# Low Momentum Particle Detector at the NA61/SHINE Experiment

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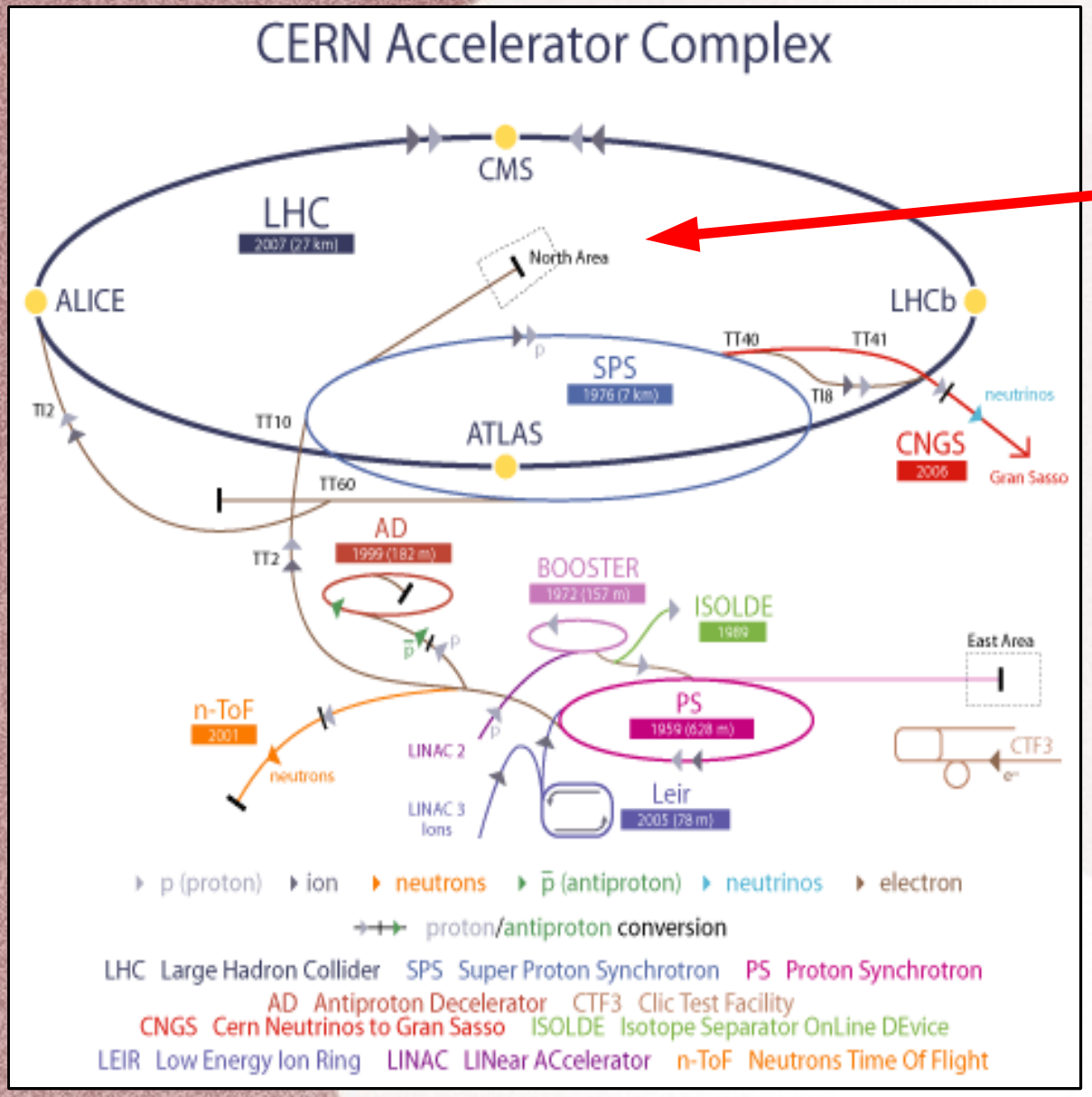
# Outline

- NA61/SHINE Experiment at CERN SPS
- Centrality and slow protons in h+A interactions
- Low Momentum Particle Detector at NA61
  - Operation principle
  - Detector construction
  - Proton identification with LMPD

