北京大學

MTD BTL test beam studies

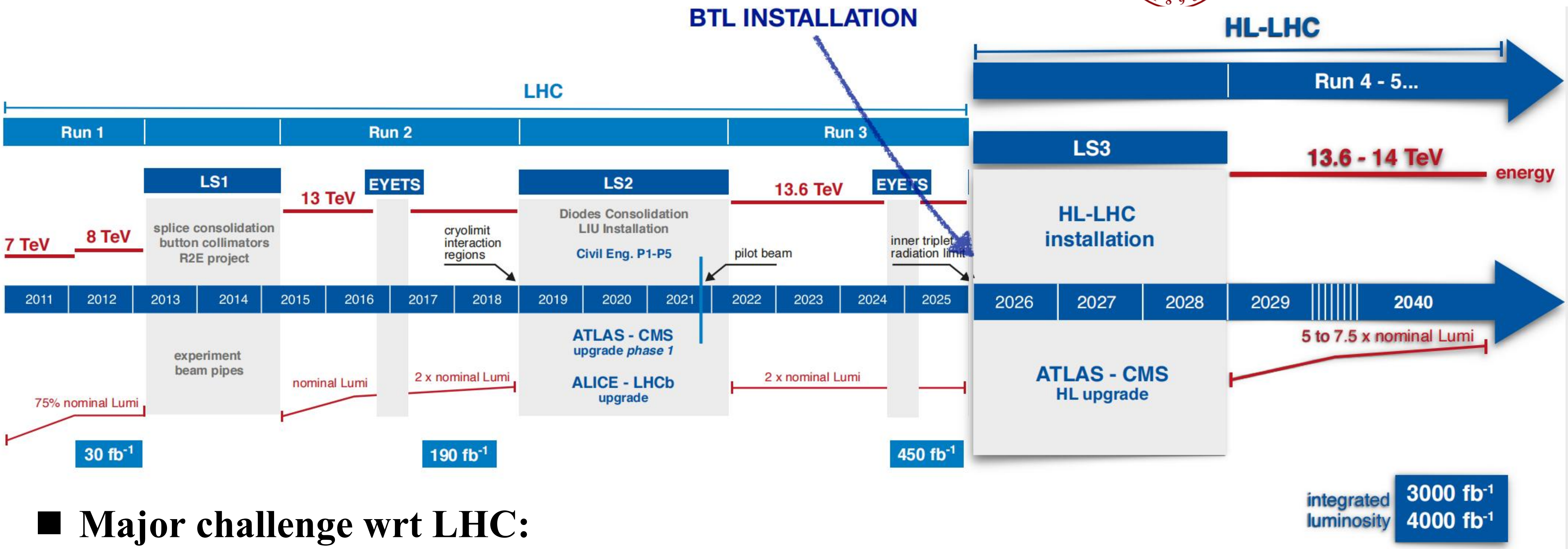
Martina Malberti, Andrea Benaglia, Mingtao Zhang, Xiaohu Sun, Yajun Mao

Peking University, INFN Sez. Milano Bicocca

Nov 25,2022

Content

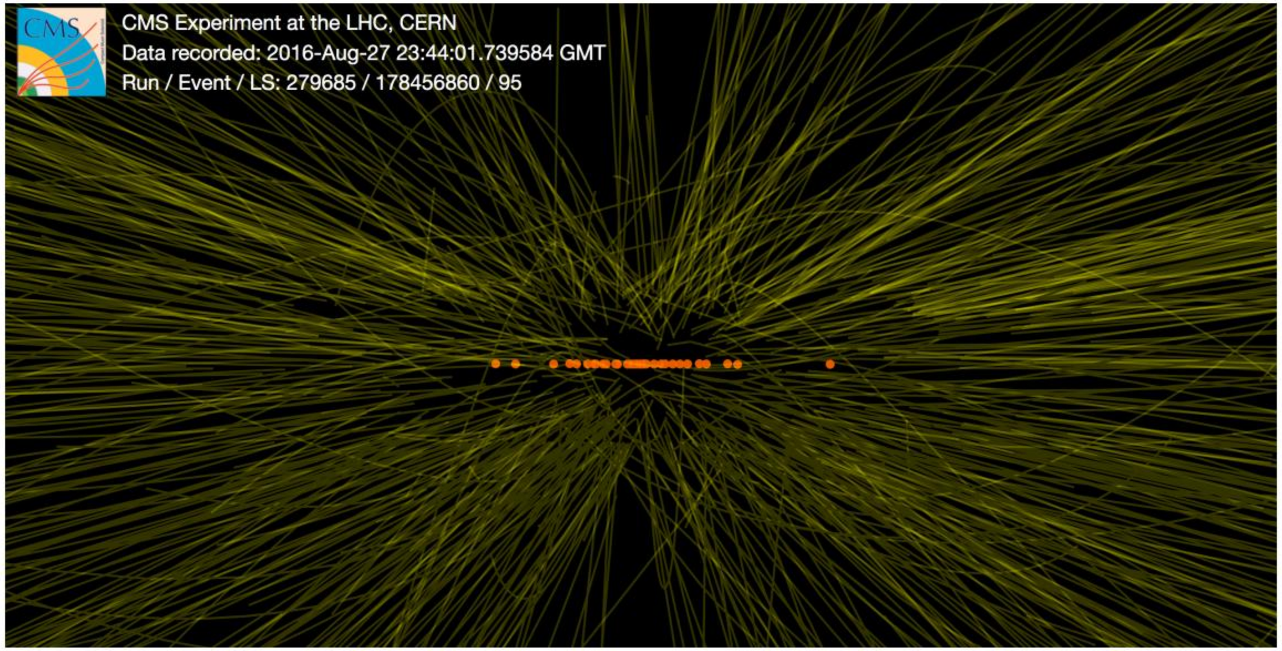
Towards HL-LHC



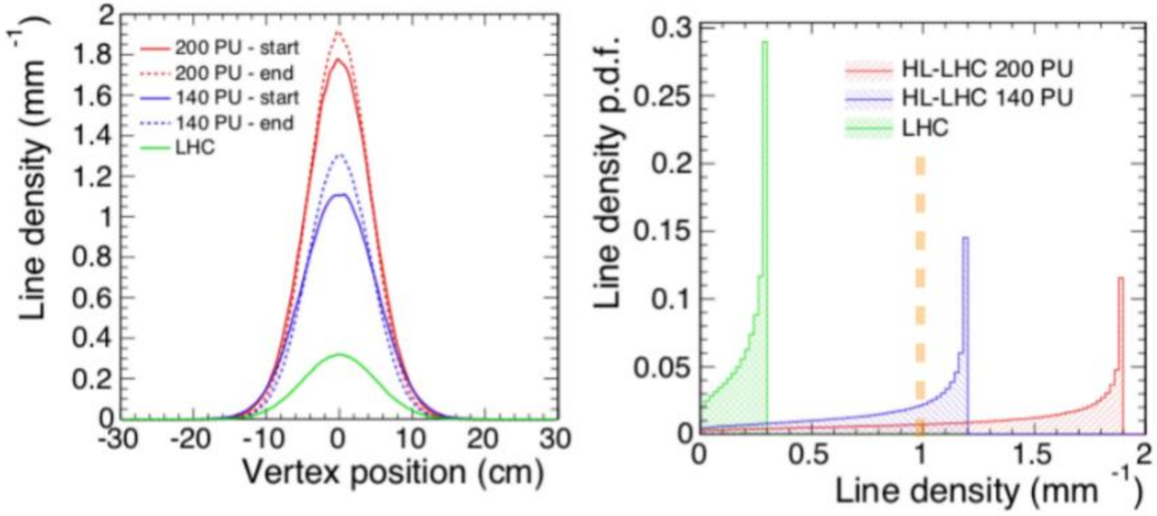
■ **Major challenge wrt LHC:**

- ×3~4 instantaneous luminosity → up to ×5 pileup interactions
- ×10 integrated luminosity → radiation damage of detector components

Pileup Impact @HL-LHC



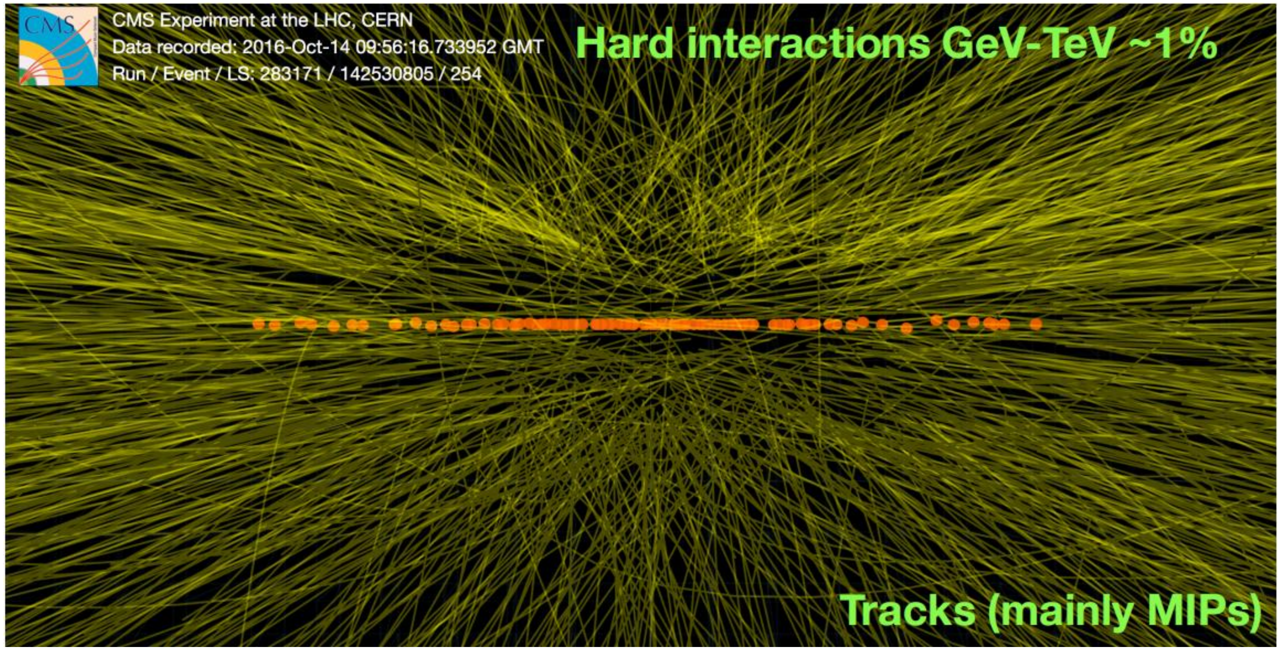
RUN II: 40-60 interactions per bunch crossing



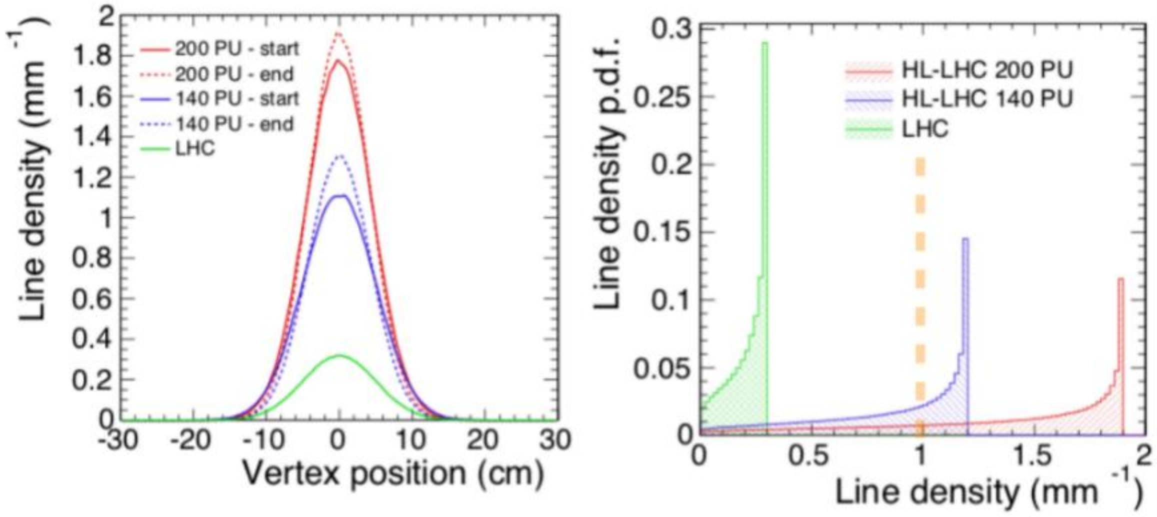
In CMS, PU mitigation relying on the high granularity of the tracking subdetectors and dedicated algorithms combining their information. Due to growing spatial overlap of tracks and energy deposits, in the transition from 140 to 200 pileup events (**Line density > 1mm^{-1}**) reduced efficiency of tracks-vertex association.

- **Misidentification, degradation of reconstruction efficiency and energy resolution**

Pileup Impact @HL—LHC



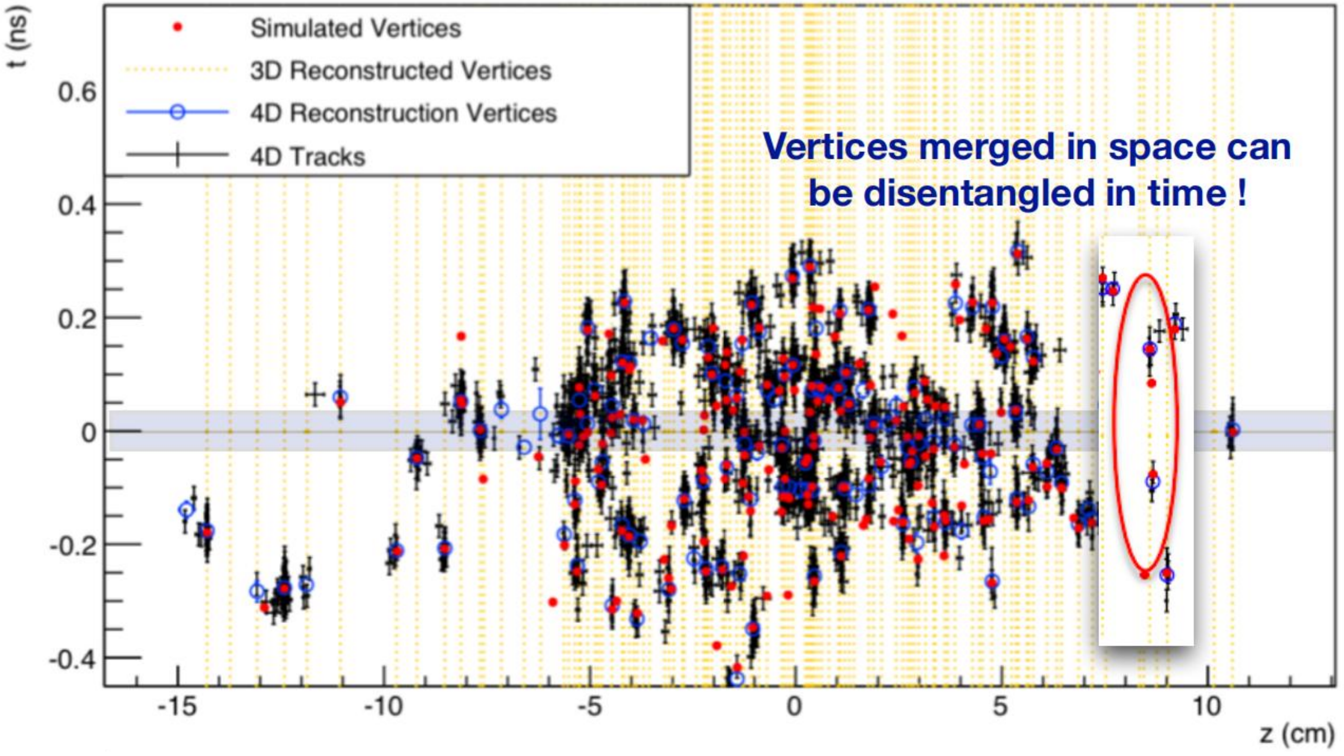
HL-LHC: 140-200 interactions per bunch crossing



In CMS, PU mitigation relying on the high granularity of the tracking subdetectors and dedicated algorithms combining their information. Due to growing spatial overlap of tracks and energy deposits, in the transition from 140 to 200 pileup events (**Line density > 1mm^{-1}**) reduced efficiency of tracks-vertex association.

- **Misidentification, degradation of reconstruction efficiency and energy resolution**

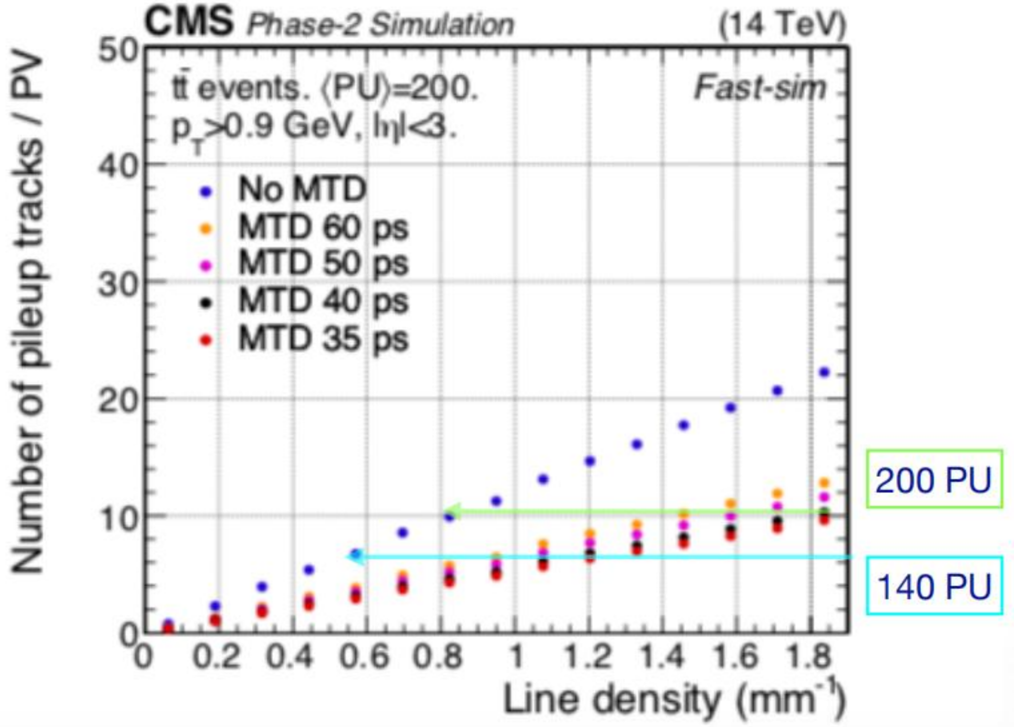
CMS strategy for PU mitigation



- Exploiting the interaction vertices distribution along the beam (4.5cm RMS) corresponding to 180-200ps RMS in the time domain

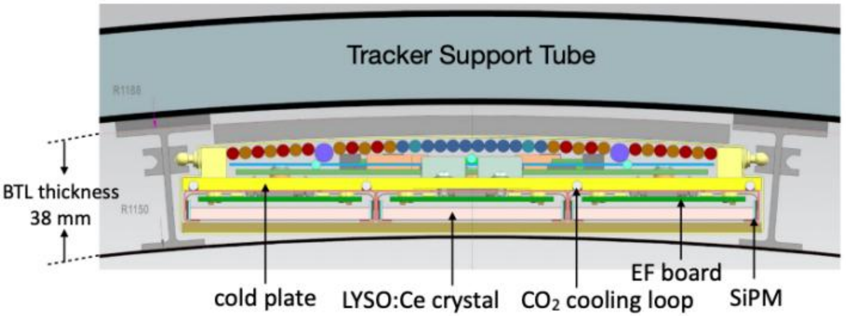
Time tagging charged particles (Mips) with time resolution ~ **30-40ps** corresponding to slicing the beam spot in consecutive time exposures of the same duration

