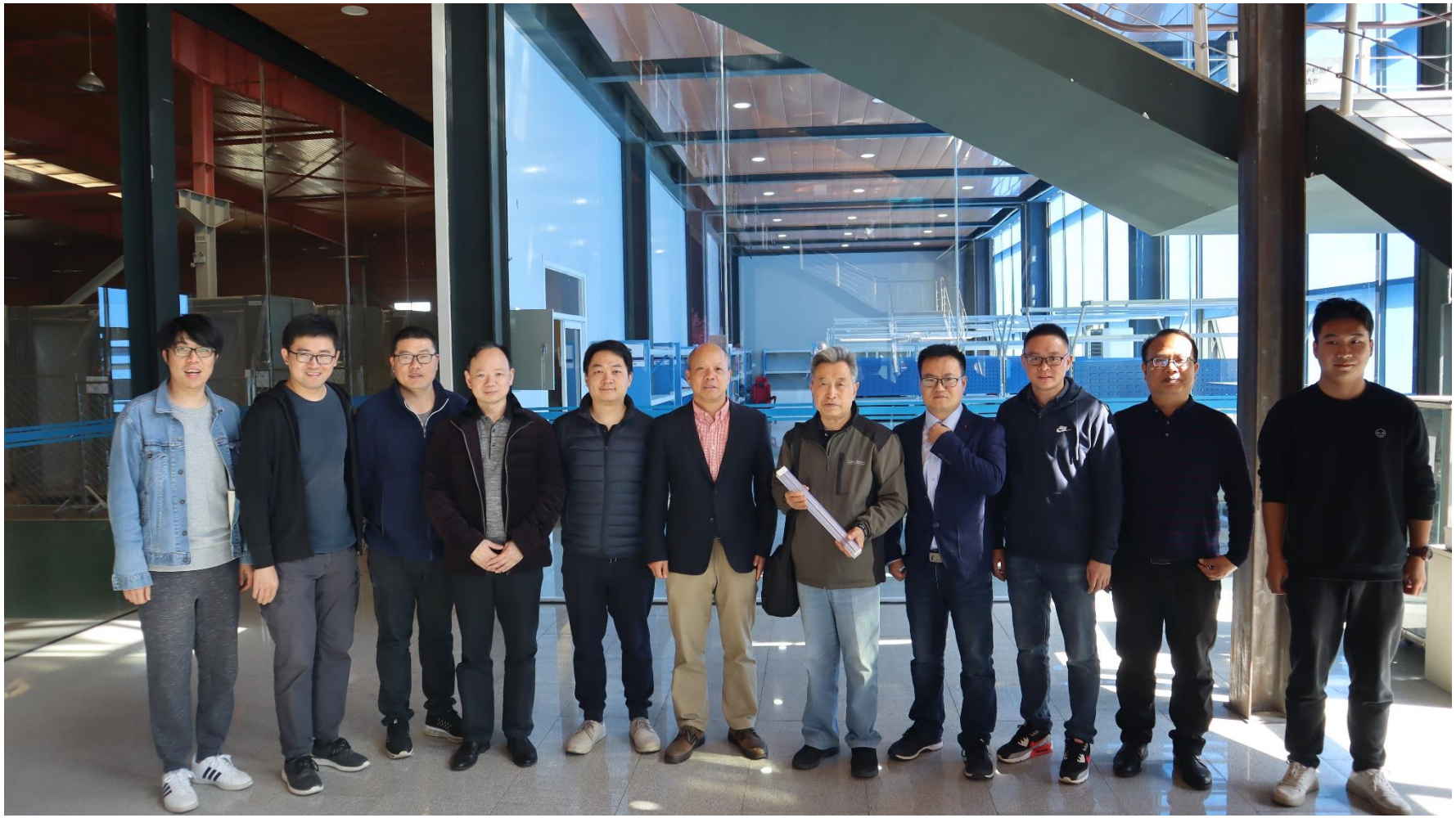
Material:

JINR: scintillator tiles

China: Other material

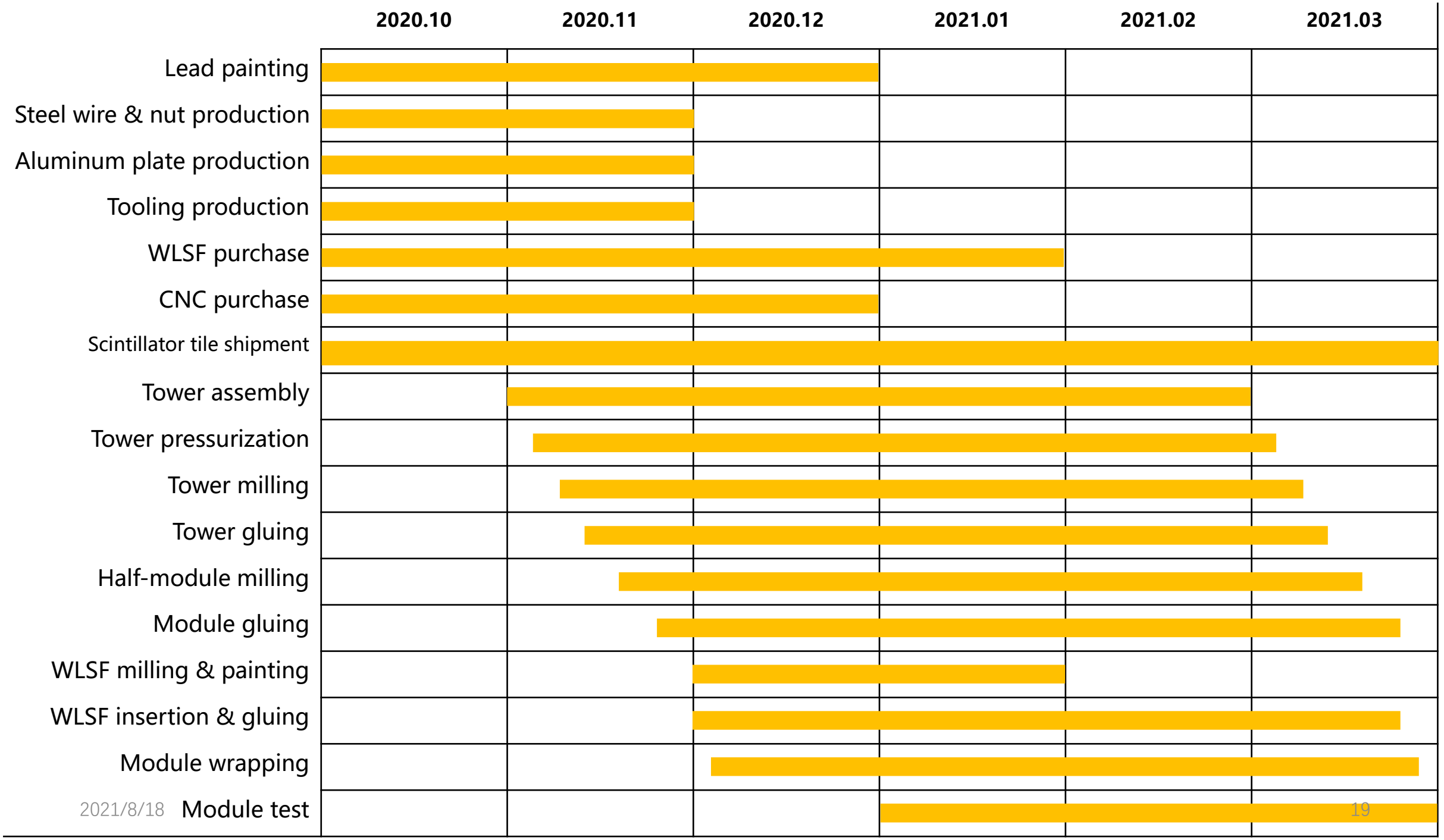
Contents

4 Progress of module production

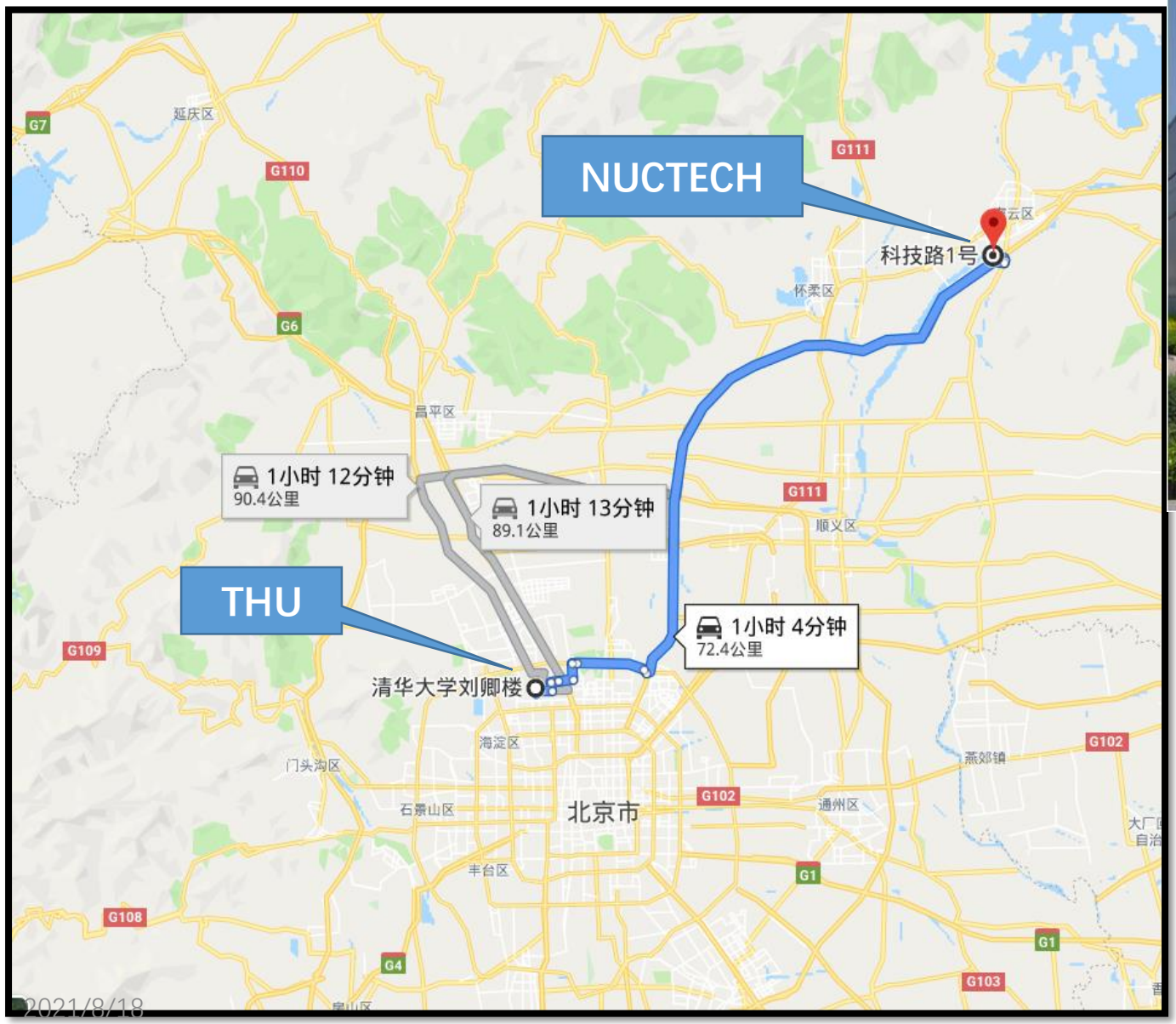


- same material
- same standard
- same procedure
- same QA and QC

Four institutions have discussed and unified the process flow of ECal module production