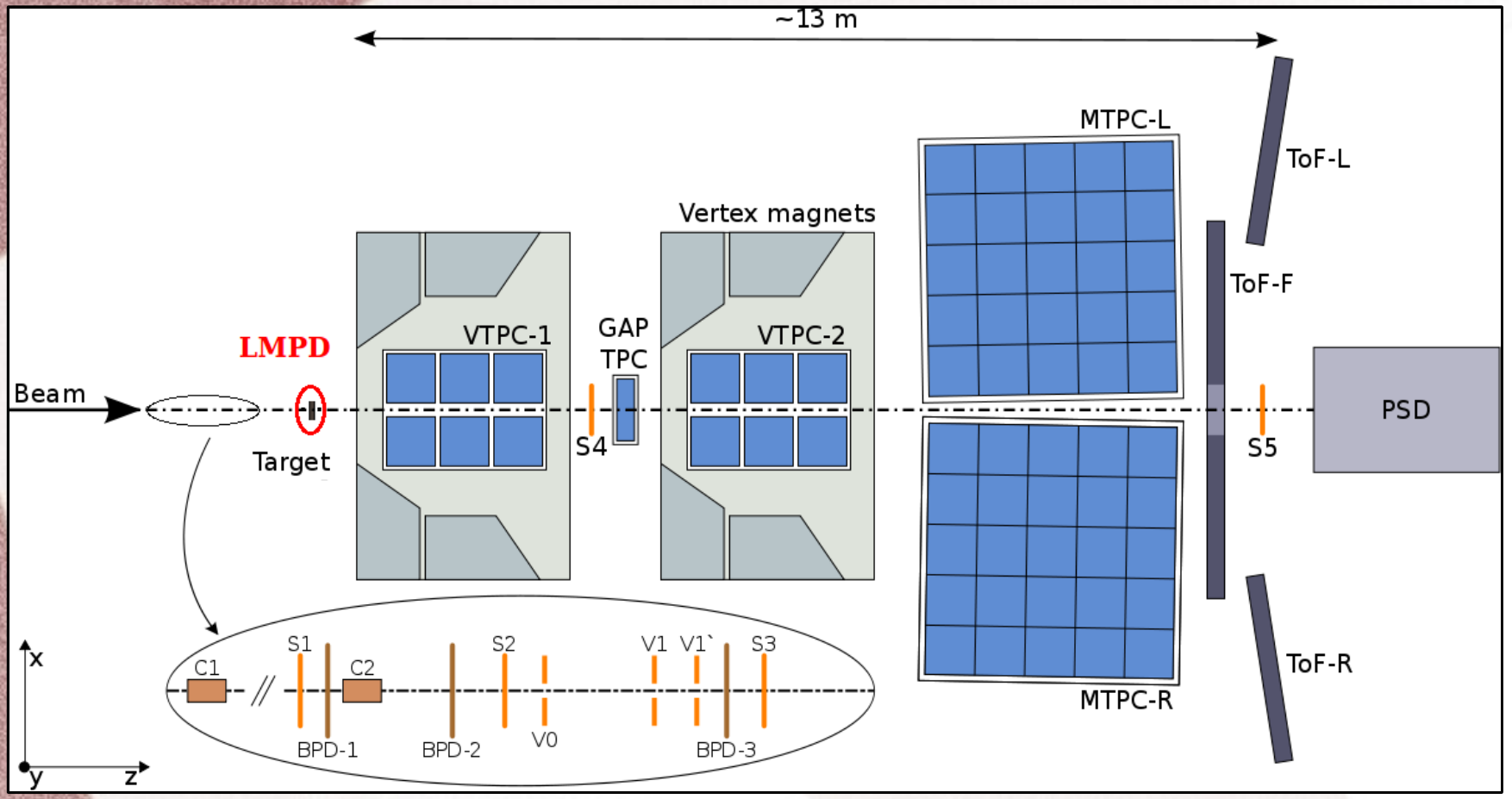
# NA61/SHINE at CERN SPS





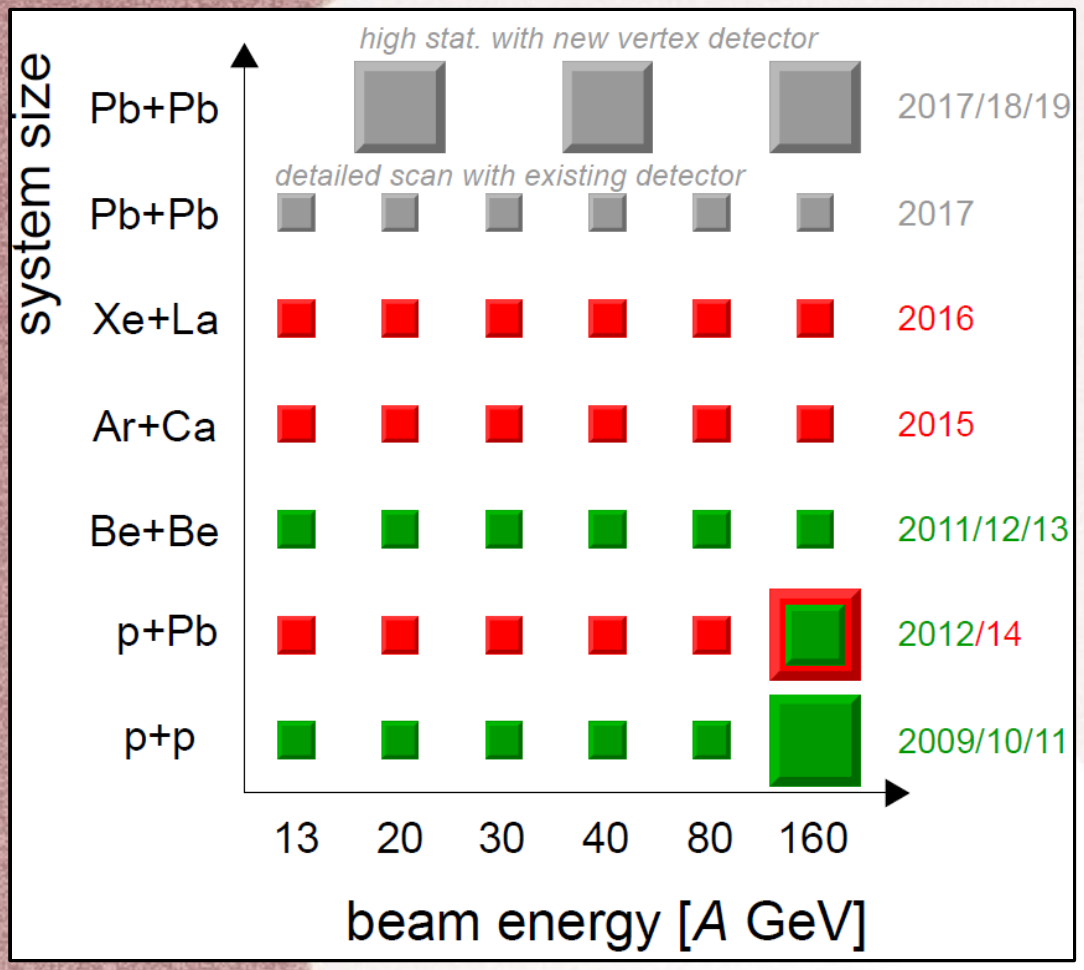
- **S**PS **H**eavy **I**on and **N**eutrino **E**xperiment
- Fixed-target experiment at CERN SPS
- Studies hadron production in hadron-nucleus and nucleus-nucleus collisions