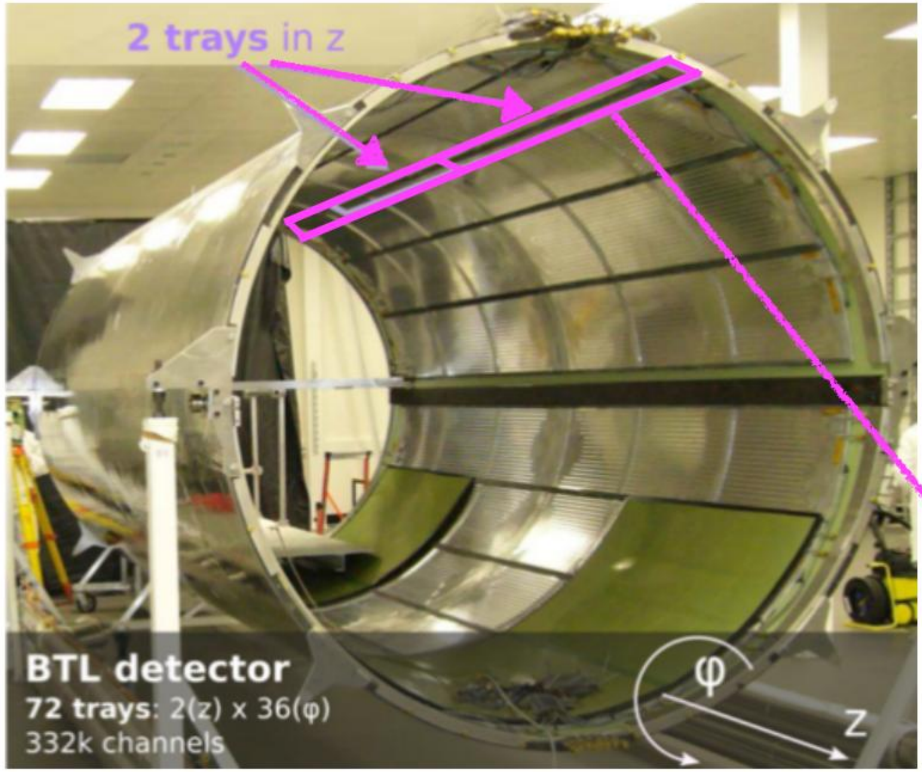
- Restoring PU levels close to RUN 2 scenario with 40-60 collisions/frame

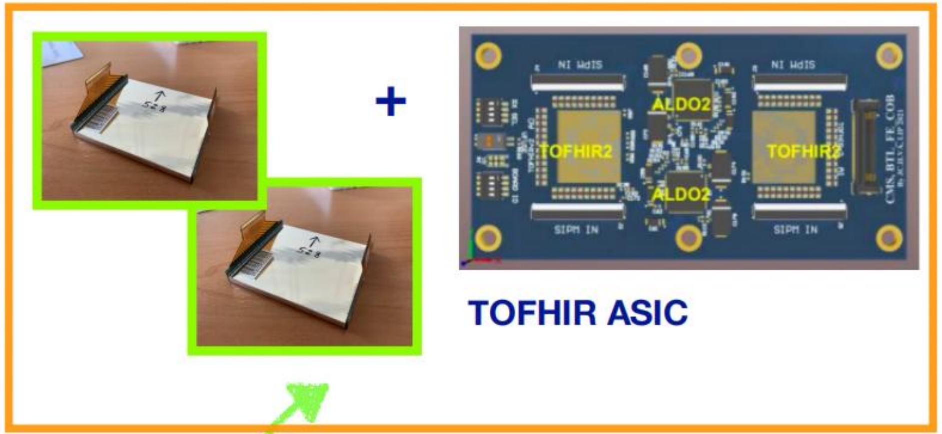


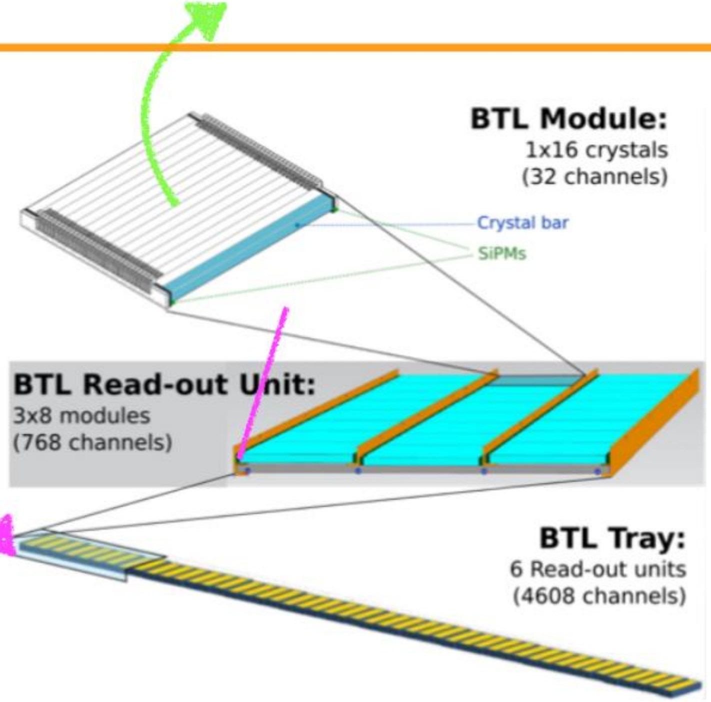
MTD —— MIP Timing Detector

北京大学



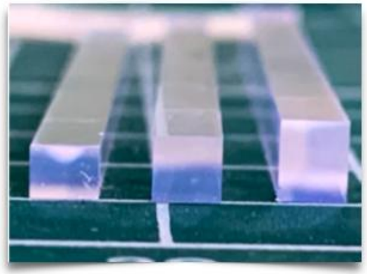






BTL: LYSO bars + SiPM readout:

- TK / ECAL interface: $|\eta| < 1.45$
- Inner radius: 1148 mm (40 mm thick)
- Length: ±2.6 m along z
- Surface ~38 m^2; 332k channels
- Fluence at 4 ab^{-1}: $2 \times 10^{14}\ n_{eq}/cm^2$



Type	t (mm)	|Eta|
1	3.75	0-0.7
2	3	0.7 - 1.1
3	2.4	1.1 - 1.5
L=56.2 mm, w=3.12 mm		

BTL sensors：LYSO（Ce）crystals & SiPMs

北京大學

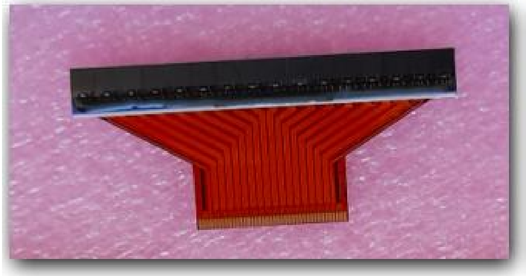
LYSO: Ce crystals

- Well established technology (PET)
- Fast scintillation kinetics:
  - rise time ~100ps
  - decay time ~40ns
- Radiation hard proven up to:
  - 50kGy with photon from ^{60}Co source
  - 3×10^{14} 1MeV neq/cm
- High Light Yeild: 40000 photons/MeV

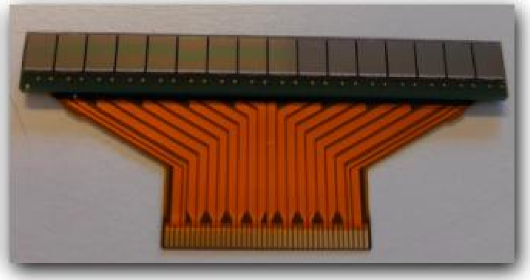
SiPMs

- Well established technology
- Compact and robust
- Insensitive to magnetic fields
- Fast recovery time < 10ns
- High dynamic range (10^5)
- PDE@Lyso emission peak 20% ~ 40%
- Radiation hard proven up to: 2×10^{14} 1MeV neq/cm

FBK, 20 μm thin glass enc

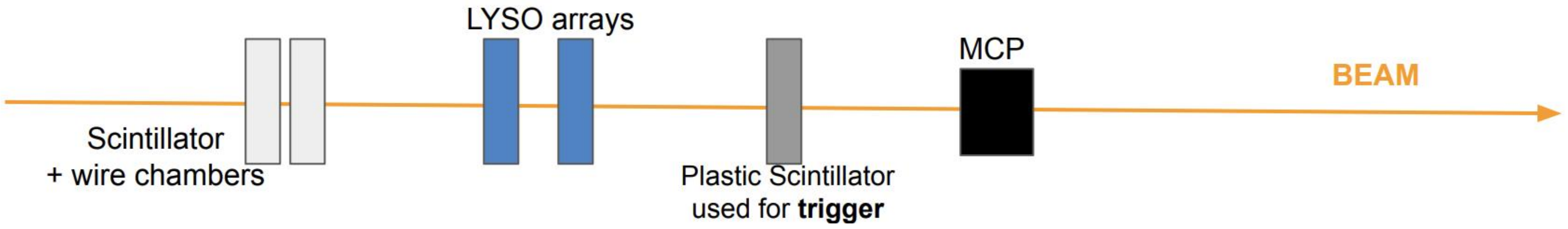


HPK, 300 μm silicon resin enc.



Goals of the test beam

- Measurement of LYSO arrays, irradiated and non-irradiated SiPMs using TOFHIR2B
- Configuration:
  - LYSO arrays + SiPMs & TECs
  - TOFHIR2B
- Test irradiated SiPMs (HPK) with TECs:
  - 0, 1e14, 2e14 irradiated fluence
- Temperature: +10℃, -33℃
- Beam:
  - Pions wide beam(~70% pions, ~15% protons, ~5% electrons and ~10% others)
  - pT = 180GeV, rate ~ 10^6 per spill



- Set up in CERN

Test beam analysis

北京大學

■ TOFHIR2B energy linearization and relative LO comparisons

- Energy linearization:

Plot the "expected energy" vs. the measured MIP Landau MPV in ADC, as measured by the TOFHIR2B at +10℃, -33℃ temperature

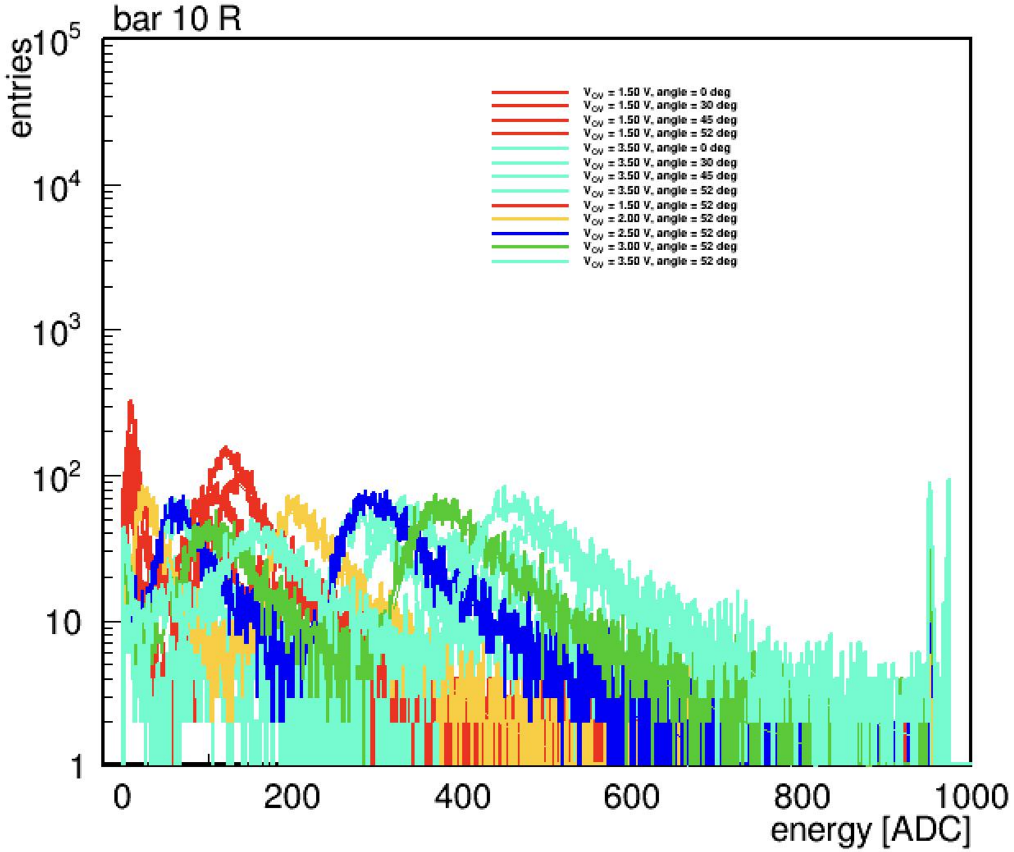
- Reconstructed energy for relative LO comparisons results for irradiated modules at the Jun22 TB:

The ratio of "linearized energy" for irradiated modules (1E14 and 2E14) and HPK 528 (non irr), chosen as reference

Energy linearization

- Plot the “expected energy” vs. the measured MIP Landau MPV in ADC, as measured by the TOFHIR2B

- two sets of comparisons:
  - vary E_{dep} → different angles (0, 30, 45, 52deg)
    - at Vov = 1.5V
    - at Vov = 3.5V
  - vary G × PDE → different Vov (1.5, 2.0, 2.5, 3.0, 3.5V)
    - at angle = 52deg

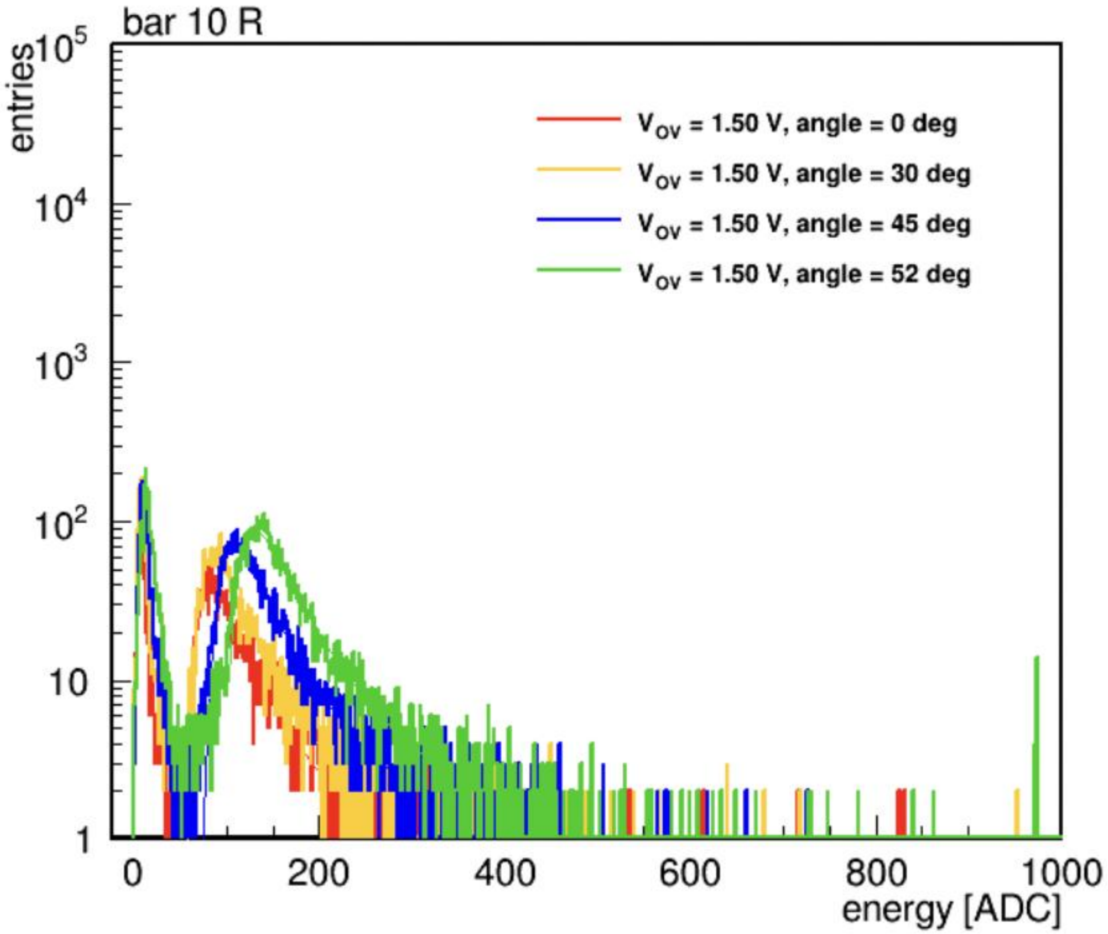


Energy linearization

vary E_{dep} → different angles = (0, 30, 45, 52deg)

- at Vov = 1.5V, T = 10℃

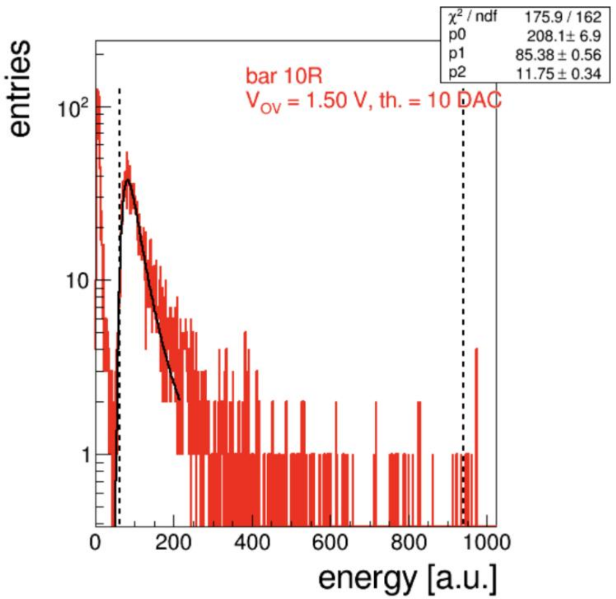
CONF13.00	Vov/V	angle/deg
Run5280	1.5	0
Run5278	1.5	30
Run5277	1.5	45
Run5273	1.5	52