2020.10
2020.11
2020.12
2021.01
2021.02
2021.03
Lead painting
Steel wire & nut production
Aluminum plate production
Tooling production
WLSF purchase
CNC purchase
Scintillator tile shipment
Tower assembly
Tower pressurization
Tower milling
Tower gluing
Half-module milling
Module gluing
WLSF milling & painting
WLSF insertion & gluing
Module wrapping
Module test

4 Production Site (THU)

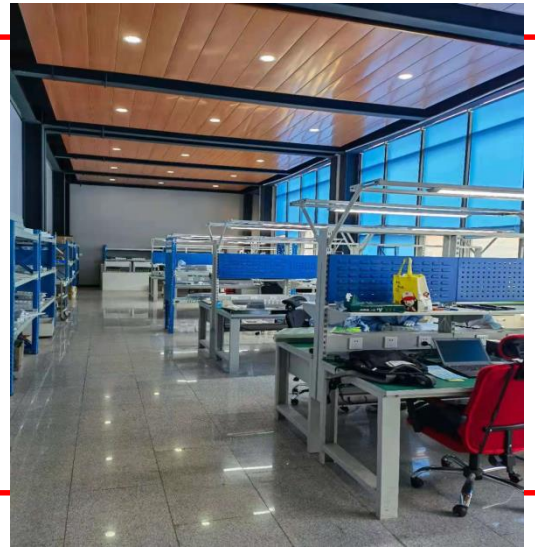


NUCTECH Company

The company is ~80km away from Tsinghua University. This is very convenient for testing and transportation of modules

4 Production Site

400m² in total



Assembling area
(two floors)

Gate

Cutting area
(2 milling machine or more)

Gate

4 Production Site @SDU

Work Space

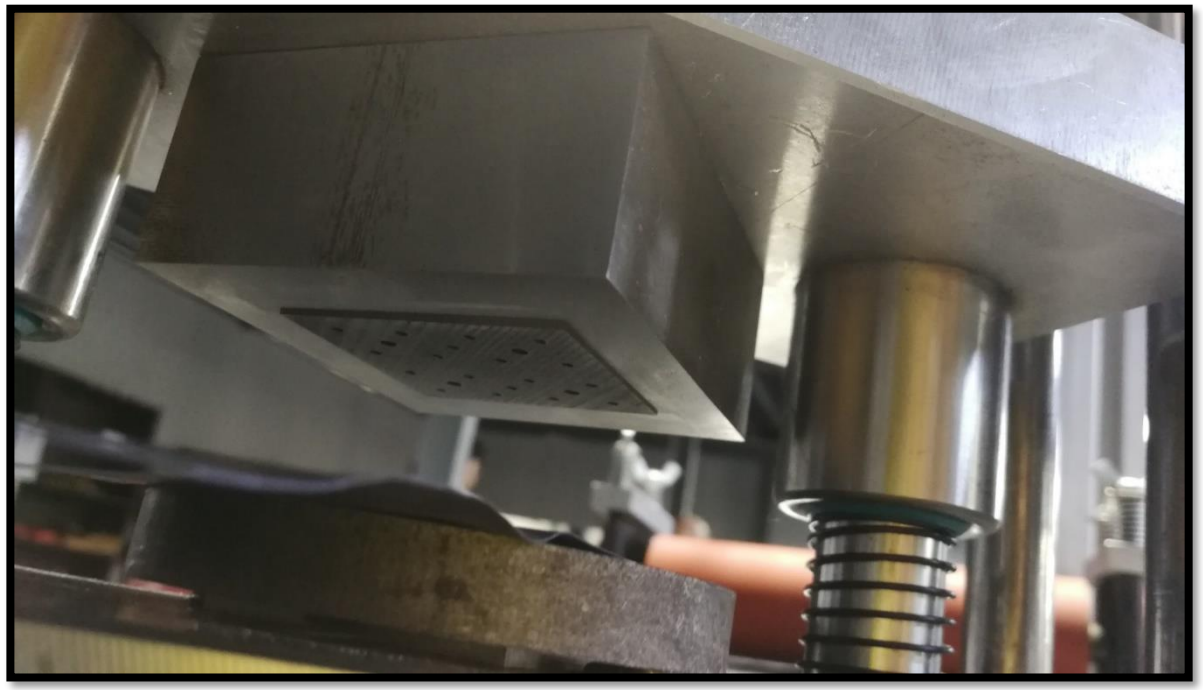
Tower Assemble Area

Half Module and Module Epoxy Area

Milling Area

Storage Area

4 Lead painting & cutting



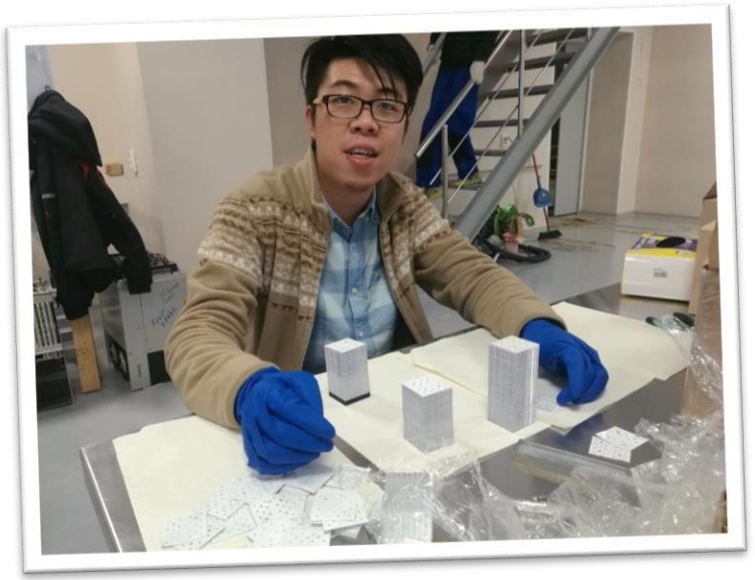
Step1. Powder painting on the whole lead (large area).