# NA61/SHINE at CERN SPS



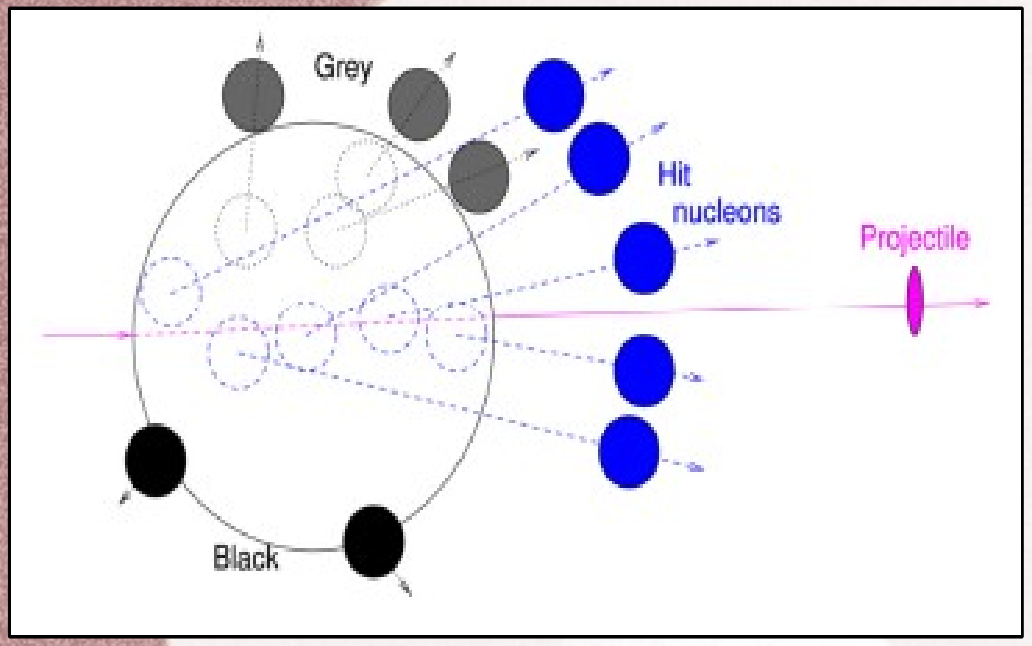

- Large acceptance hadron spectrometer with excellent capabilities for momentum, charge and mass measurements
- Time Projection Chambers, Time of Flight and Projectile Spectator Detectors

# NA61/SHINE at CERN SPS




- Search for the critical point of strongly interacting matter
- Detailed study of the onset of deconfinement
- **Study of high transverse momentum phenomena in p+p and p+A**
- Reference measurements for neutrino and cosmic-ray experiments