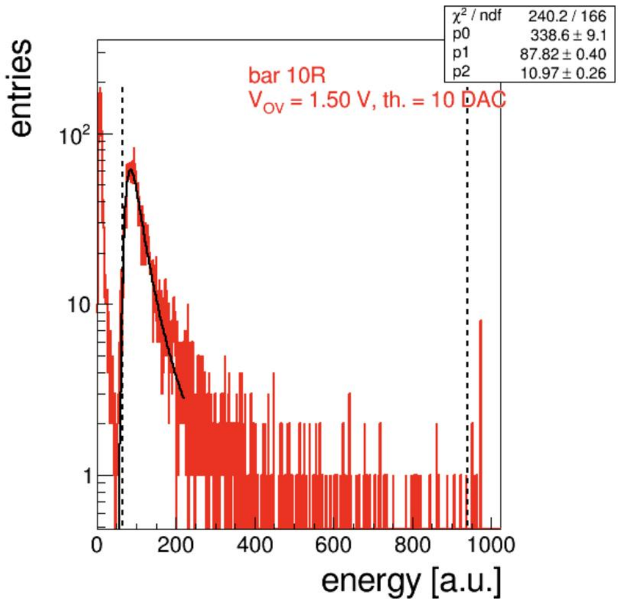


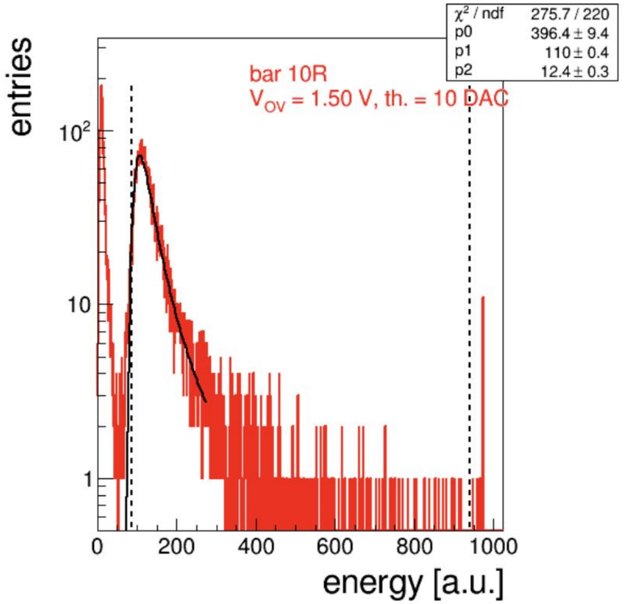
Vov=1.5V, angle=0, 30, 45, 52deg

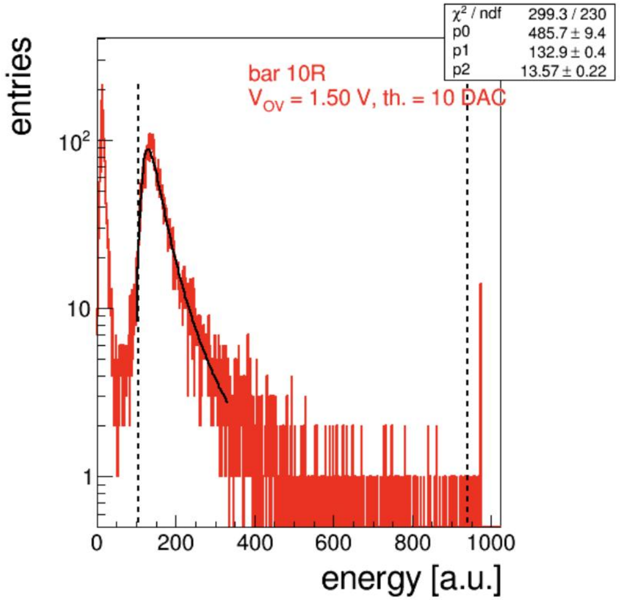
北京大學

- Use landau function to fit the energy deposition measured by TOFHIR2B









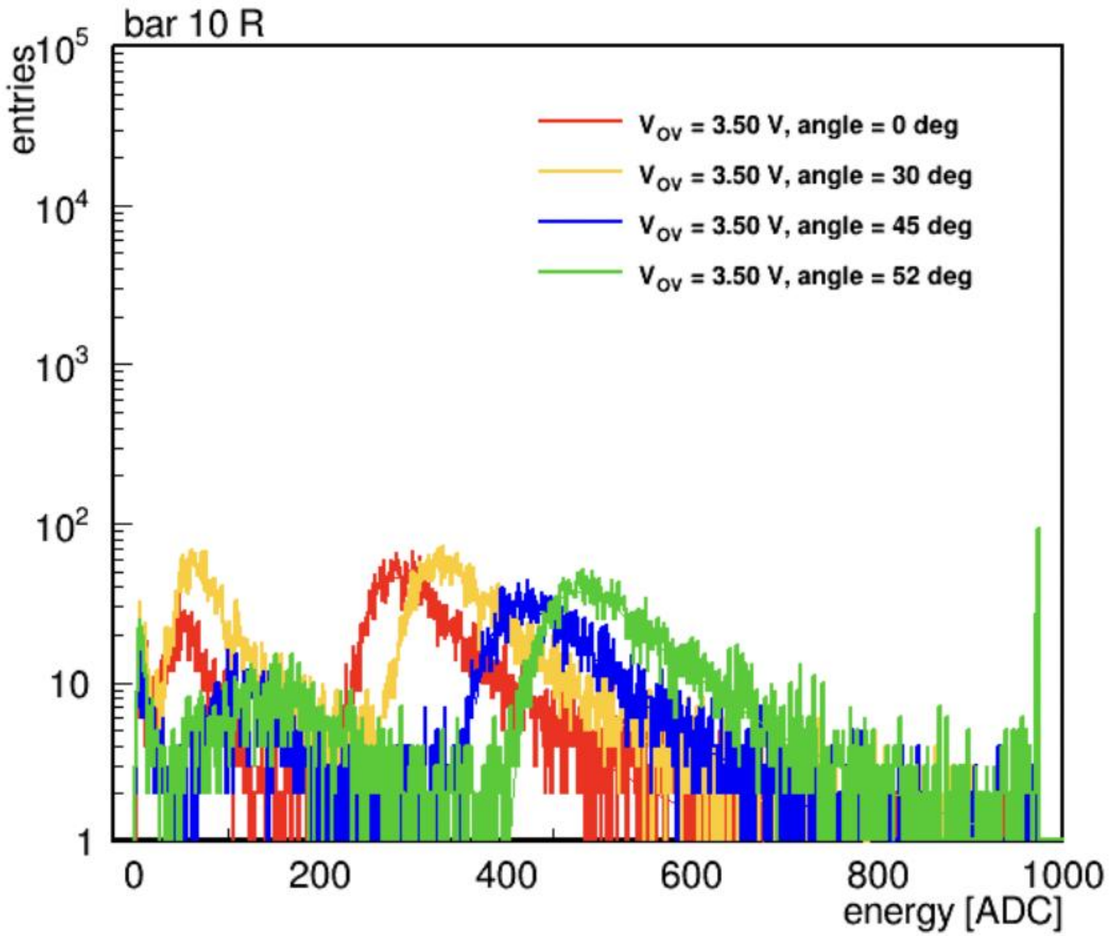
Energy linearization

北京大學

vary E_{dep} → different angles = (0, 30, 45, 52deg)

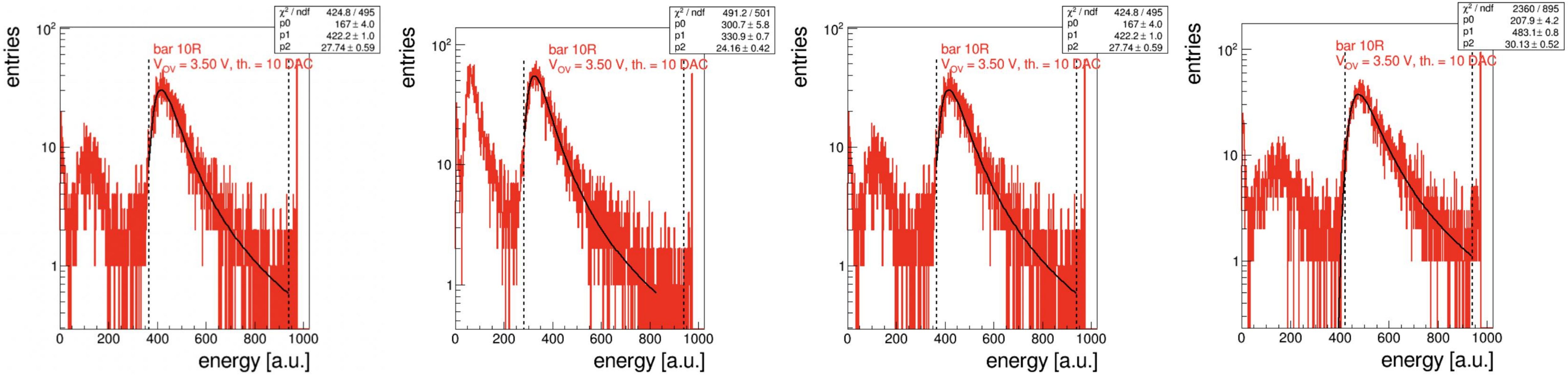
- at Vov = 3.5V, T = 10℃

CONF13.00	Vov/V	angle/deg
Run5281	3.5	0
Run5279	3.5	30
Run5276	3.5	45
Run5271	3.5	52



Vov=3.5V，angle=0，30，45，52deg

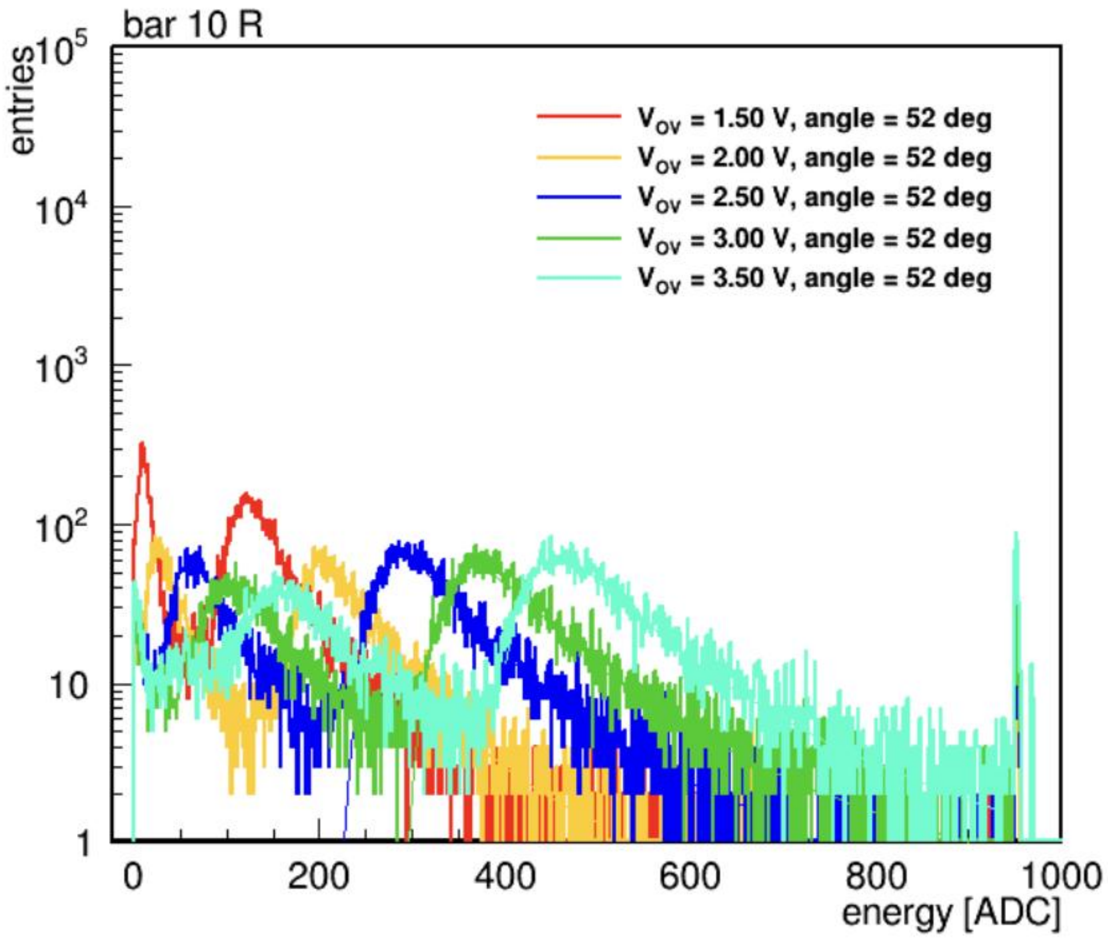
- Use landau function to fit the energy deposition measured by TOFHIR2B



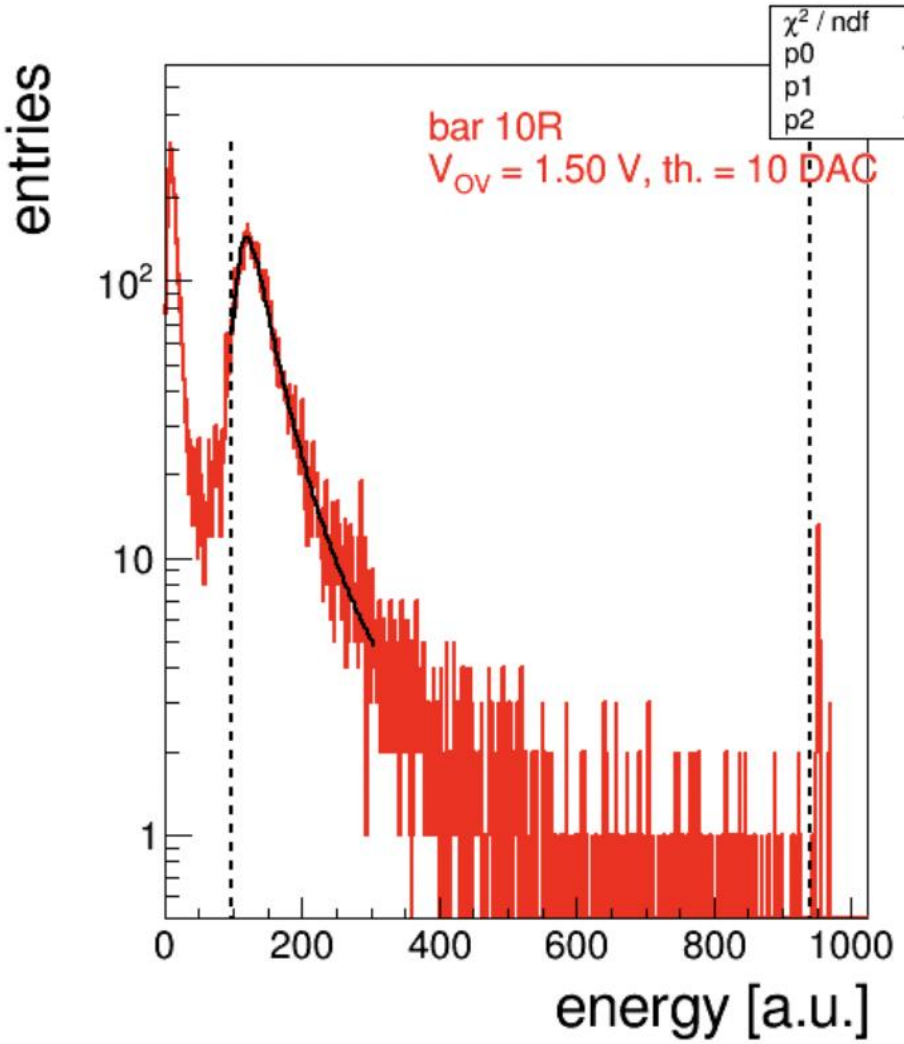
Energy linearization

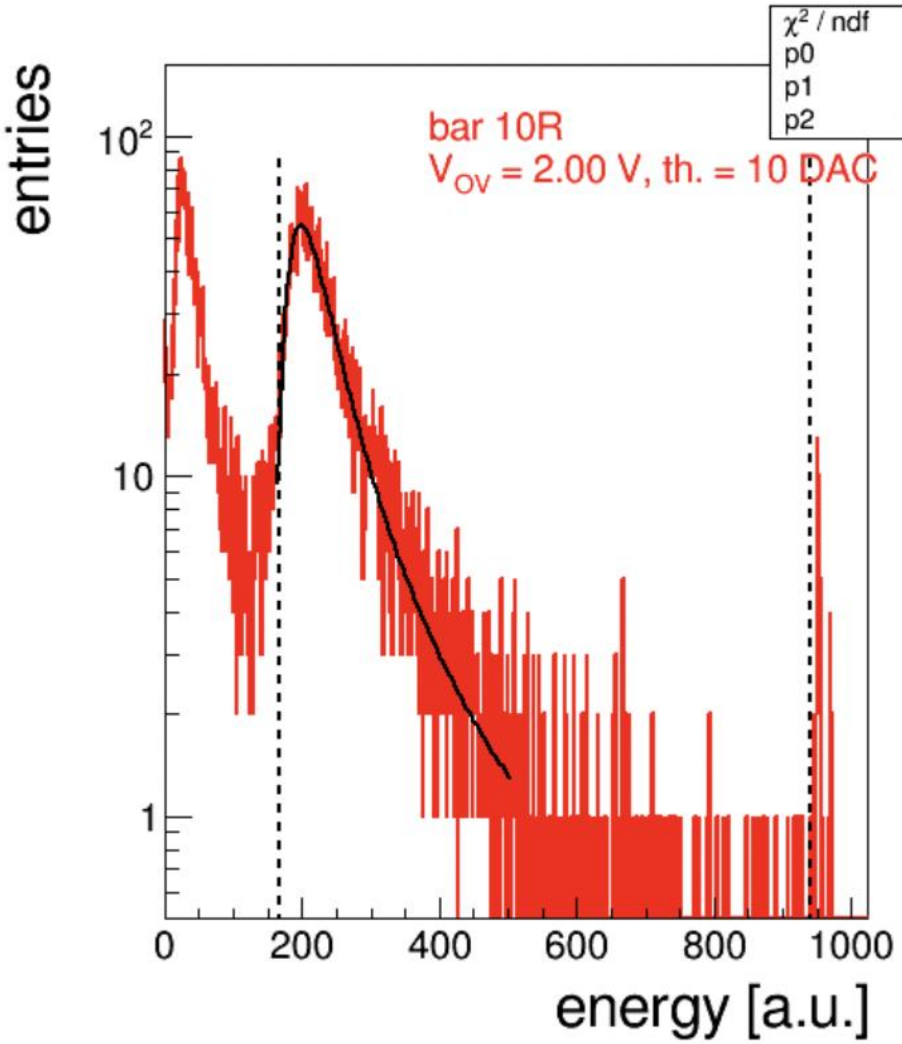
- vary G × PDE → different Vov between 1.5V and 3.5V
  - at angle = 52deg, T = -33℃

CONF13.01	Vov/V	angle/deg
Run5281	1.5	52
Run5279	2.0	52
Run5276	2.5	52
Run5271	3.0	52
Run5293	3.5	52