Step2. Cutting lead into a circle with a width of 5cm.

Step3. Punching with automatic machine.

✓ Thickness uniformity is very good by this method.

2 Automatic tower assembly

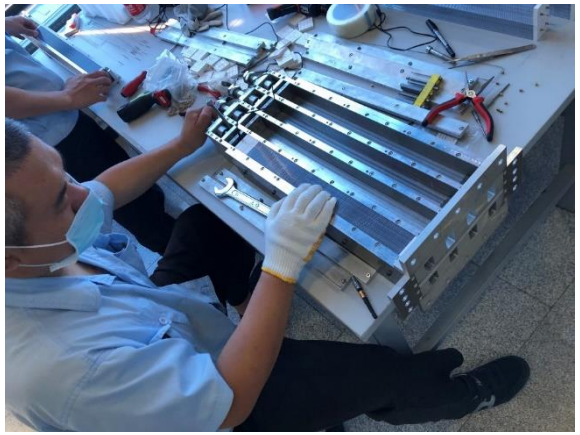


手工安装，费时费力!

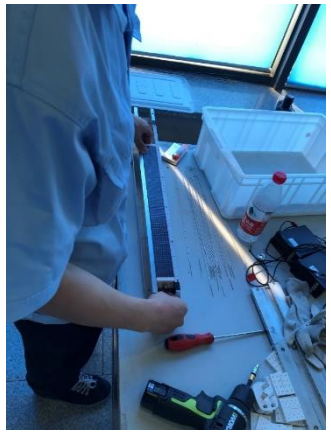
- ✓ Assemble a tower in 20 min.
- ✓ Fully automatic.

4 process flow of module production (1)