# Centrality of h+A collisions



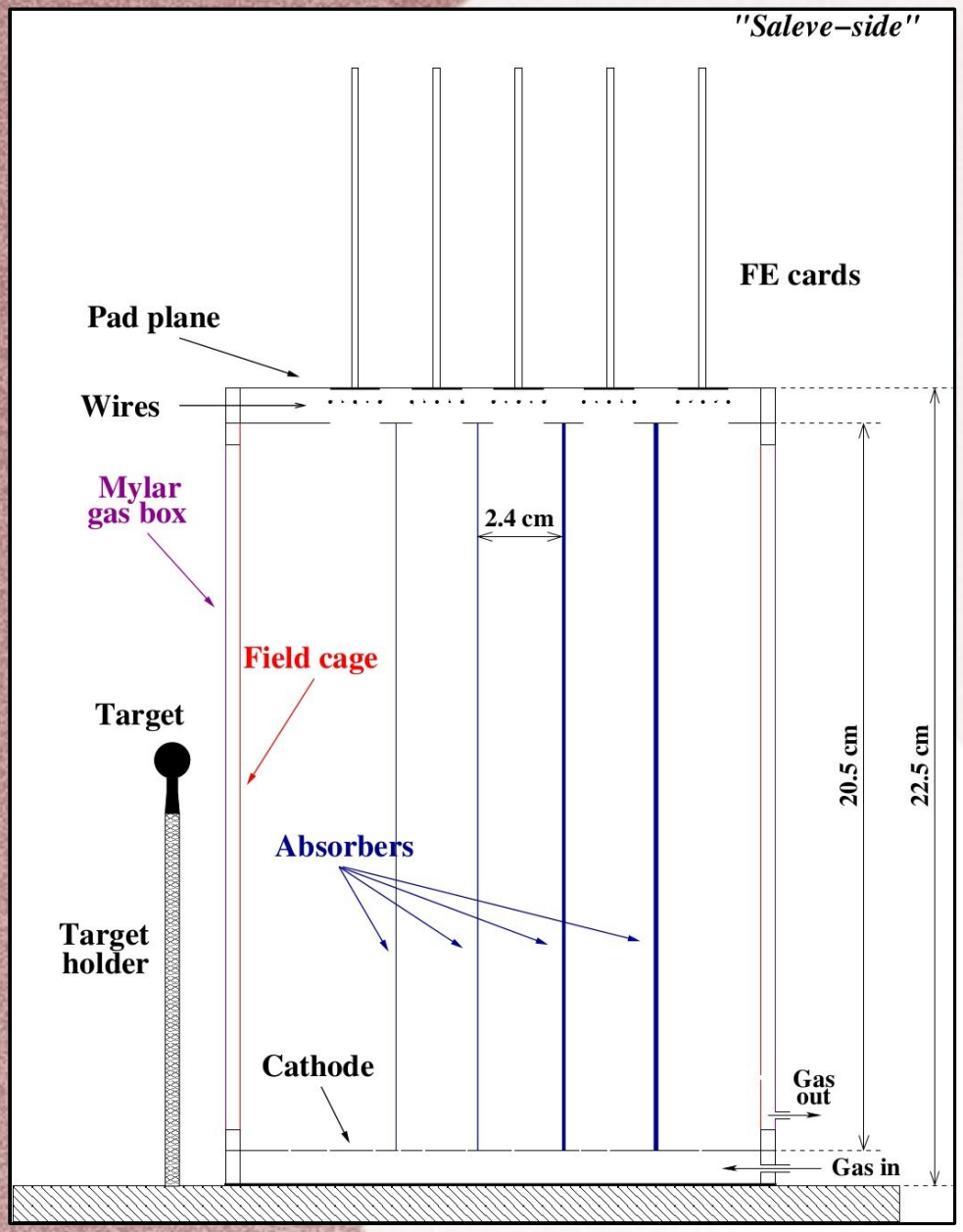

- Centrality dependence of charged hadron production in h+A collisions is observed
- Earlier h+A measurements → **Centrality** of h+A collision is correlated to the **number of slow** (“gray”) **nucleons** (produced by the “break-up” of the nucleus)

**Low Momentum Particle Detector** at NA61

→ identification and energy measurement of low momentum particles in p+A collisions