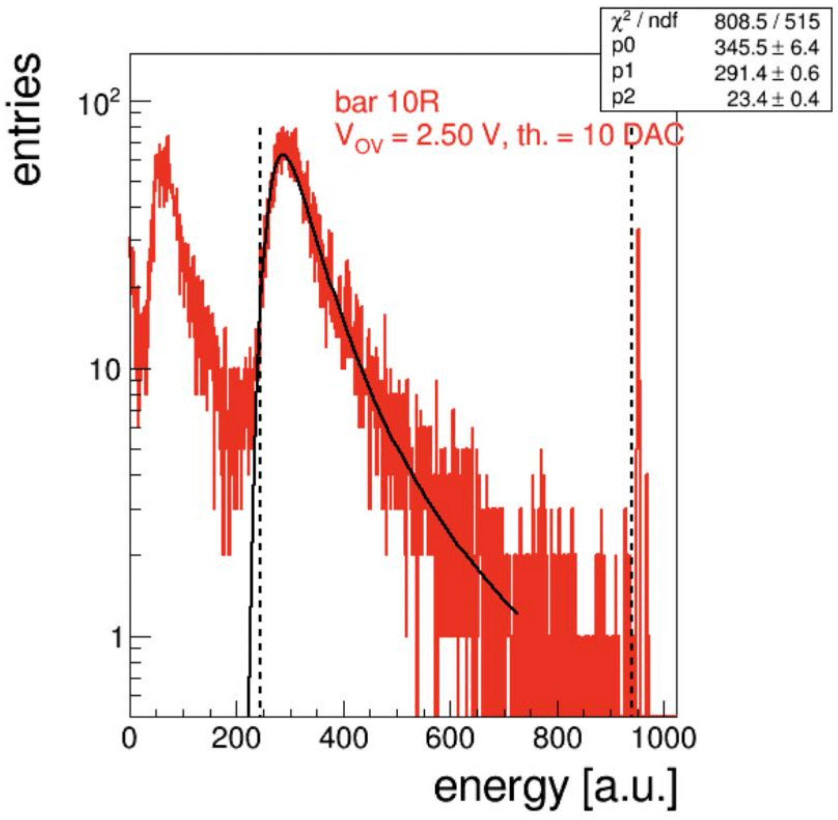
Angle=52deg，Vov=1.5，2V

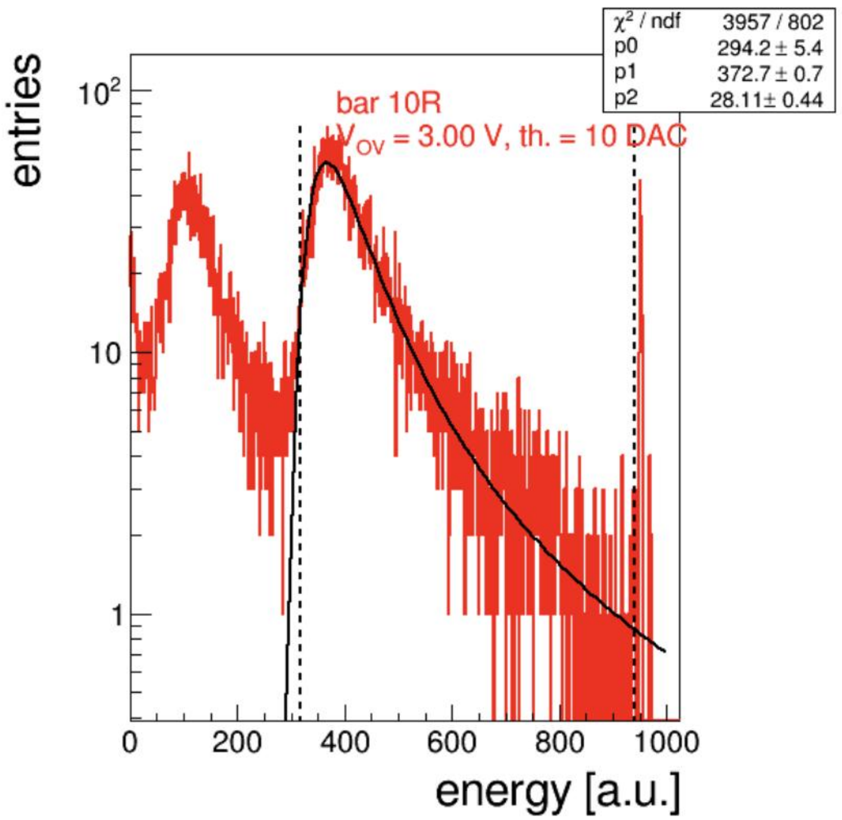


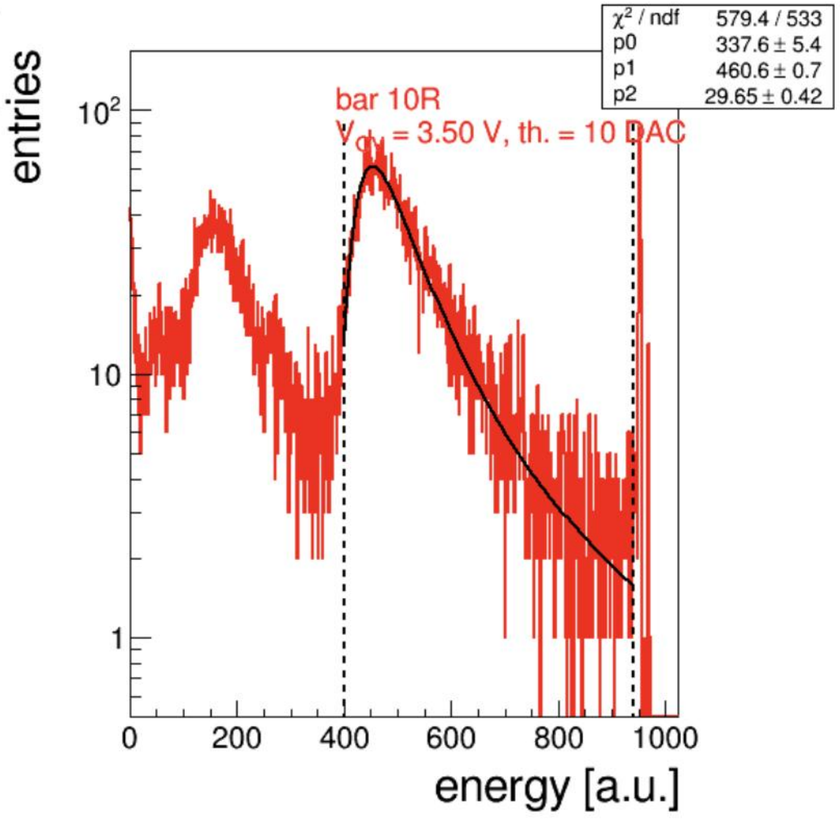


Angle=52deg, Vov=2.5, 3V, 3.5V

北京大學







北京大学

■ Plot the "expected energy" vs. the measured MIP Landau MPV in ADC, as measured by the TOFHIR2B

- energy [ADC] (x-axis):
  MIP peak obtained by Landau fitting

- "expected energy" (y-axis):
  E_{dep} [MeV] $\times$ G $\times$ PDE $\times$ ECF $\times$ $k_{saturation}$ / Norm

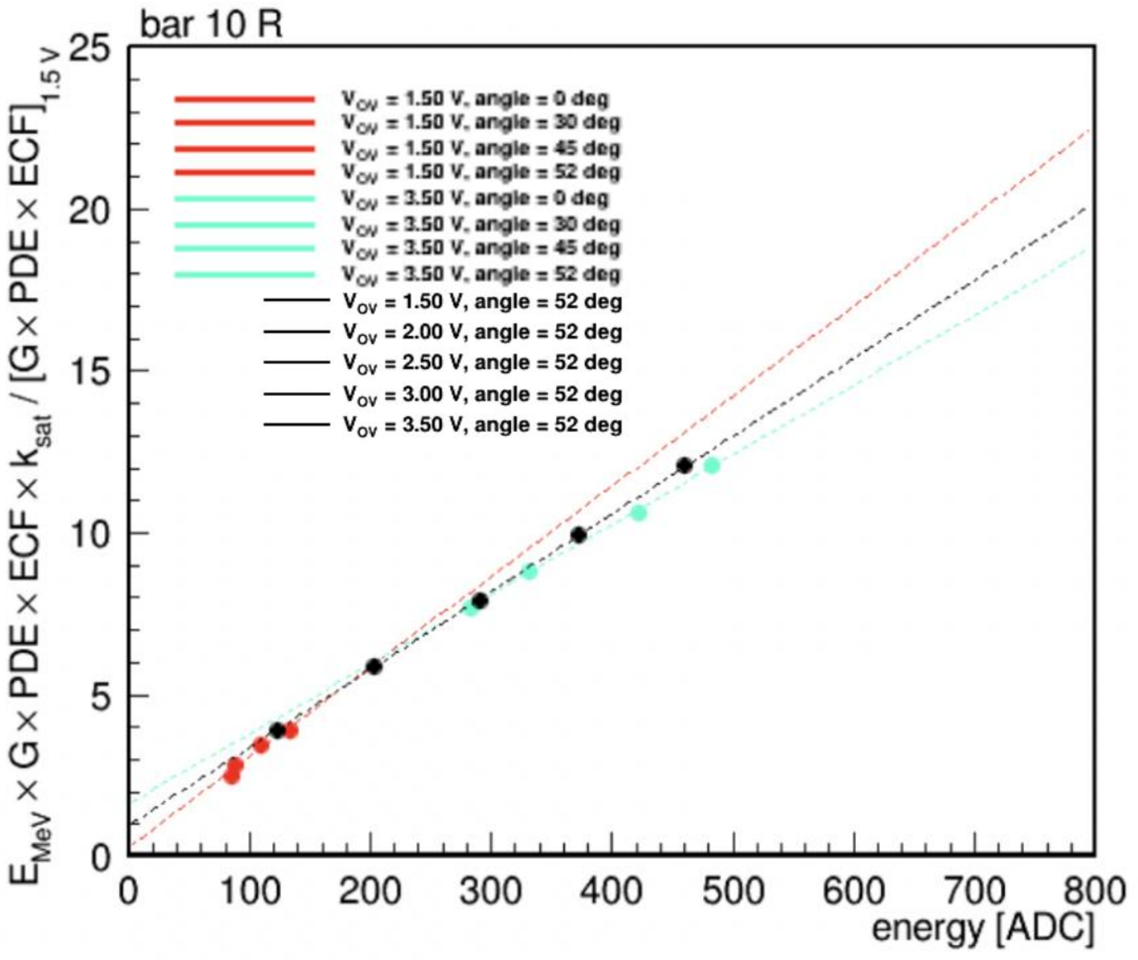
E_{dep} = 0.86 MeV/mm * 3 mm / cos(angle)

G = sipm Gain

PDE = photon detection efficiency

ECF = excess charge factor

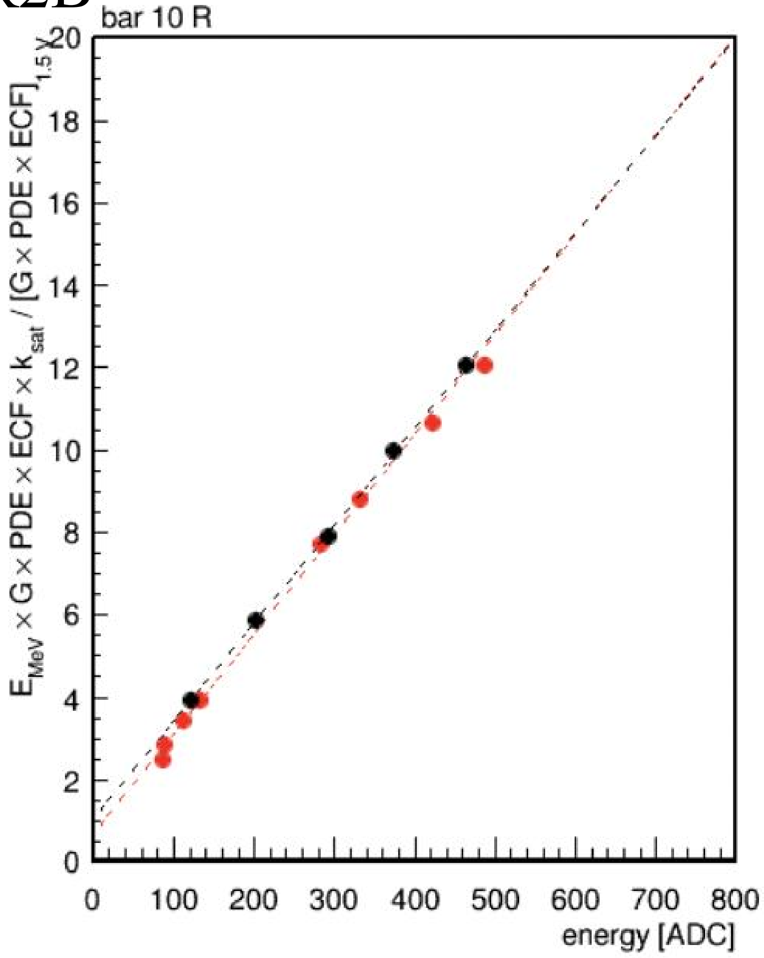
$k_{saturation} = N_{pixels} \times [1 - \exp(-N_{pe} / N_{pixels})] / N_{pe}$ (with Npixels = 40000)

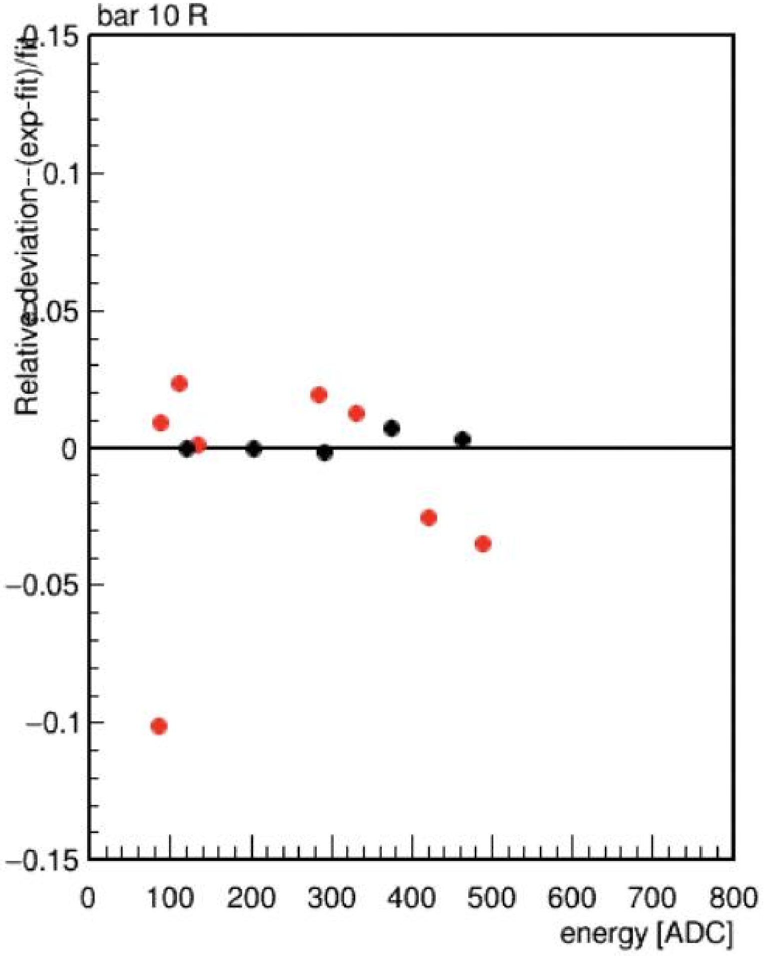


Relative deviation

- Plot the "expected energy" vs. the measured MIP Landau MPV in ADC, as measured by the TOFHIR2B

- The data points at the same temperature are fitted into the same line
  - Red point: T=10℃, Vov=(1.5, 3.5)V, angle=(0, 30, 45, 52)deg
  - Black point: T=-33℃, Vov=(1.5, 2.0, 2.5, 3.0, 3.5)V, angle=52deg
- Deviation < 5%



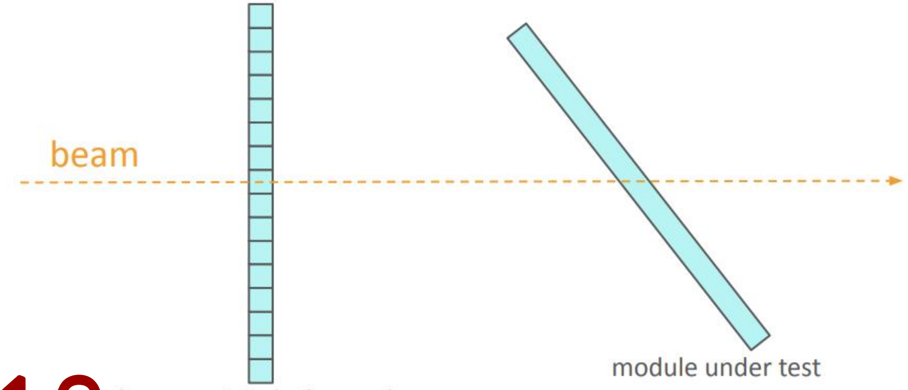


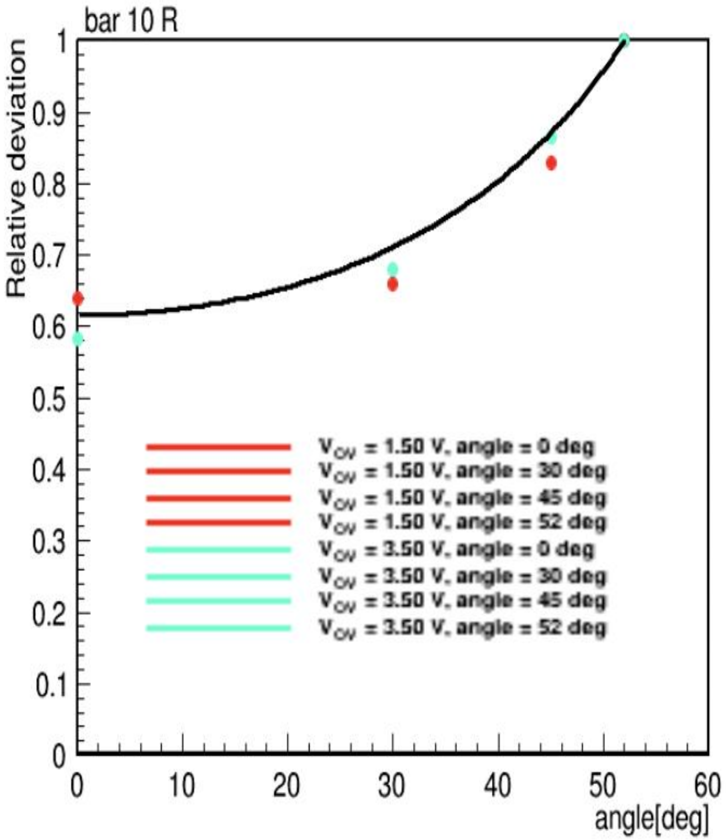
Relative deviation

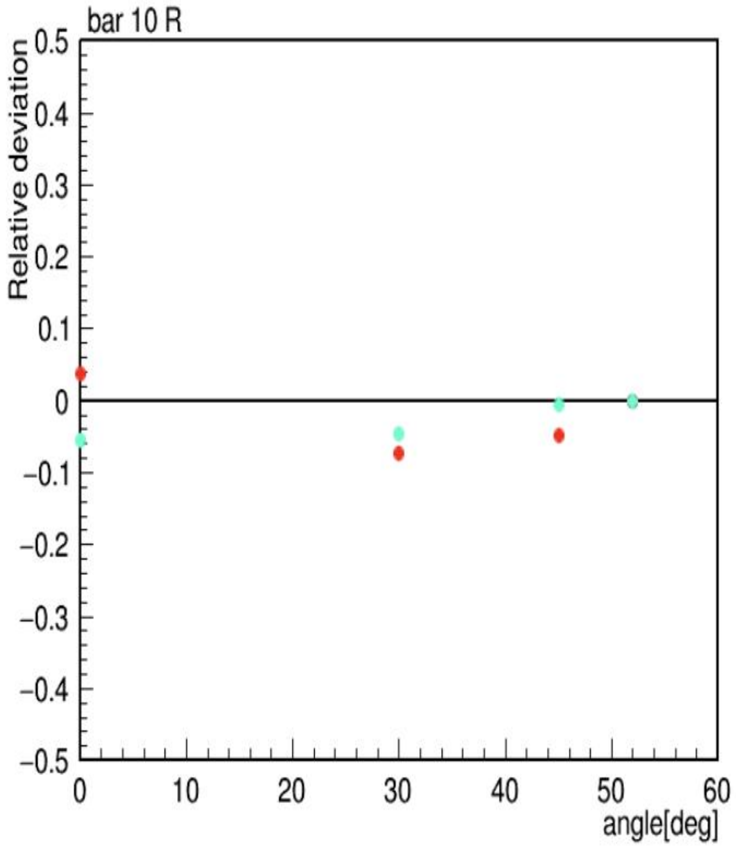
- Plot the “expected energy” vs. the measured MIP Landau MPV in ADC, as measured by the TOFHIR2B