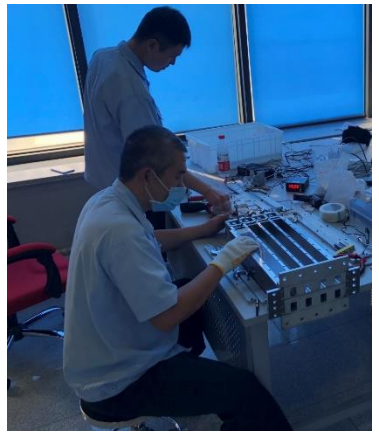
Photo taken in 2020



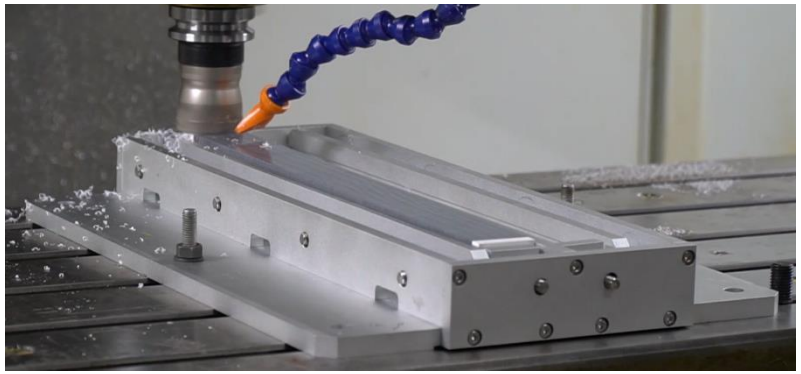
- Pre-pressure



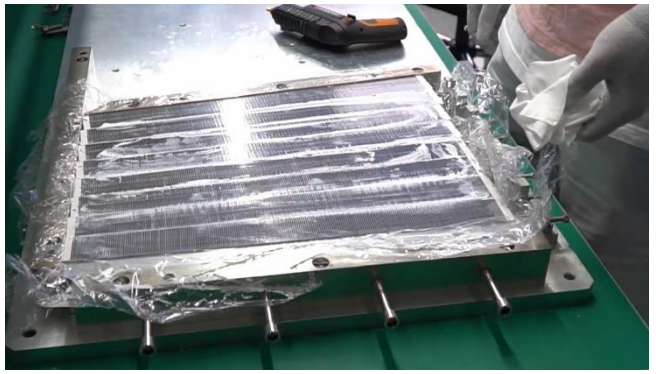
- Adjust length



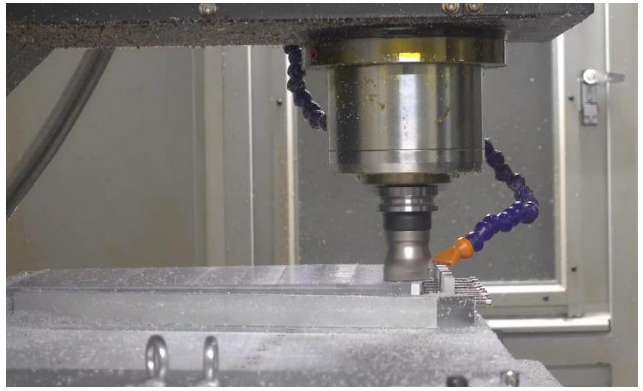
- Pressure transmission



- Tower milling



- Half-module gluing

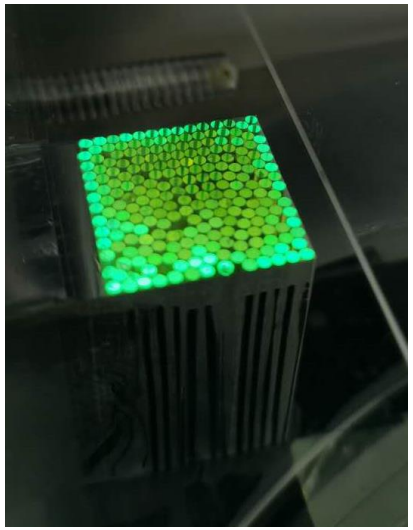


- Half-module milling

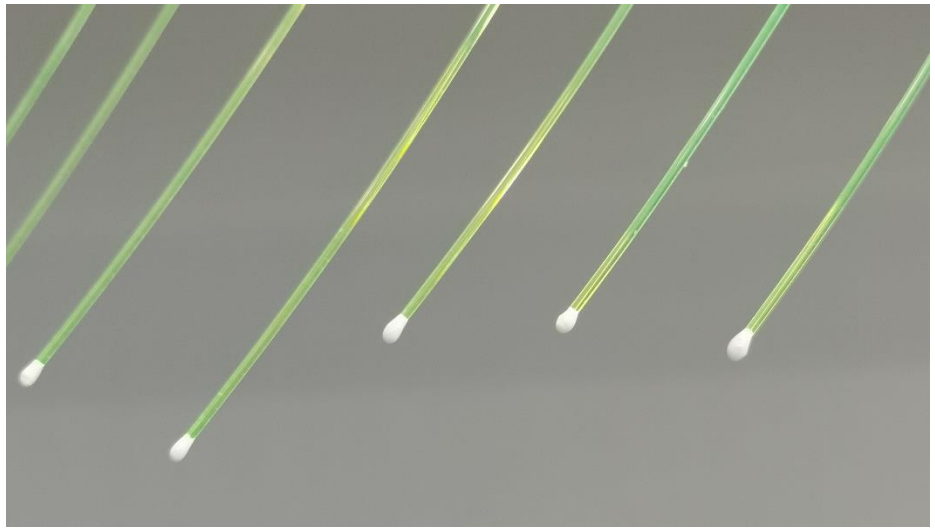
4 process flow of module production (2)

Photo taken in 2020

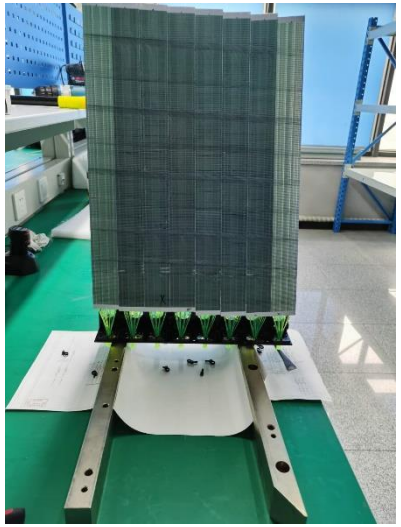
- Module gluing



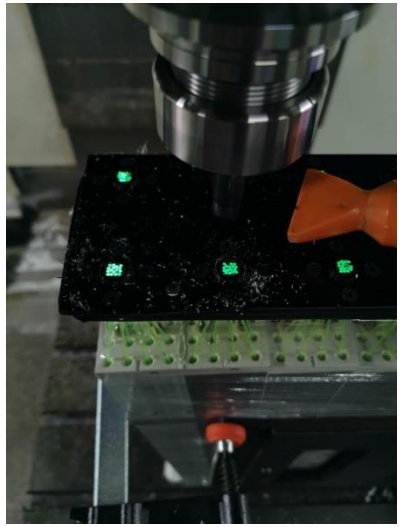
- WLSF cutting (A bundle)



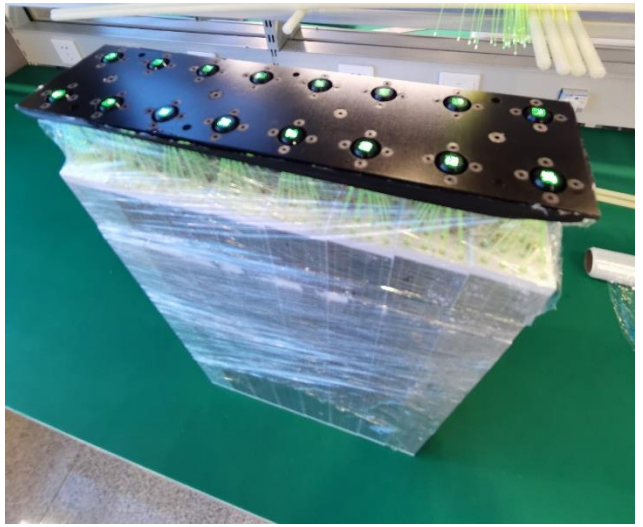
- WLSF painting



- Fiber insertion & gluing



- WLSF milling (diamond cutter)