- The ratio of the energy[ADC] at different angles to the energy at 52 degrees is expected to be cos(52deg)/cos(angle)

- Deviation ~ 10%







Irradiated module relative LO

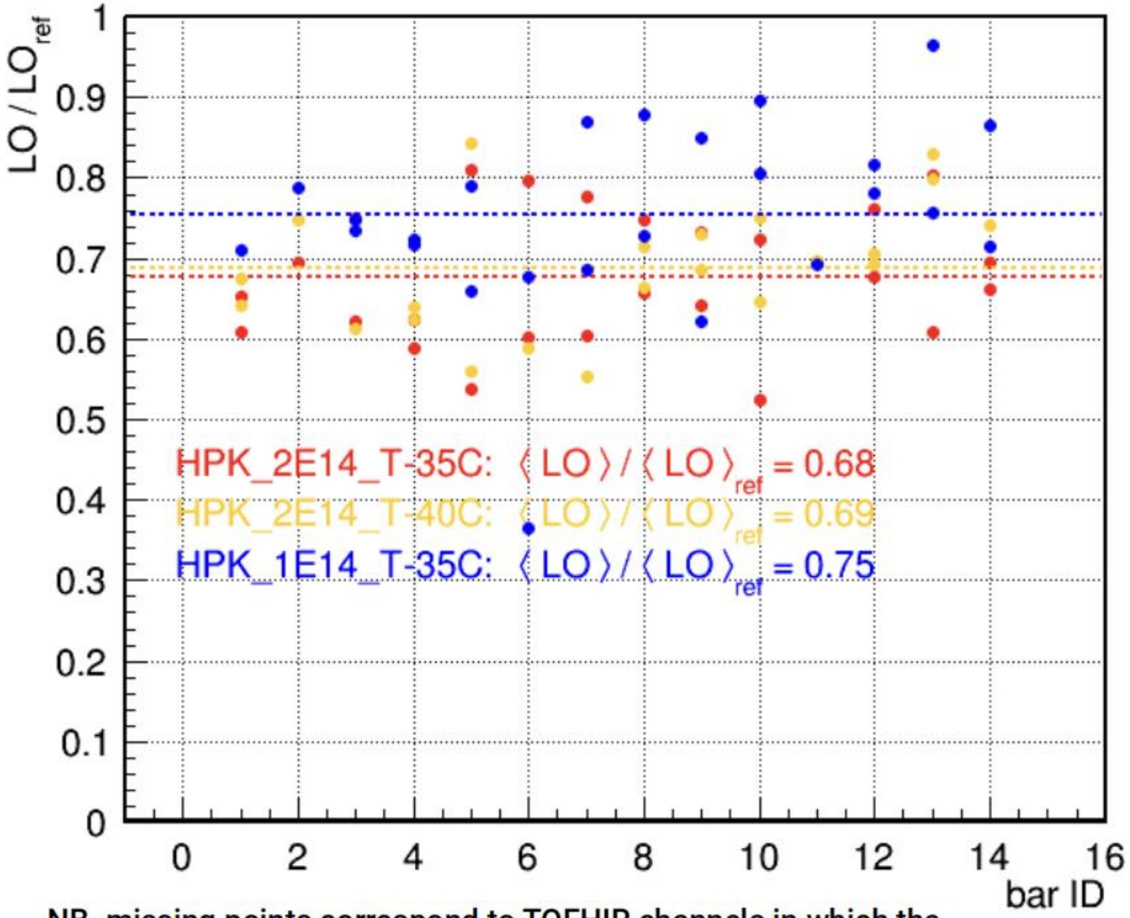
■ Here showing the ratio of "linearized energy" for irradiated modules and HPK 528 (non irr), chosen as reference

- $LO/LO_{ref} = PDE/PDE_{HPK\ non\ irr} \times G/G_{HPK\ non\ irr} \times (LY \cdot LCE)/(LY \cdot LCE)_{HPK\ nonirr}$

➢ LY: Light Yeild
➢ LCE: Light Collection Efficiency

HPK	irradiation	Temperature
CONF14.02	2E14	-35
CONF14.03	2E14	-40
CONF15.00	1E14	-35
Run5298(Ref)	0	-33

2E14_T-40C: except (3,6,7,11,14)L 2R
2E14_T-35C: except 11L 2R
1E14_T-35C: except (1,11)L 2R



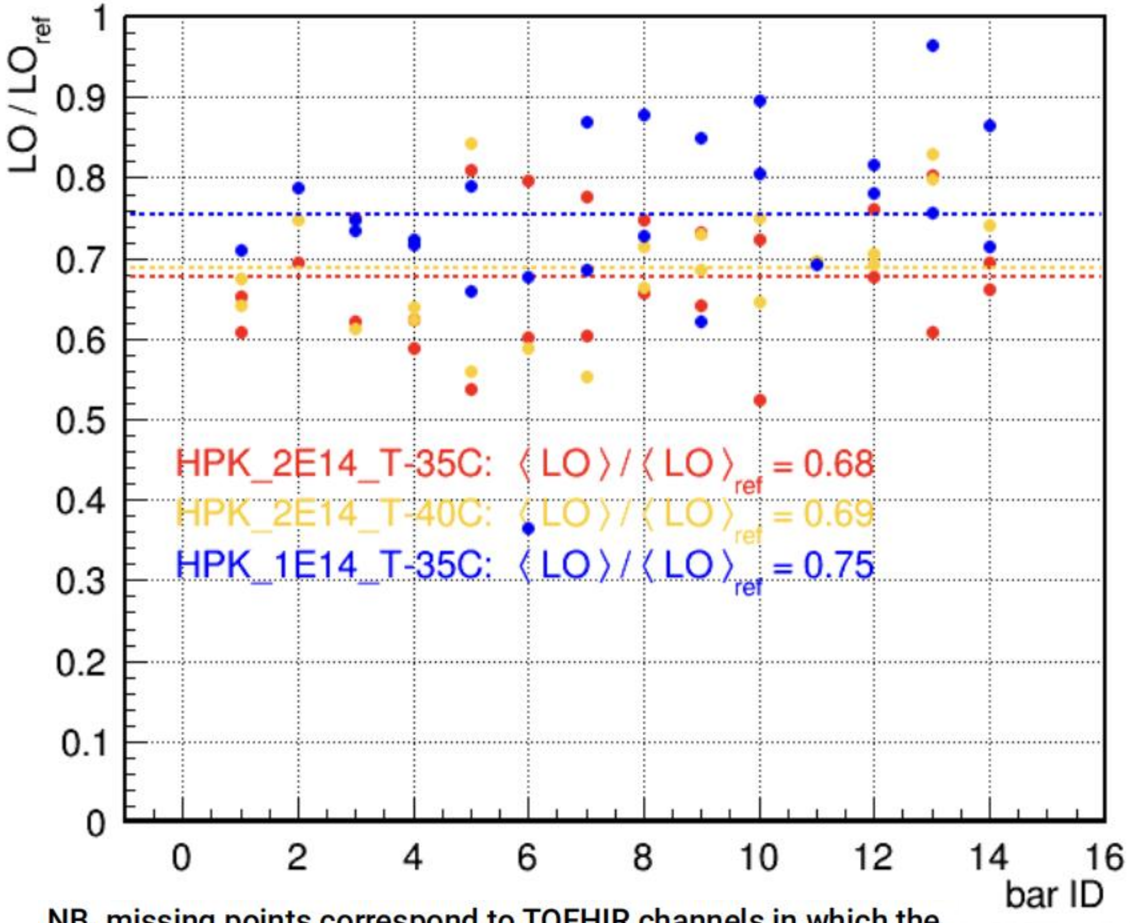
NB. missing points correspond to TOFHIR channels in which the MIP peak was not visible

Irradiated module relative LO

- Here showing the ratio of "linearized energy" for irradiated modules and HPK 528 (non irr), chosen as reference

- HPK2E14: Vov = (1.40, 1.60, 2.00)V
- HPK1E14: Vov = (1.40, 1.60, 1.80, 2.00)V
- HPK non-irr: Vov = 1.50V

HPK2E14_T-40C: except (3,6,7,11,14)L 2R
HPK2E14_T-35C: except 11L 2R
HPK1E14_T-35C: except (1,11)L 2R



NB. missing points correspond to TOFHIR channels in which the MIP peak was not visible

Irradiated module relative LO

■ Here showing the ratio of "linearized energy" for irradiated modules and HPK 528 (non irr), chosen as reference

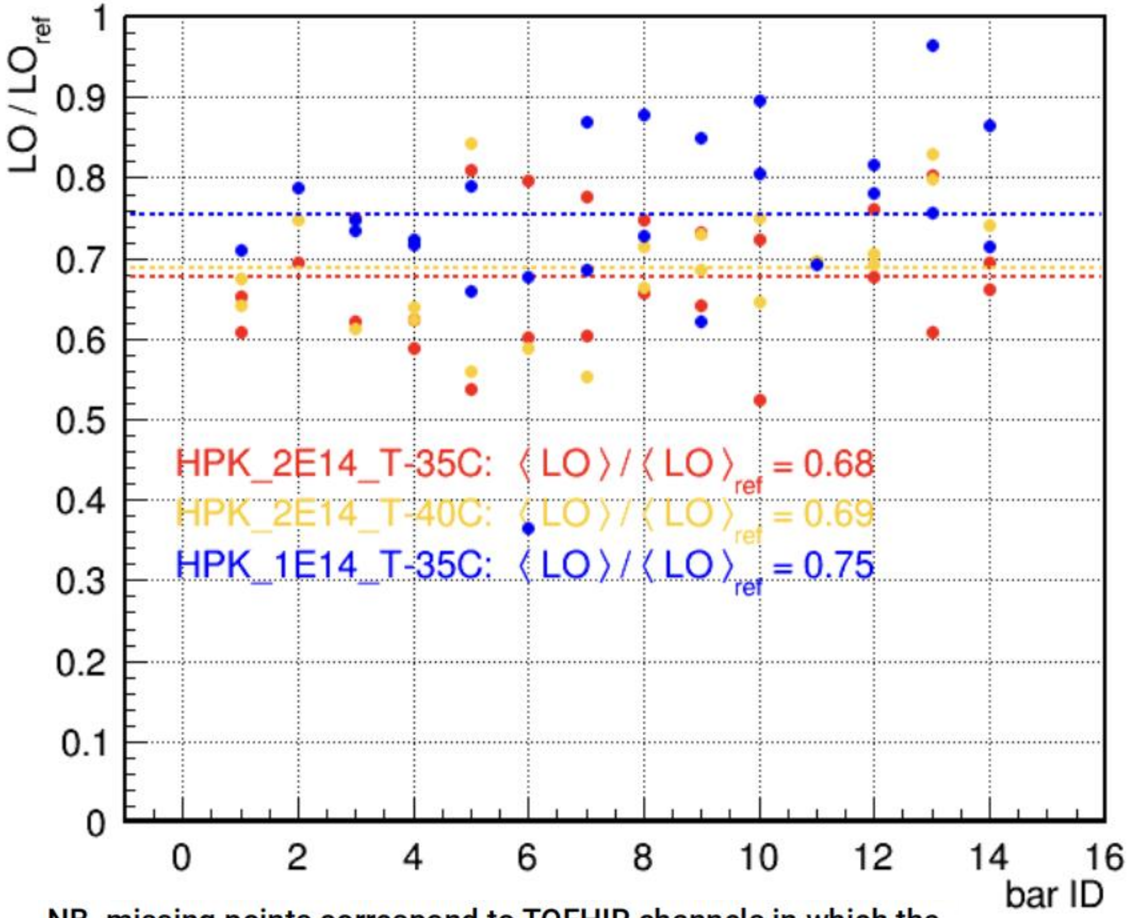
- HPK2E14: expected $LO/LO_{ref} = 0.70$

  22%PDE loss+8%Gain loss (-40℃)

- HPK1E14: expected $LO/LO_{ref} = 0.85$

  11%PDE loss+4%Gain loss (-40℃)

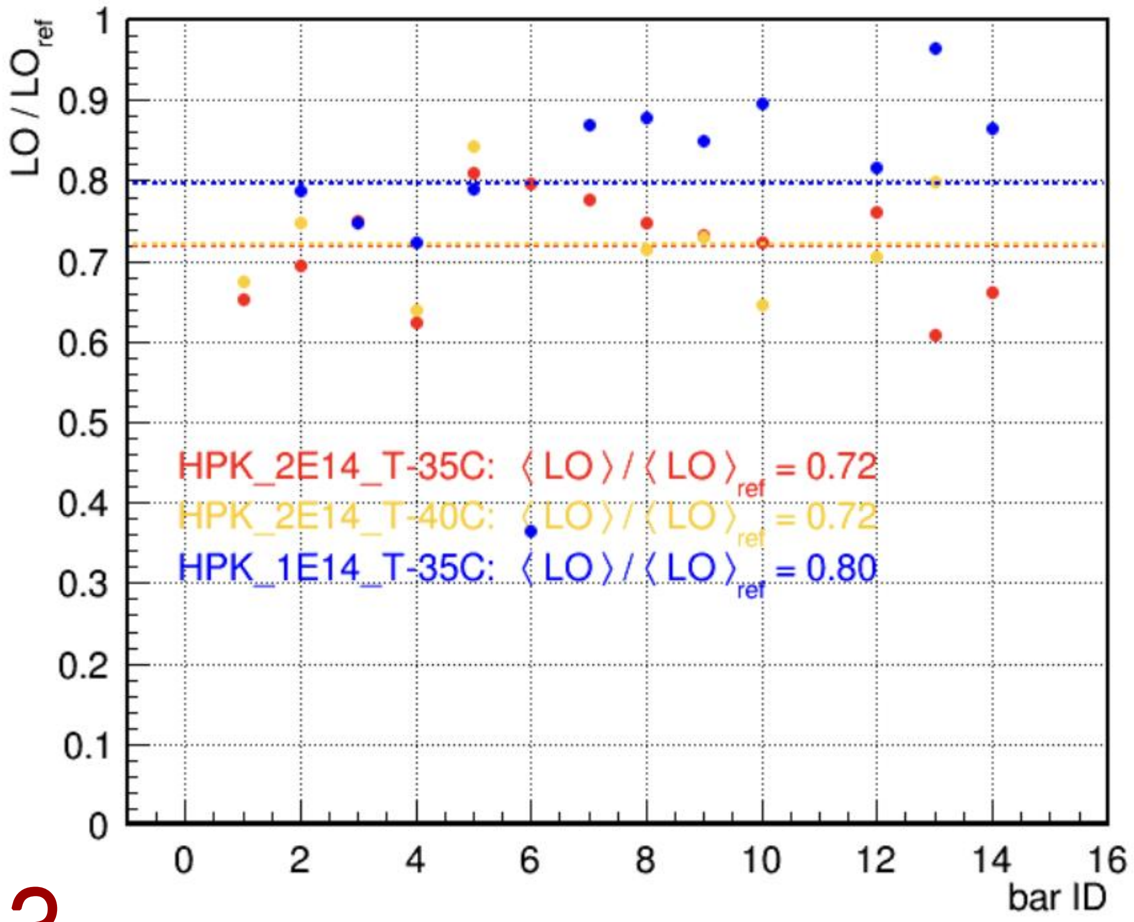
HPK2E14_T-40C: except (3,6,7,11,14)L 2R
HPK2E14_T-35C: except 11L 2R
HPK1E14_T-35C: except (1,11)L 2R



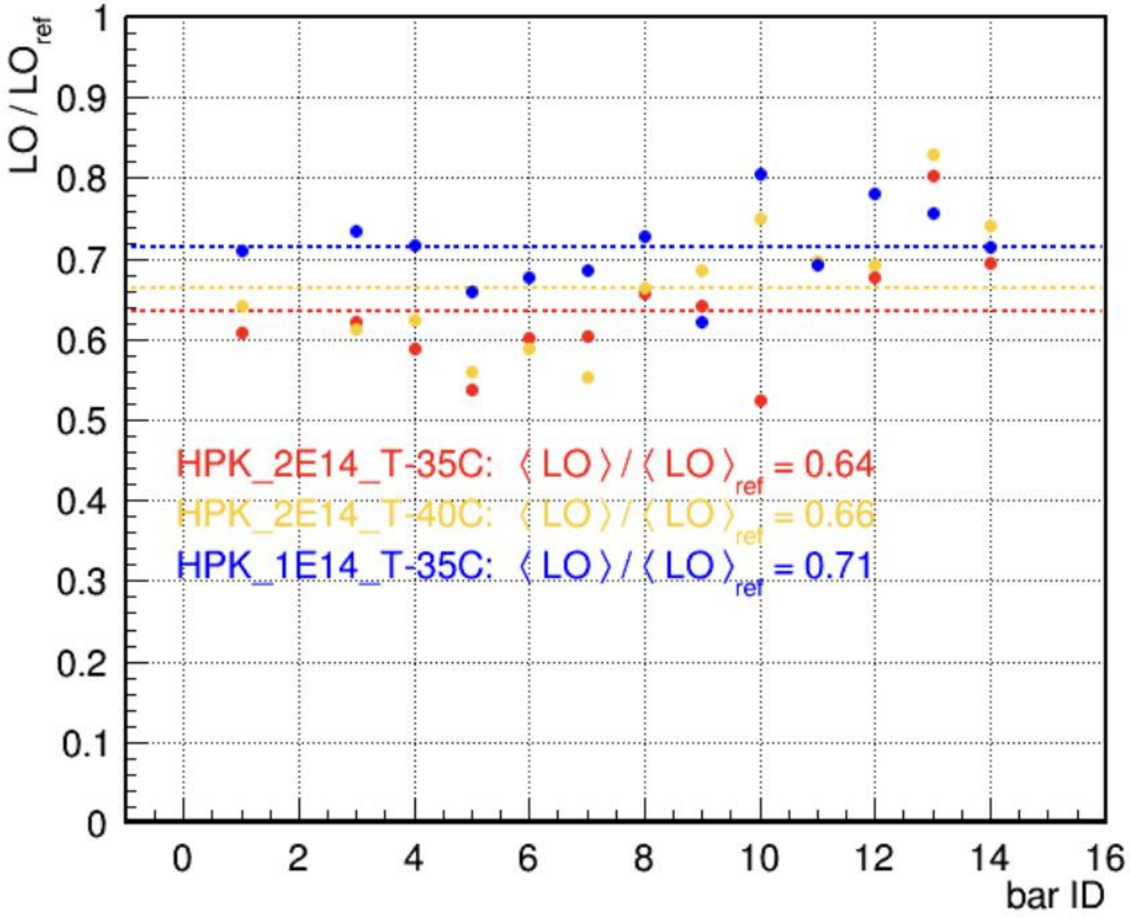
NB. missing points correspond to TOFHIR channels in which the MIP peak was not visible

Irradiated module relative LO

- Left



- Right



Summary

- Performed test beam analysis to study the energy response of MTD BTL sensor modules with the data taken from June
- Found good linearization of the energy digitized by TOFHIR2B ASIC
- Observed radiation effects rougly consistent with expectations
- Futher studies are undergoing for more conditions and configurations

Thanks for your attention!

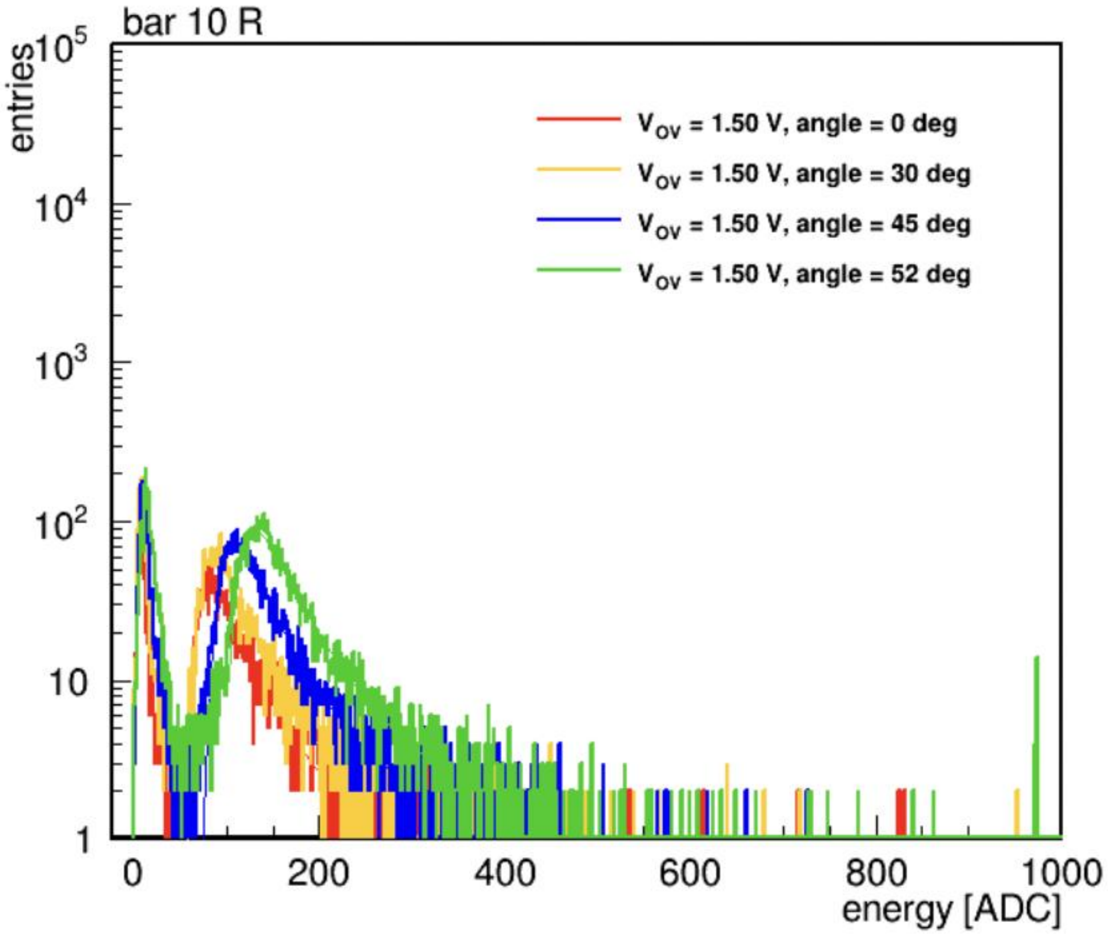
Back up

Energy linearization

vary E_{dep} → different angles = (0, 30, 45, 52deg)

- at Vov = 1.5V, T = 10℃
- delayE = 0b01111111

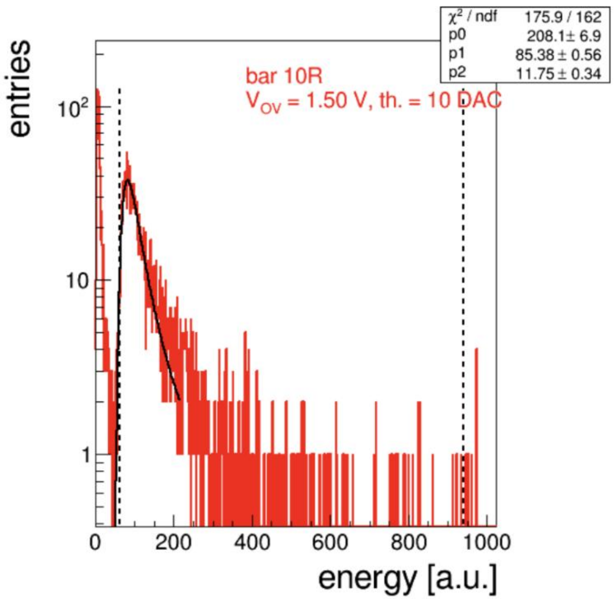
CONF13.00	Vov/V	angle/deg
Run5280	1.5	0
Run5278	1.5	30
Run5277	1.5	45
Run5273	1.5	52

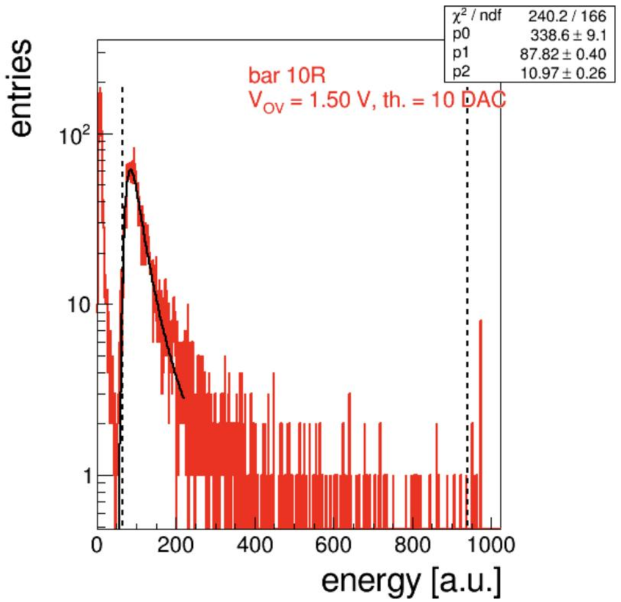


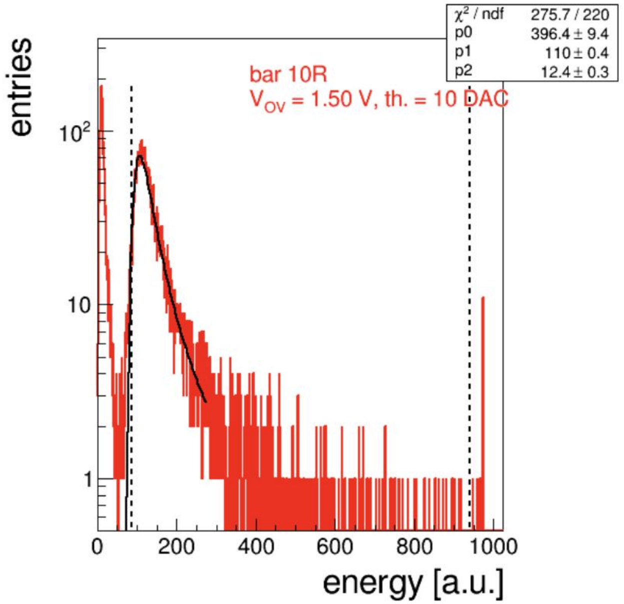
Vov=1.5V, angle=0, 30, 45, 52deg

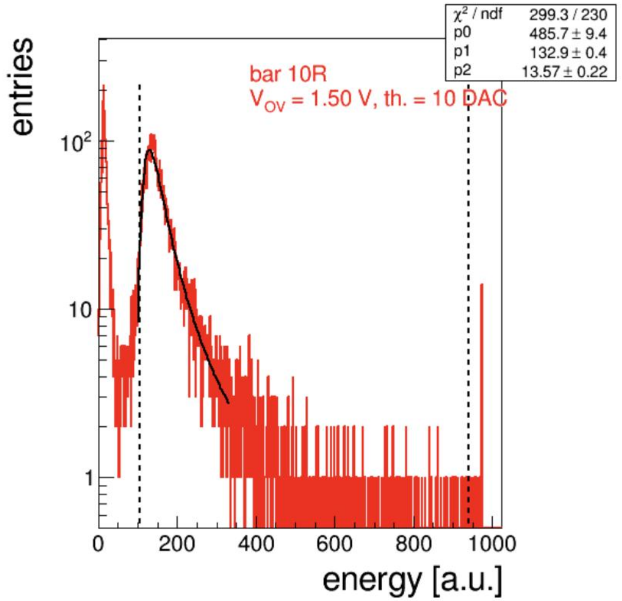
北京大学

- Use landau function to fit the energy deposition measured by TOFHIR2B







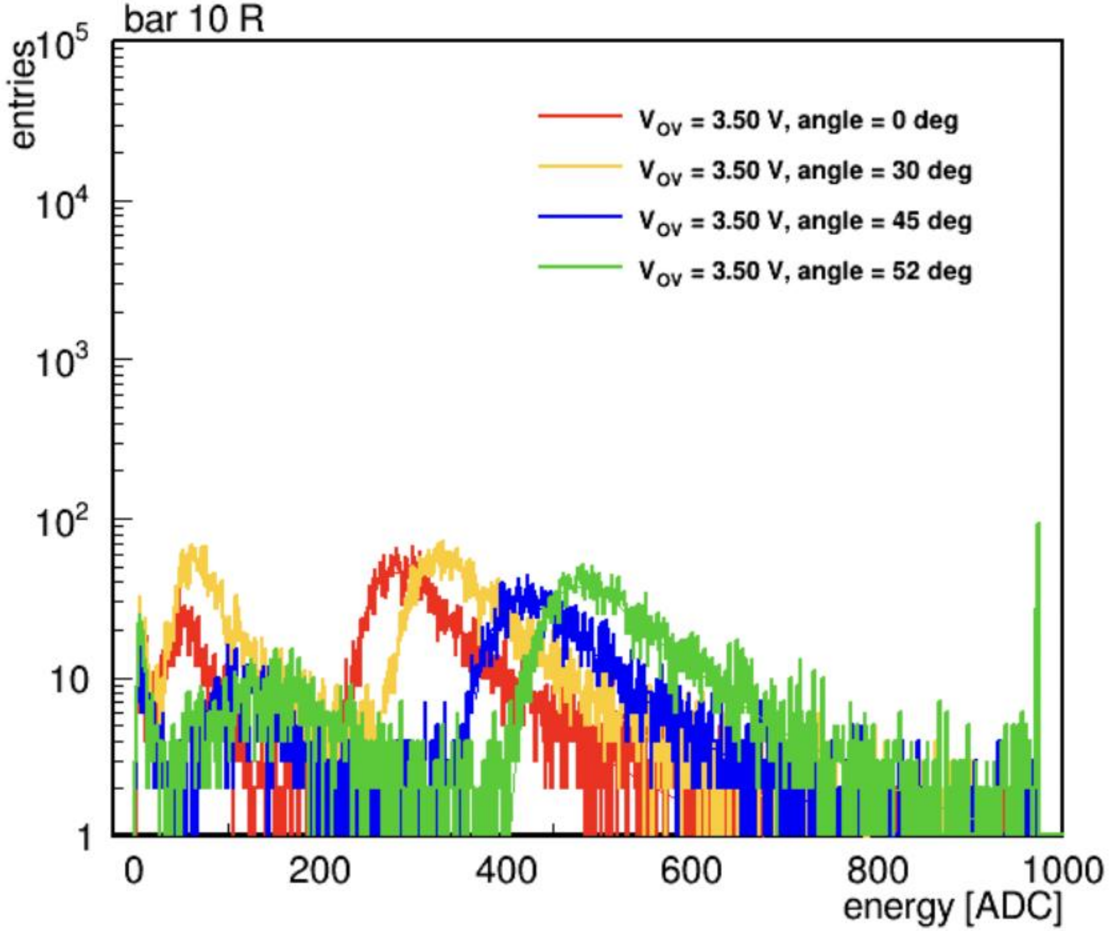


Energy linearization

vary E_{dep} → different angles = (0, 30, 45, 52deg)

- at Vov = 3.5V, T = 10℃
- delayE = 0b01111111

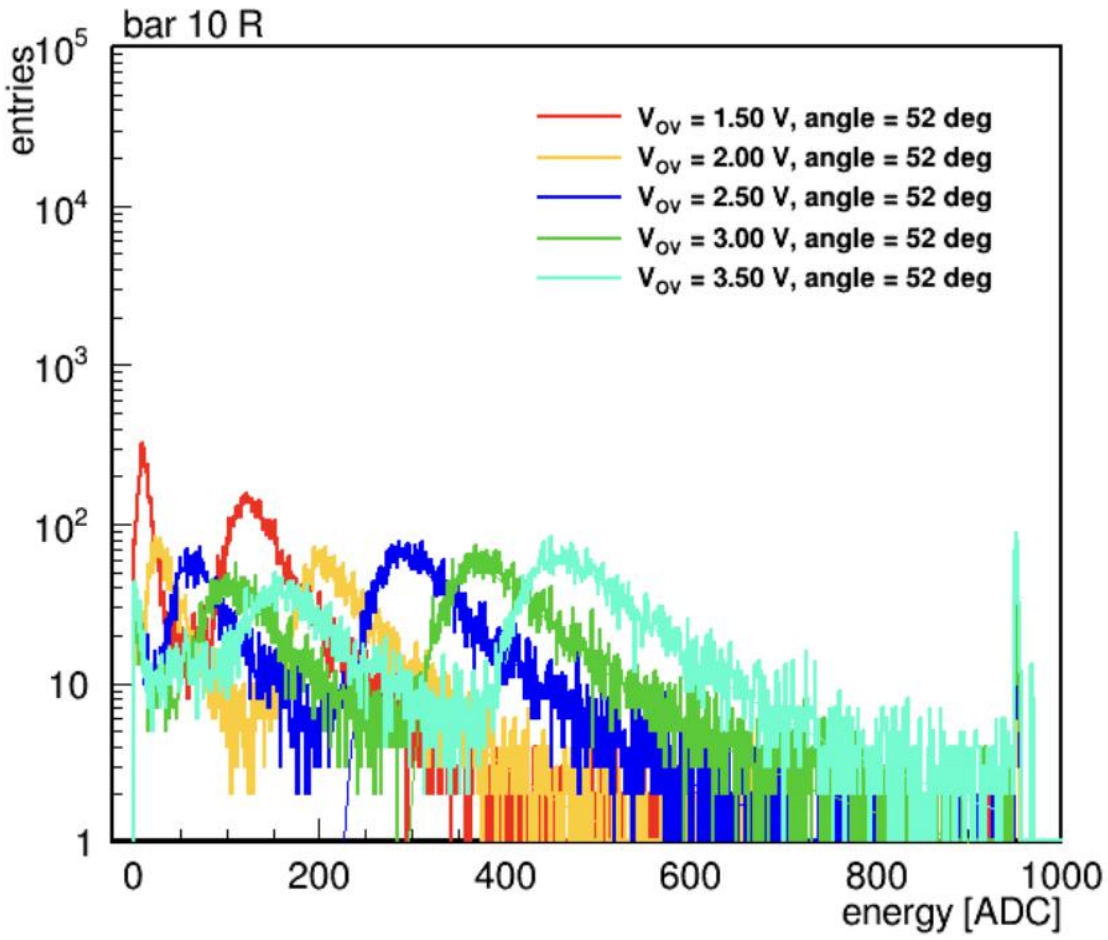
CONF13.00	Vov/V	angle/deg
Run5281	3.5	0
Run5279	3.5	30
Run5276	3.5	45
Run5271	3.5	52



Energy linearization

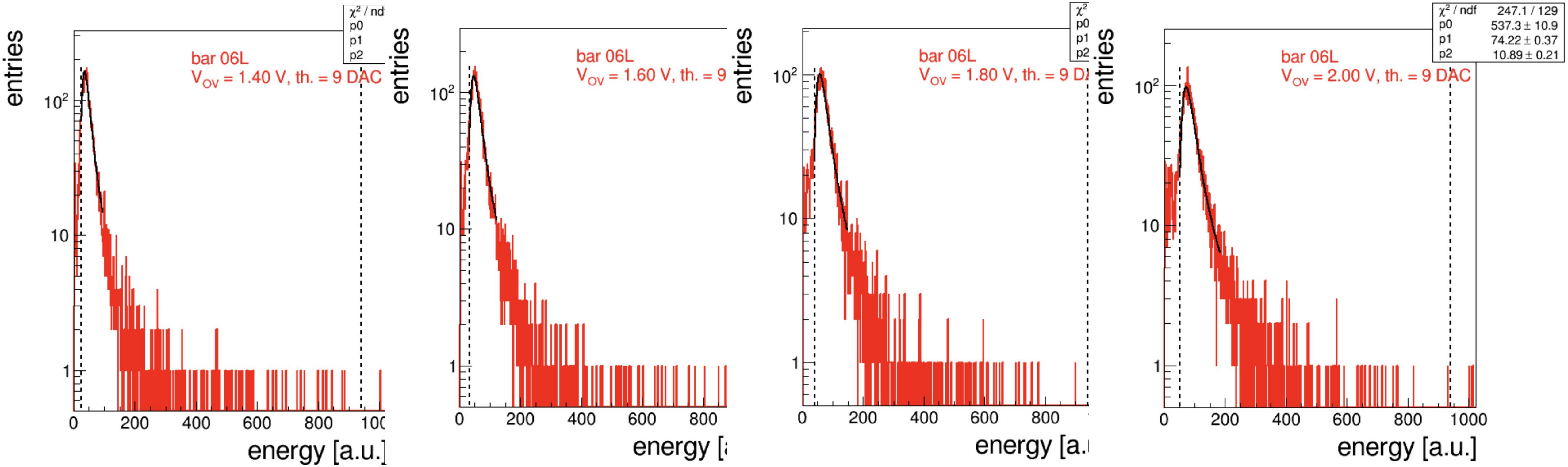
- vary G × PDE → different Vov between 1.5V and 3.5V
  - at angle = 52deg, T = -33℃
  - delayE = 0b01111111

CONF13.01	Vov/V	angle/deg
Run5281	1.5	52
Run5279	2.0	52
Run5276	2.5	52
Run5271	3.0	52
Run5293	3.5	52