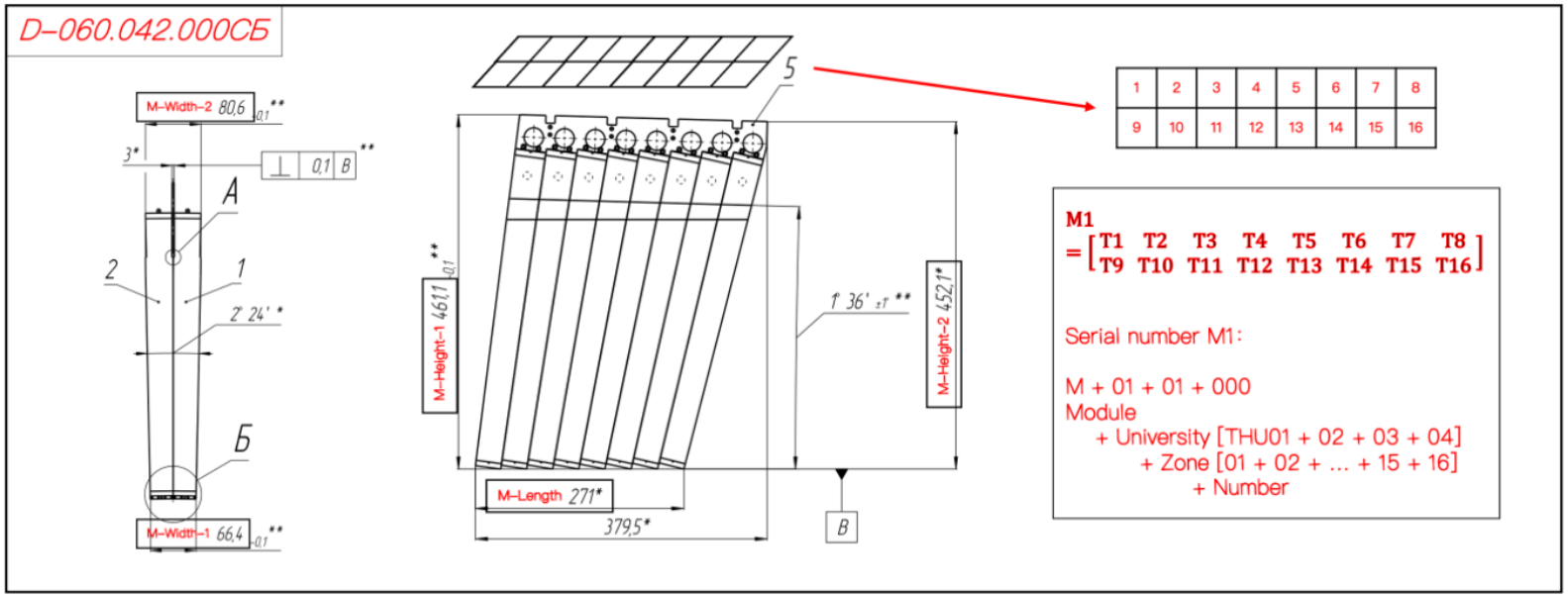
- finished

4 Production data base

https://hepd2.ep.tsinghua.edu.cn/hepd/database/database.html

Database of ECal Mass Production — Summary | Zone | Module | Tower

Zone1



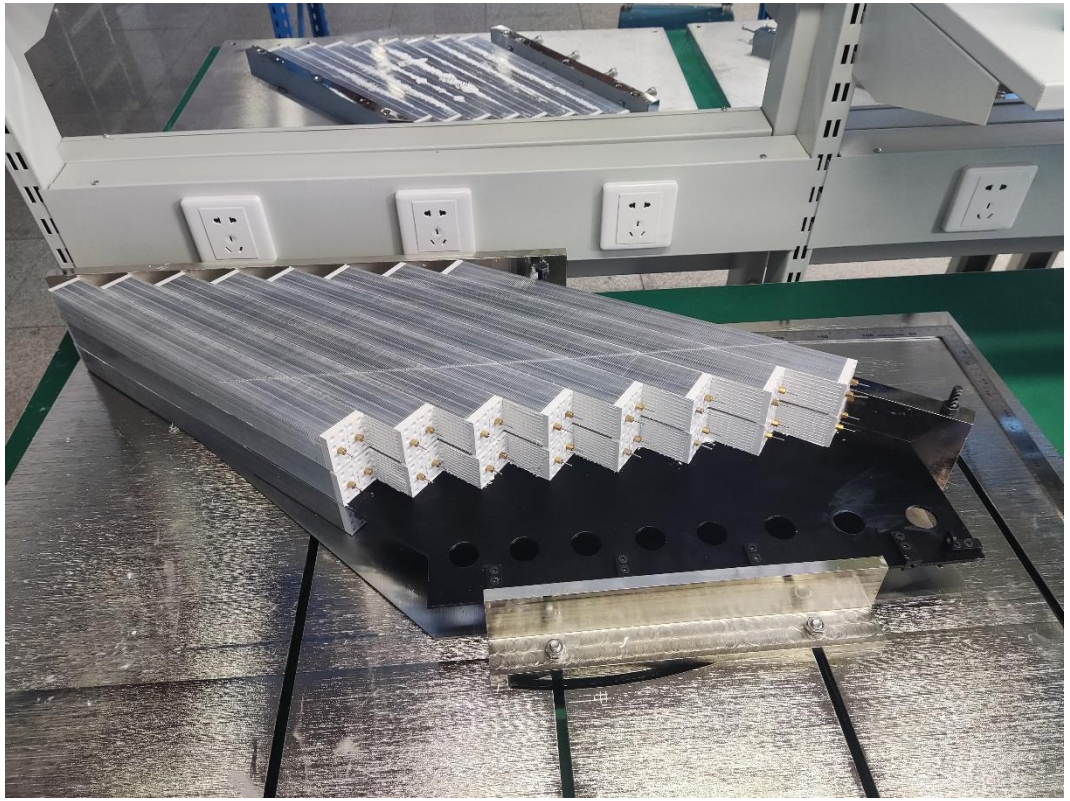
Serial number	MHeight-1 / mm	MHeight-2 / mm	MLength-1 / mm	MWidth-1 / mm	MWidth-2 / mm	Assembly date	Details
Module01:M0101001	462.1	452	270	66.3	80.6	2021-03-05	Test Result.zip
Tower01	Tower02	Tower03	Tower04	Tower05	Tower06	Tower07	Tower08
Tower09	Tower10	Tower11	Tower12	Tower13	Tower14	Tower15	Tower16