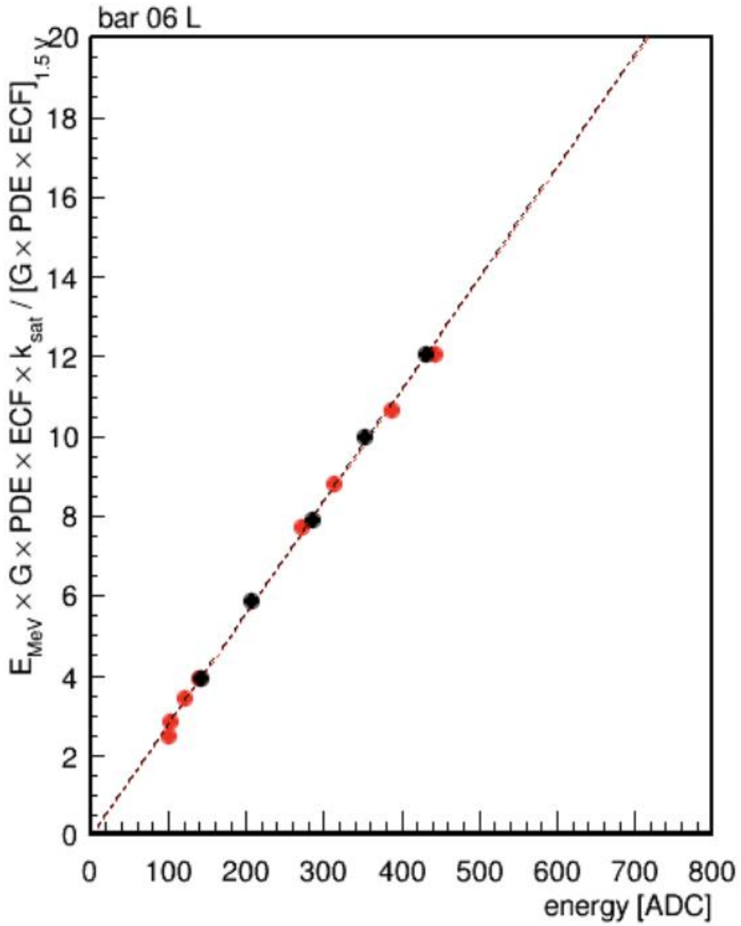
Abnormal points in LO

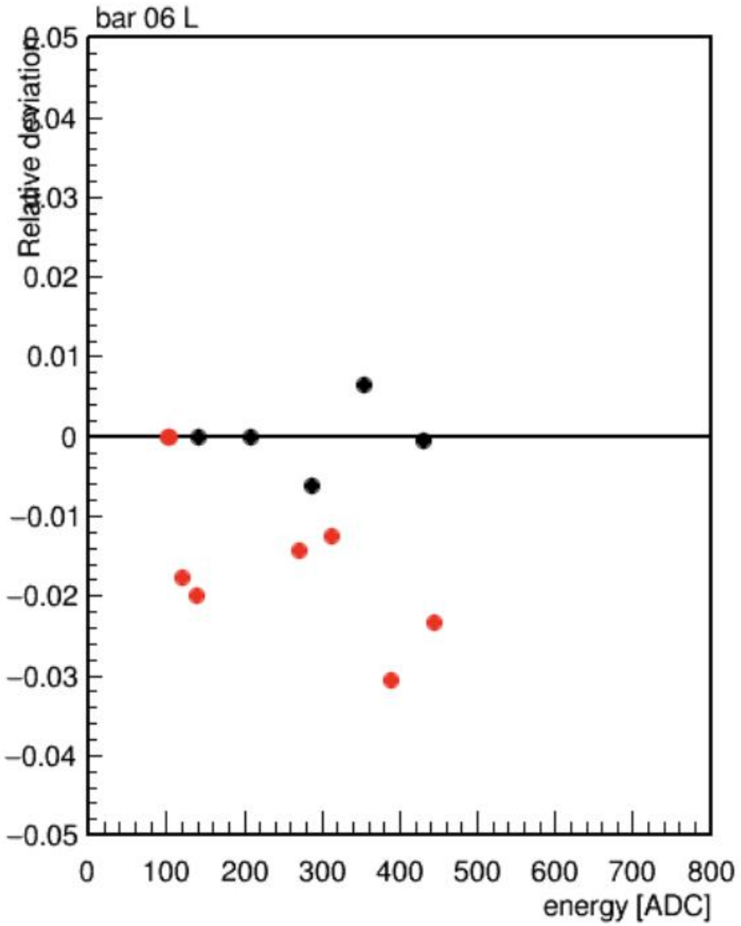
- bar 06L in 1E14



It doesn't seem to be a fitting problem

Abnormal points in LO

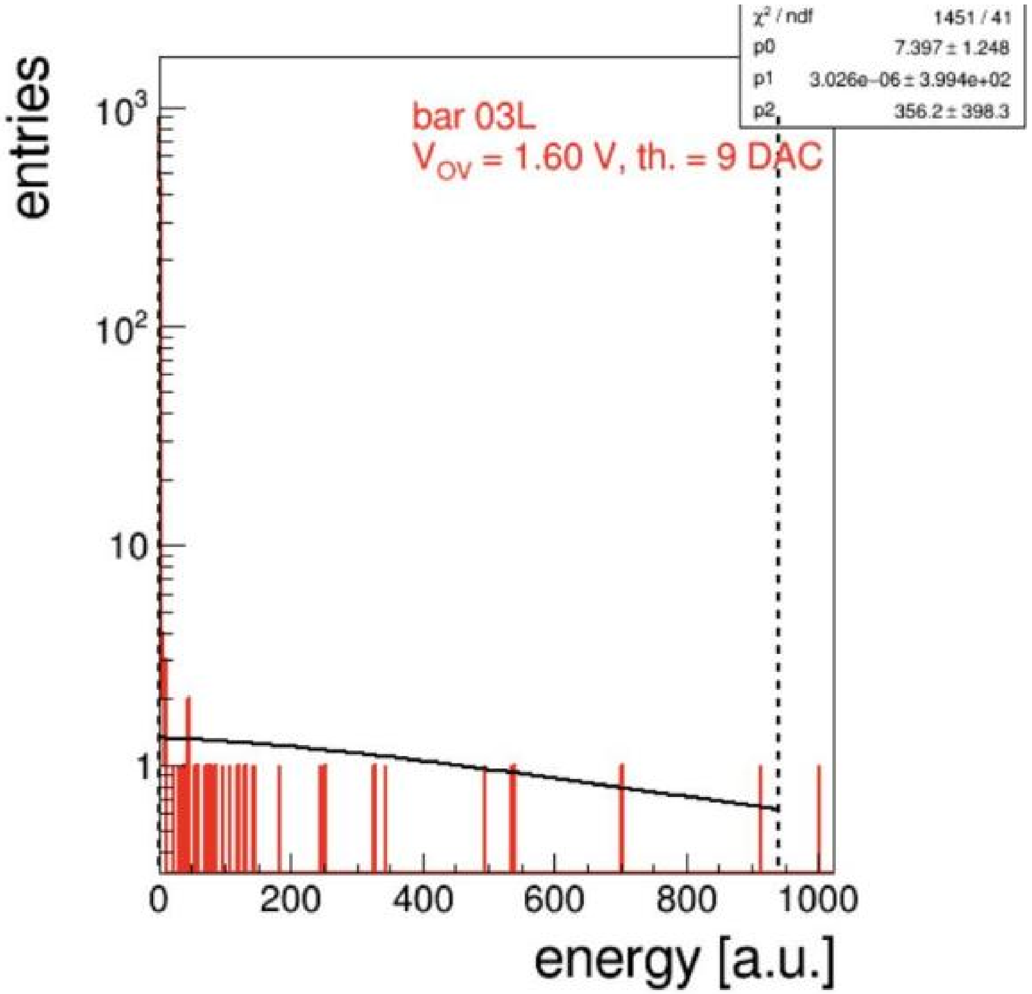


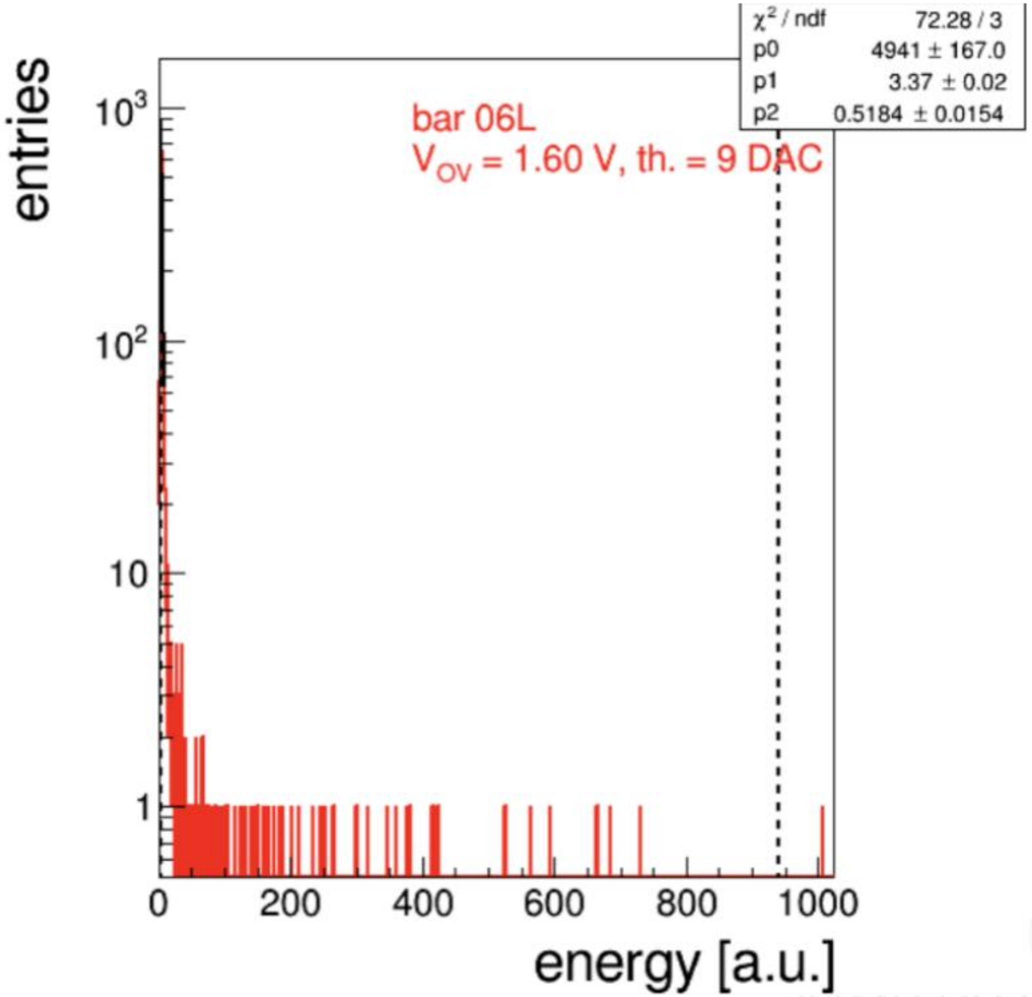


It doesn't seem to be a fitting problem

invisible MIP peak——2E14T—40

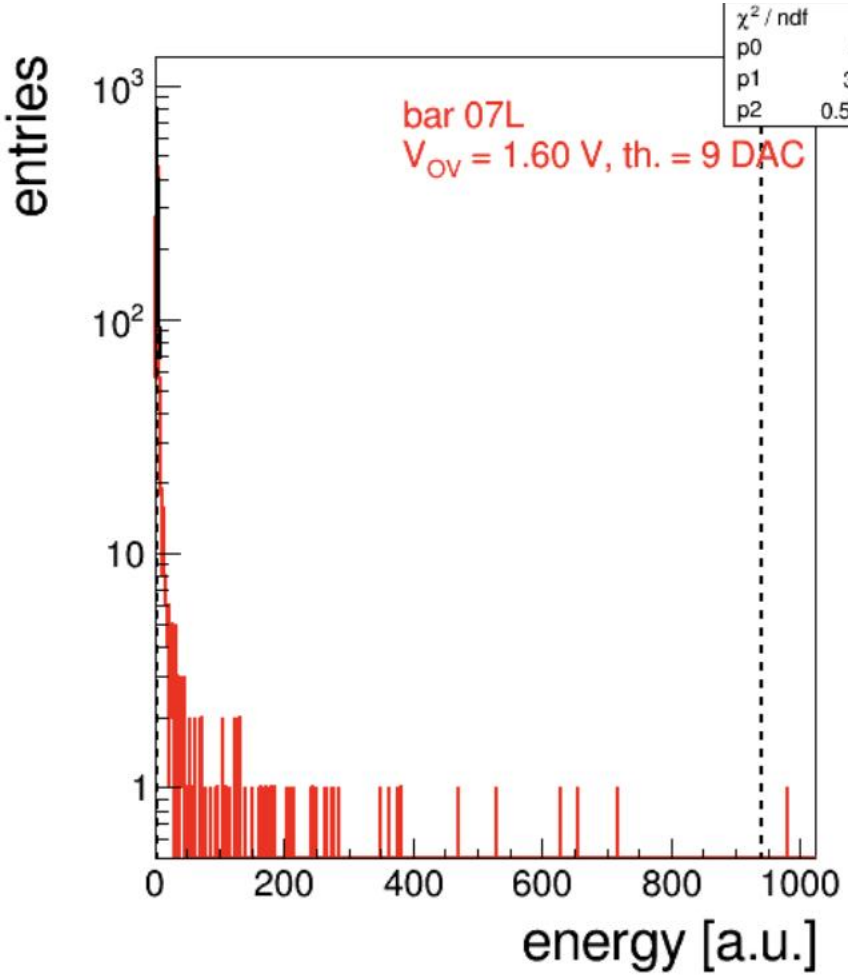
北京大學

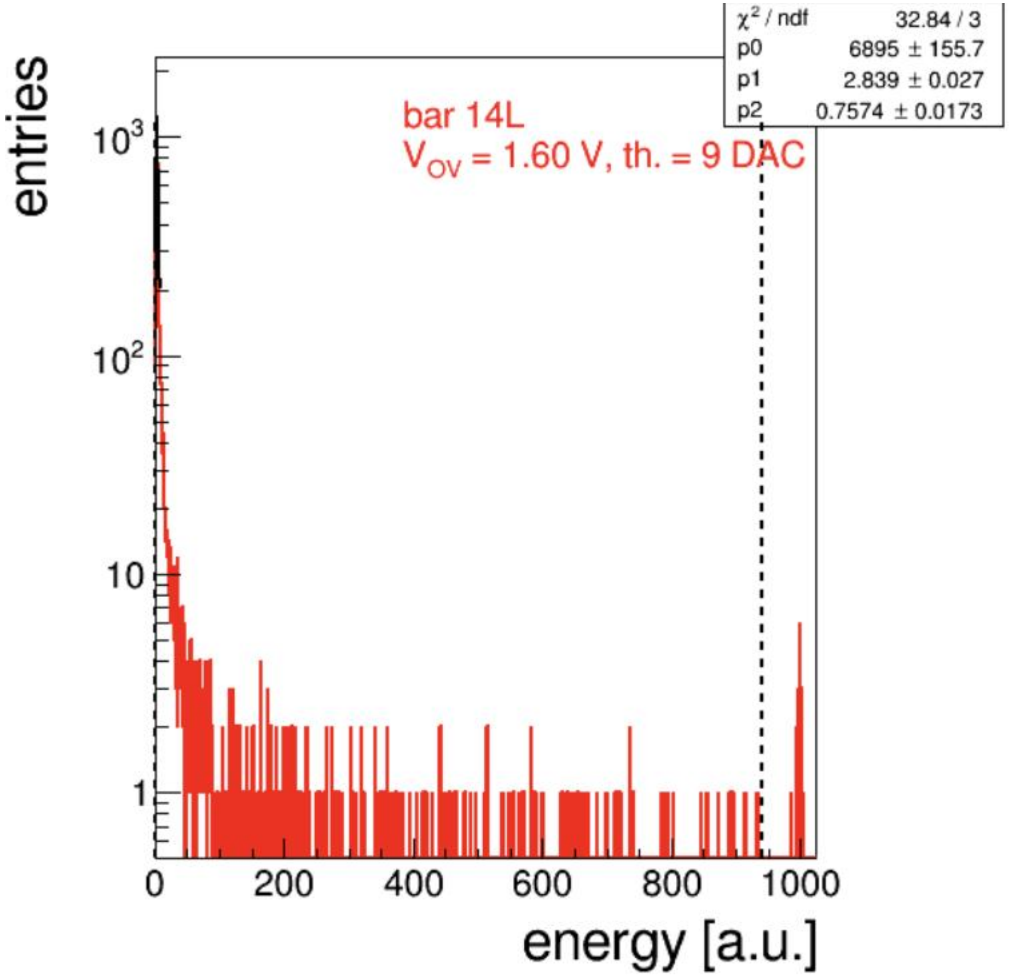




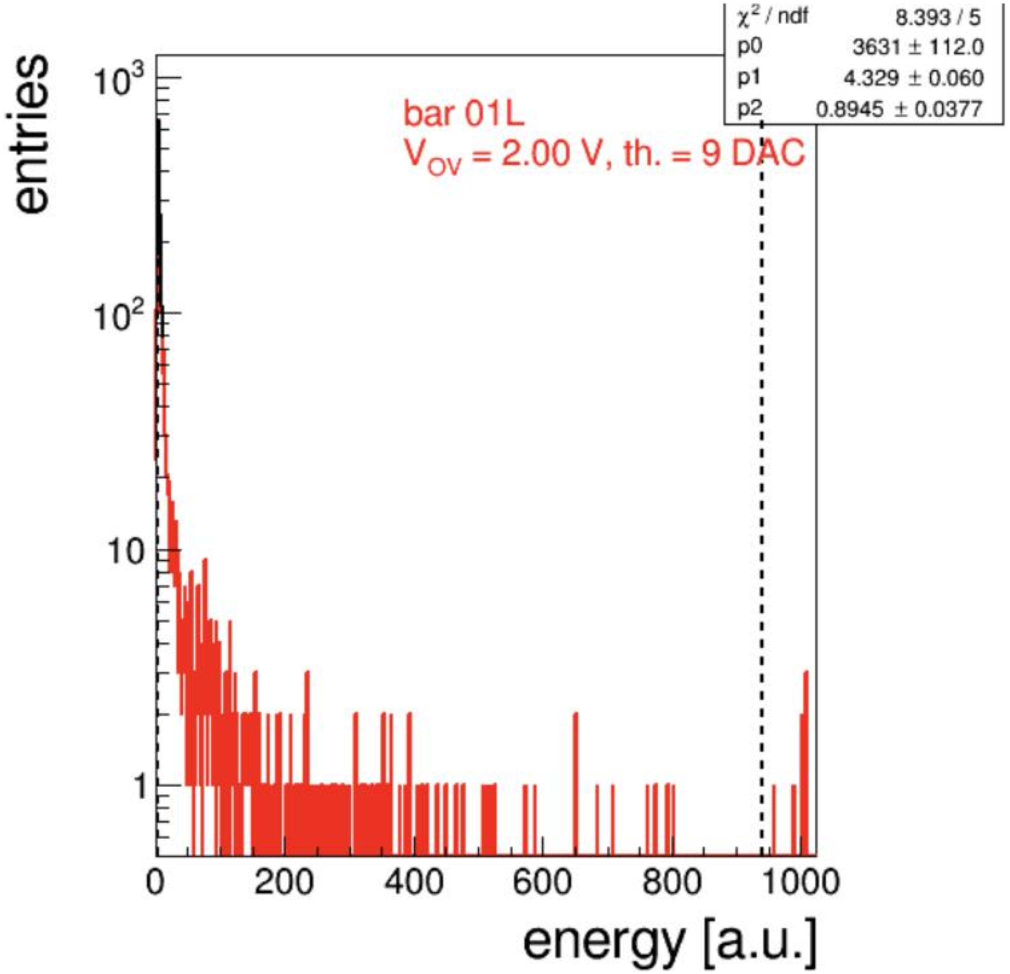
invisible MIP peak——2E14T—40

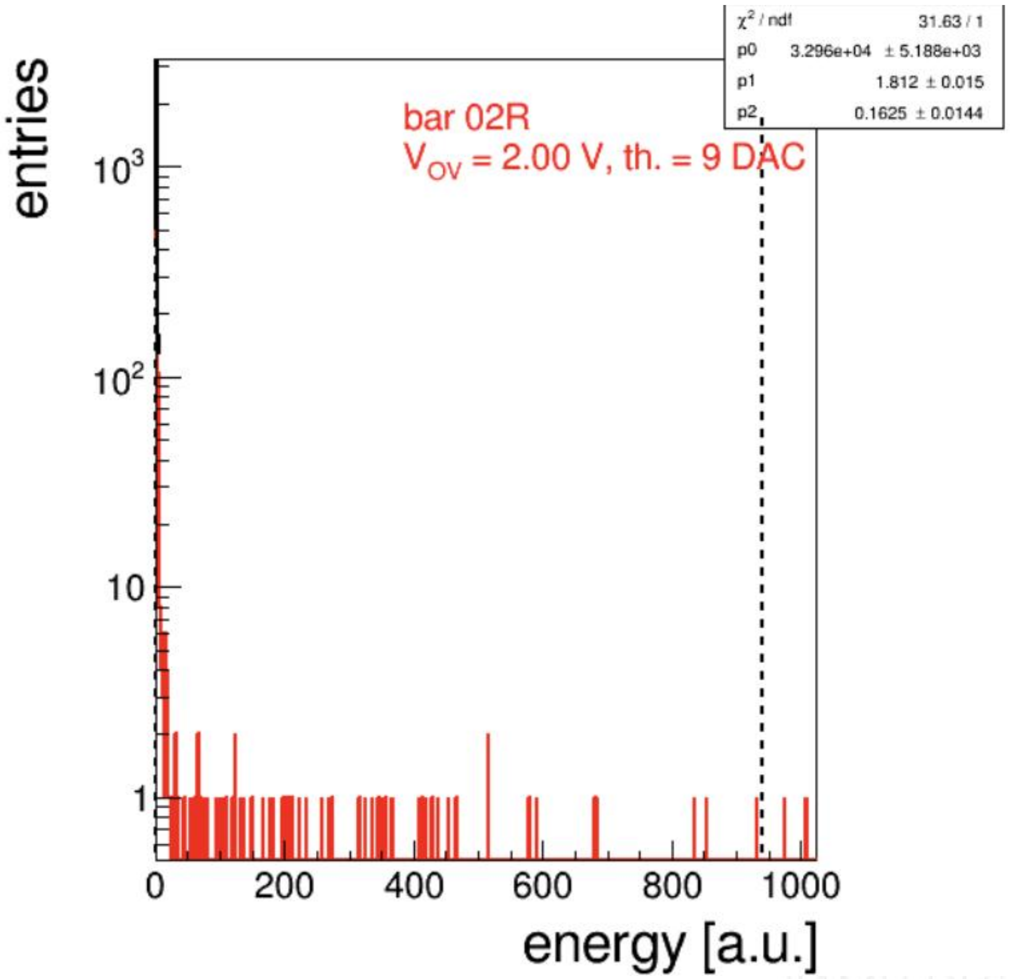
北京大學





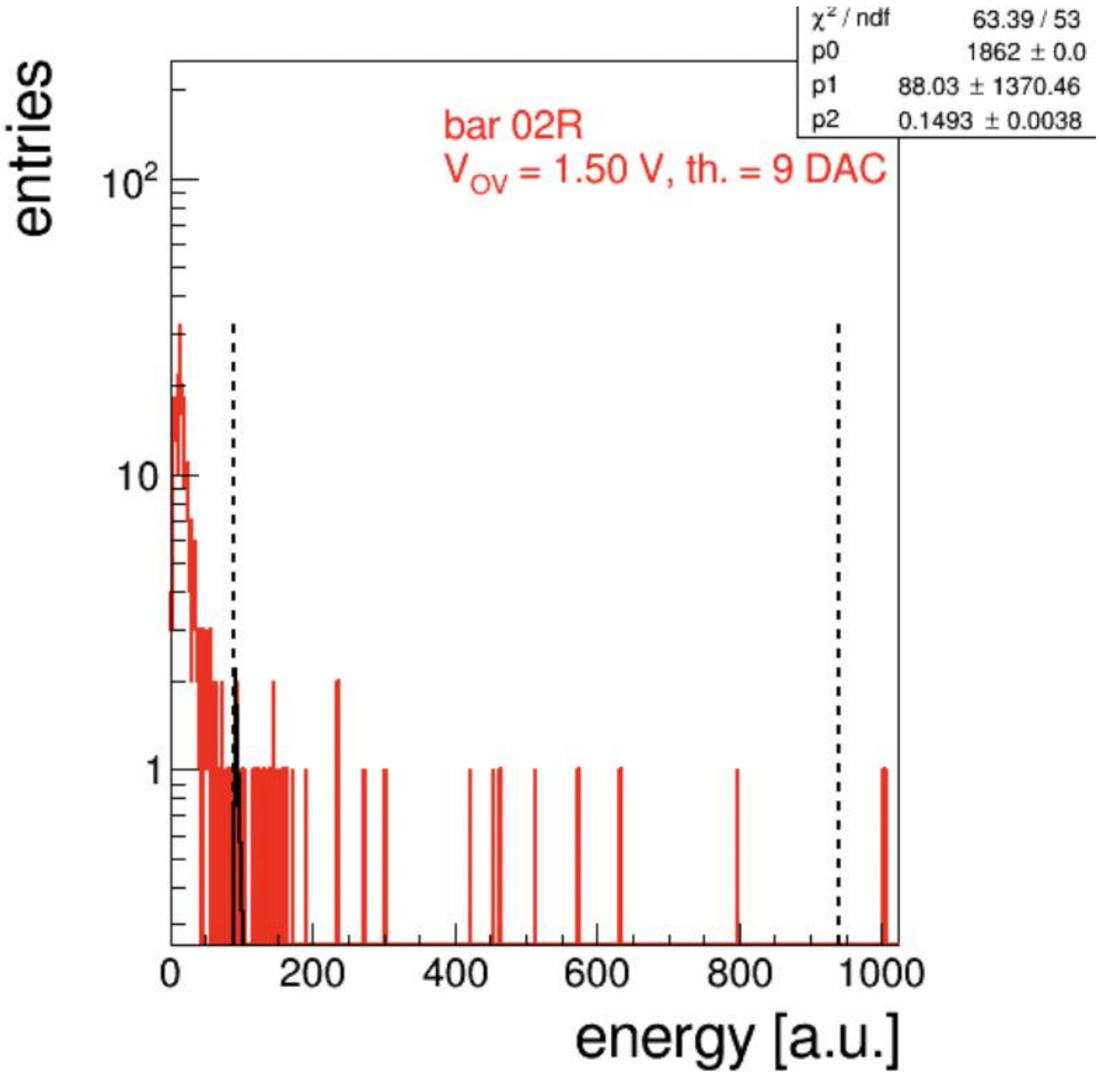
invisible MIP peak——1E14





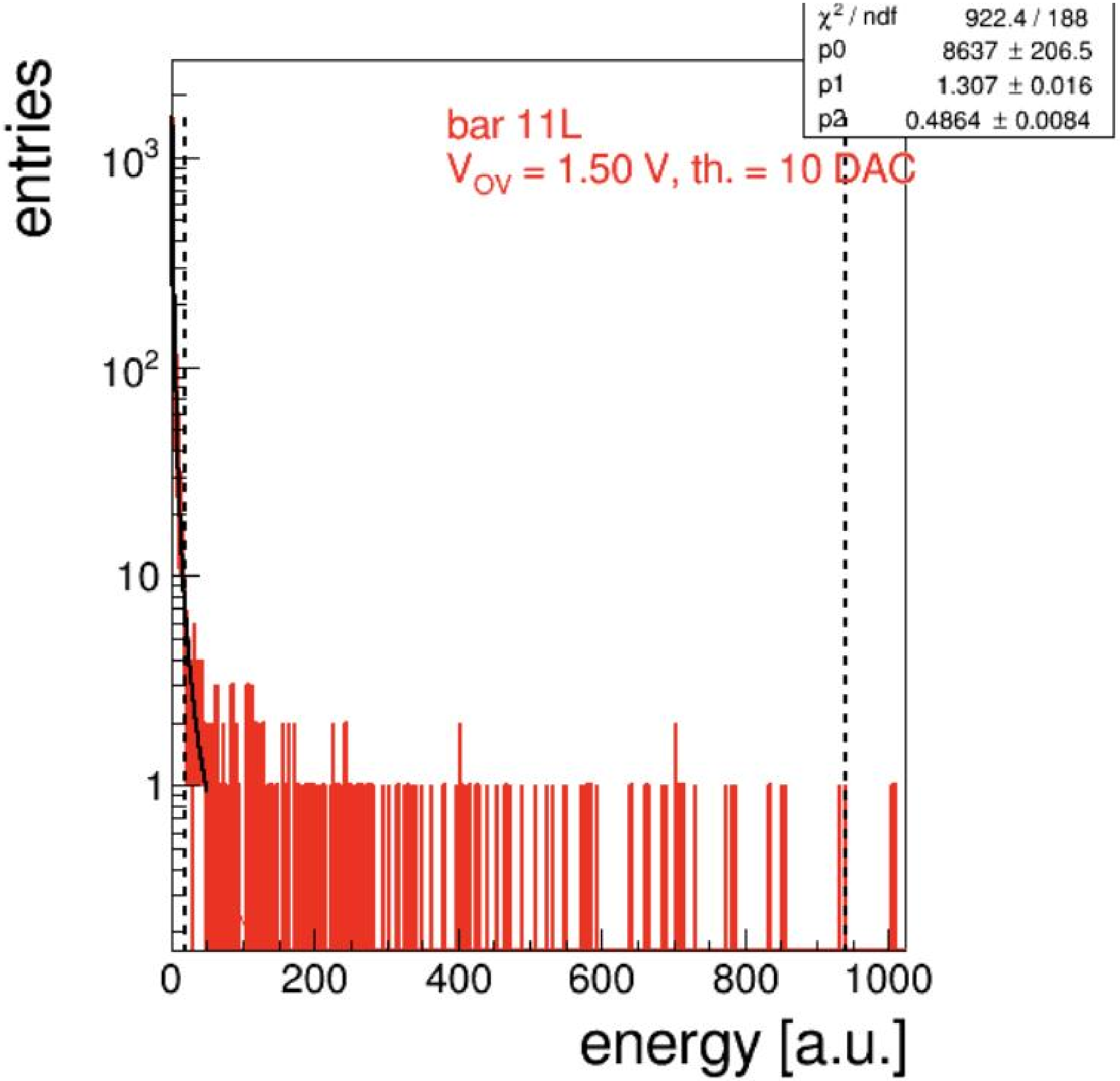
invisible MIP peak——Reference module

- Run5298 (1.50V)



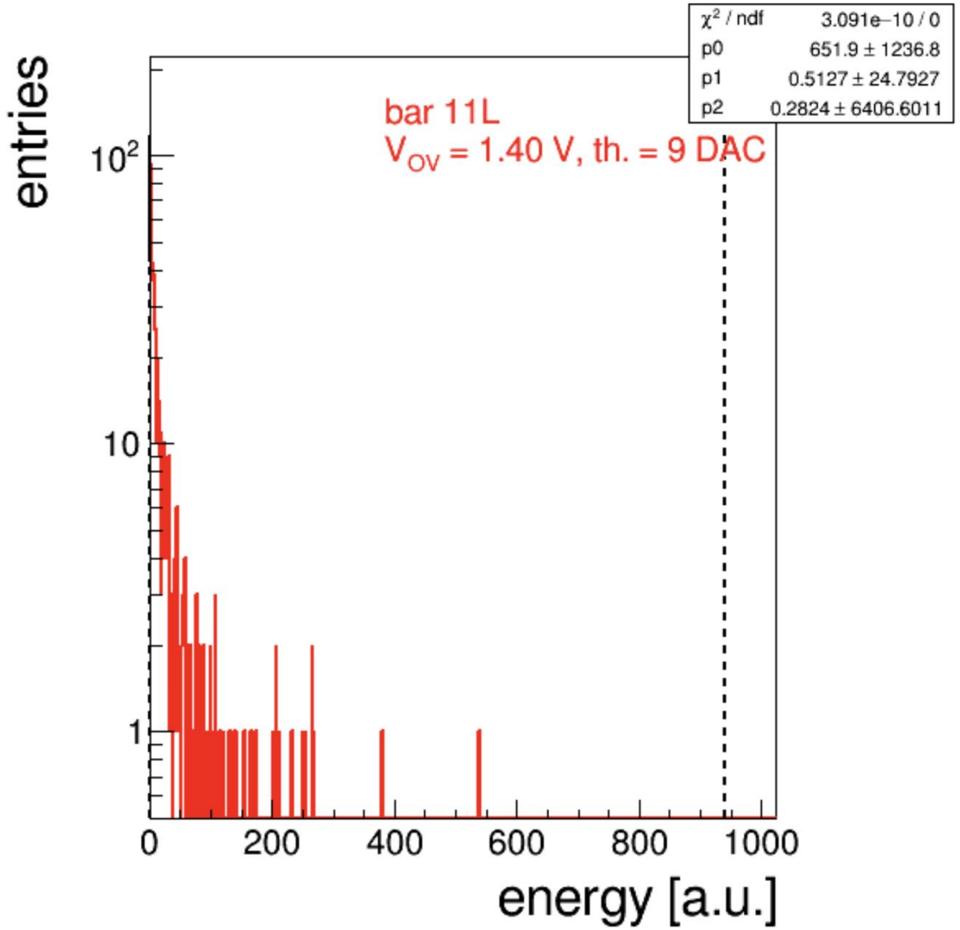
invisible MIP peak——linearization

- Run5278(1.5V, 30deg)

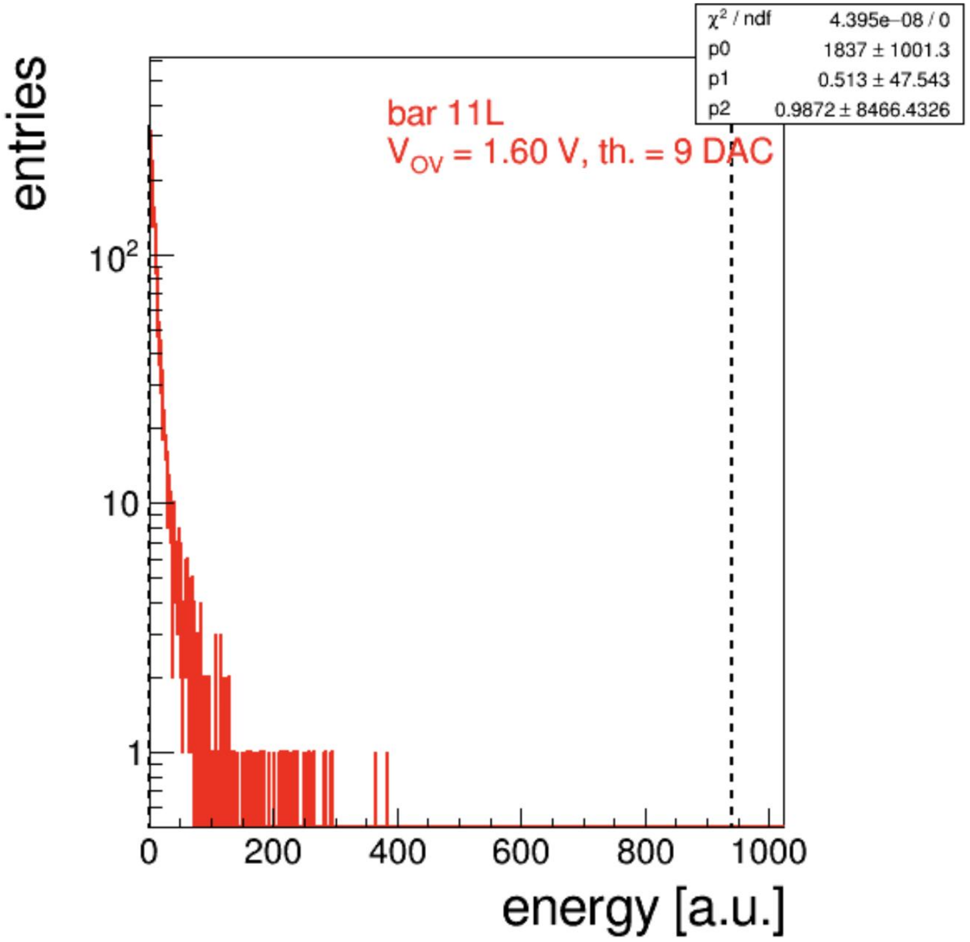


invisible MIP peak——linearization

- Run5328(1.40V, 52deg) FBK1E14

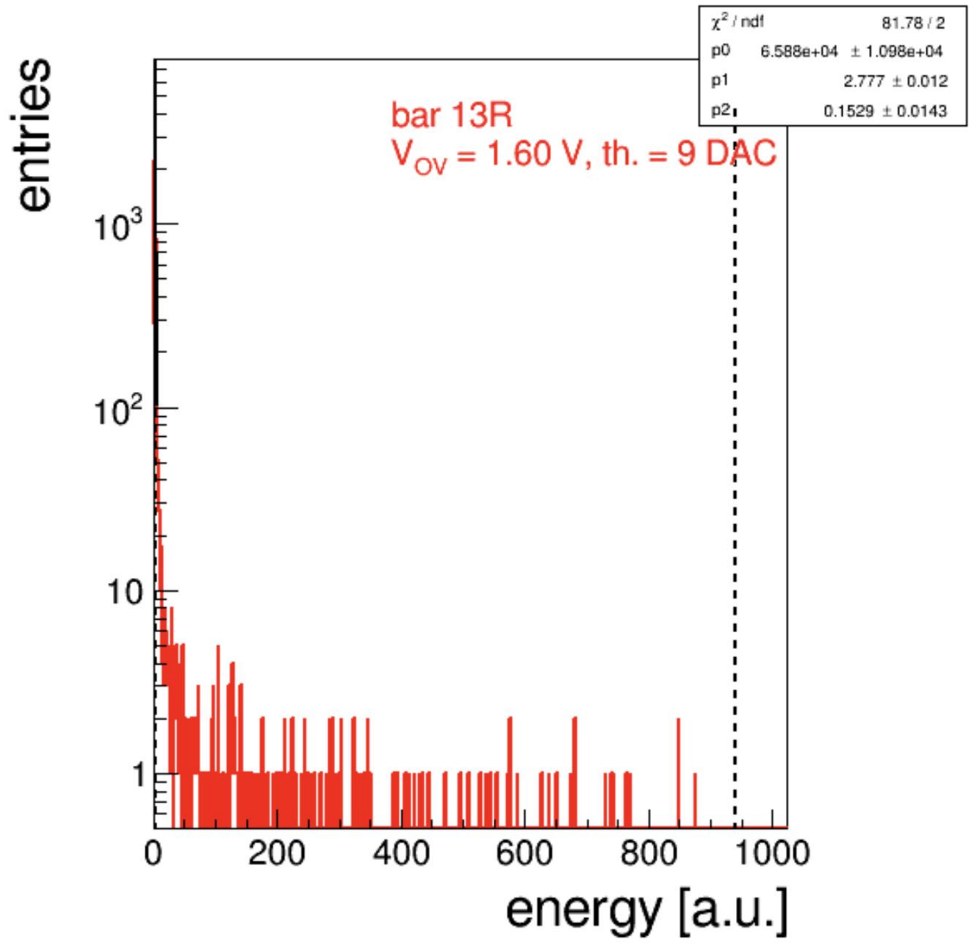


- Run5326(1.60V, 52deg) FBK1E14



invisible MIP peak——linearization

- Run5331(1.60V, 52deg) FBK2E14



- Run5333(1.70V, 52deg) FBK2E14