Serial number	MHeight-1 / mm	MHeight-2 / mm	MLength-1 / mm	MWidth-1 / mm	MWidth-2 / mm	Assembly date	Details
Module02:M0101002	X	X	X	X	X	2021-0X-0X	Test Result.zip
Tower01	Tower02	Tower03	Tower04	Tower05	Tower06	Tower07	Tower08
Tower09	Tower10	Tower11	Tower12	Tower13	Tower14	Tower15	Tower16

Serial number	MHeight-1 / mm	MHeight-2 / mm	MLength-1 / mm	MWidth-1 / mm	MWidth-2 / mm	Assembly date	Details

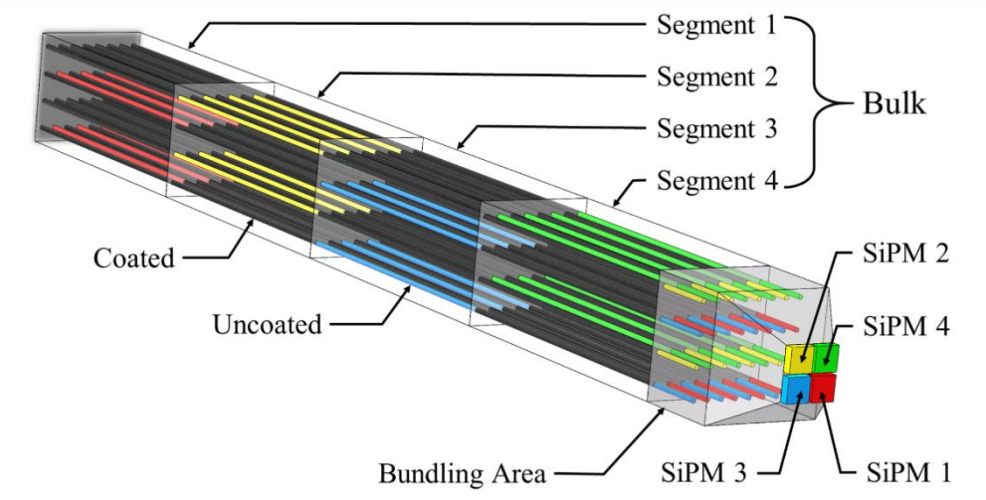
Cosmic test results: wave form, spectrum, energy,…

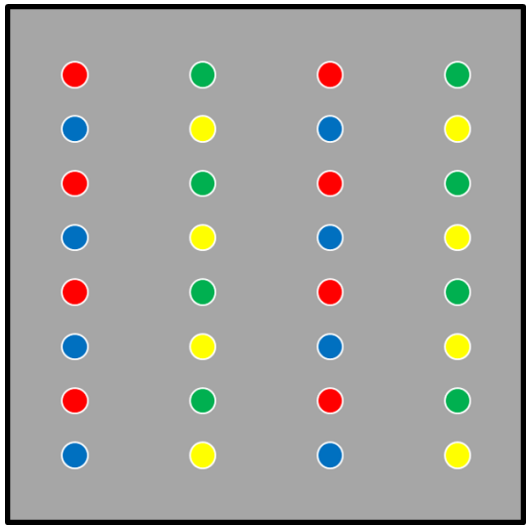
4 Production schedule

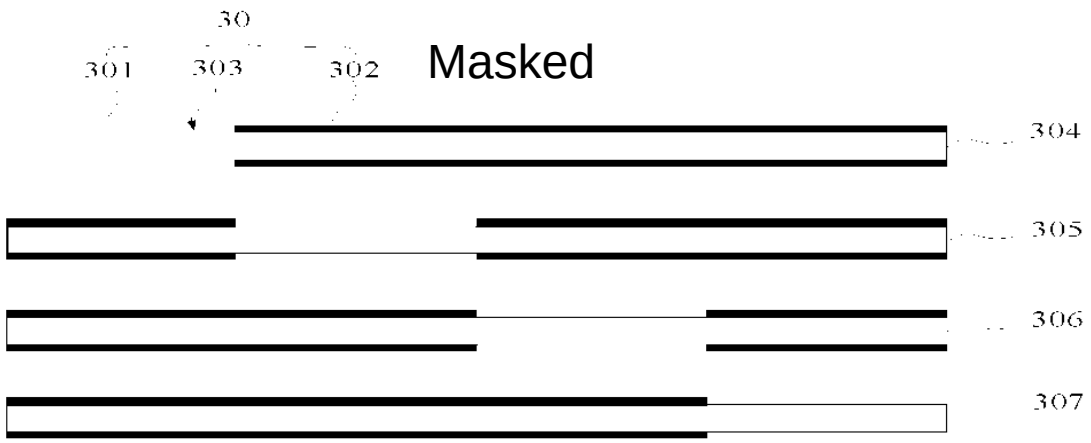


- ✓ 100 modules were produced until now.
- ✓ Around 600 modules will be ready in this year
- ✓ 768 modules will be ready before June of 2022

4 Conceptional design of 5-D shashlyk ECAL

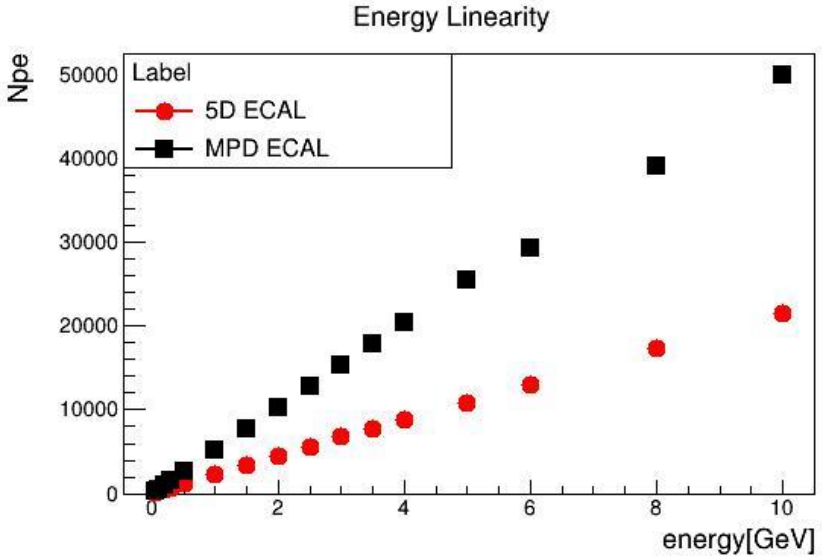


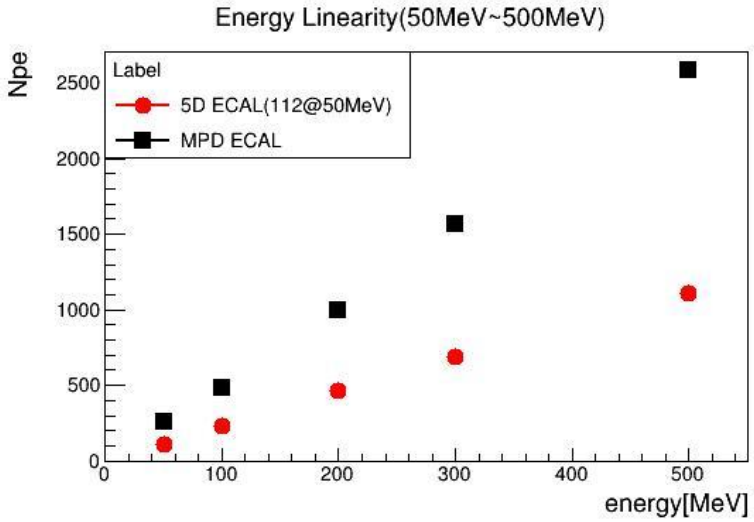


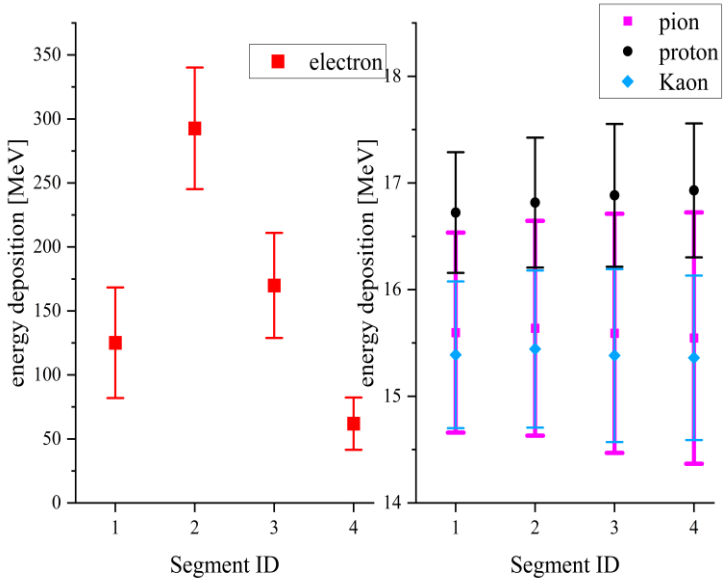


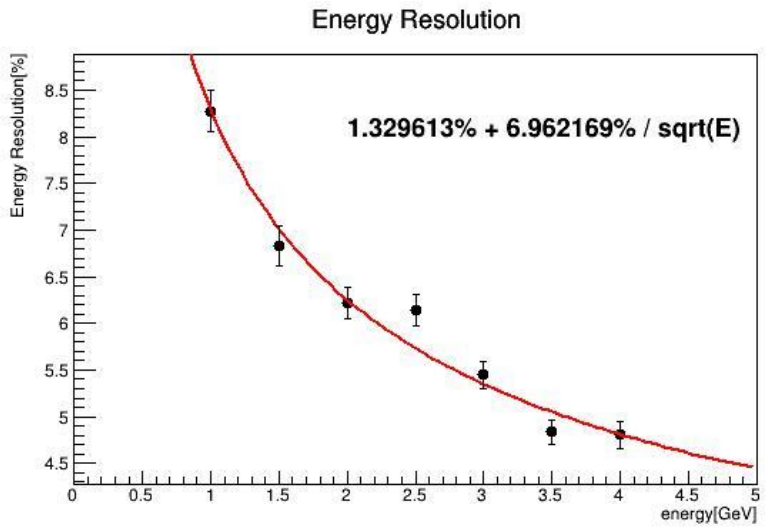
- 220 layer is separated into 4 parts, each part consists of 55 layers
- Readout with 32 WLSFs, each part is readout with 8 WLSFs+SiPM
- Mask technology of WLSF
- 5D: x,y,z, energy (5%), time (~50ps)

4 Performance of 5-D shashlyk ECAL









Good PID by energy thickness distribution

Compared with MPD/ECAL：

- Readout channel: 4 times
- Npe: ~60%
- Energy resolution: comparable
- +depth distribution of energy deposition
- good direction reconstruction (cluster)
- + 50ps time, good PID

Contents

Summary

- ✓ Chinese group has setup the whole production line of MPD-ECal.
- ✓ 100 Modules have been produced and 10 has been shipped to JINR.
- ✓ Review for production readiness will be done soon.
- ✓ **768 modules will be ready by 2022.6**
- ✓ **5D Shashlyk Ecal has good energy resolution, time resolution and depth distribution of energy deposition. So it has perfect PID capability!**

Thanks for your attention