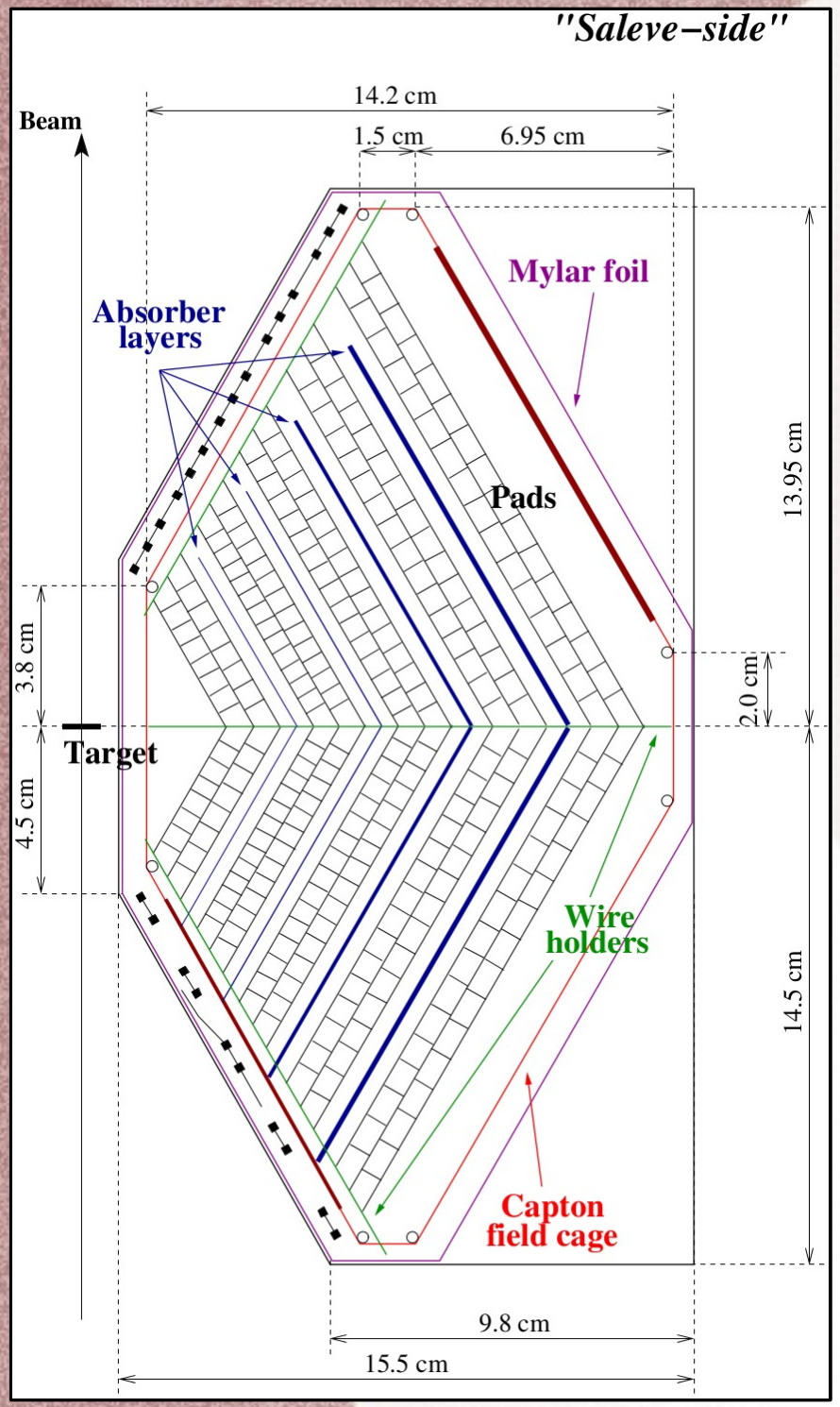
→ *Centrality Detector*

# Low Momentum Particle Detector - Operation principle

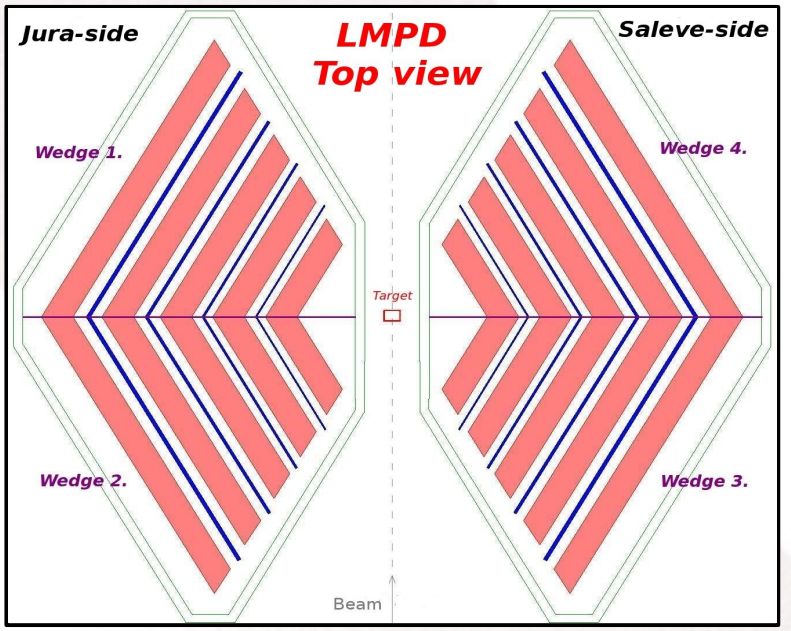



- Time Projection Chamber
- Intervals in particle range defined by absorber layers
- Simultaneous measurement of **dE/dx** and **range**: energy and identification
- dE/dx measured over 1.2 cm in a small TPC (field cage printed on absorber)
- Electronics: same as for other NA61 TPCs

# LMPD – Readout MWPC




- Radial pad-structure
- 5x2 detection layers, number and size of pads increase towards the outer pad-rows
- 4 absorber layers, 2x2 wedges



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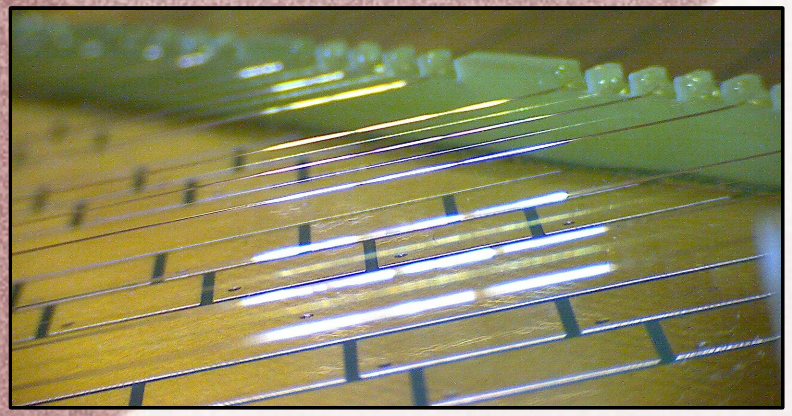
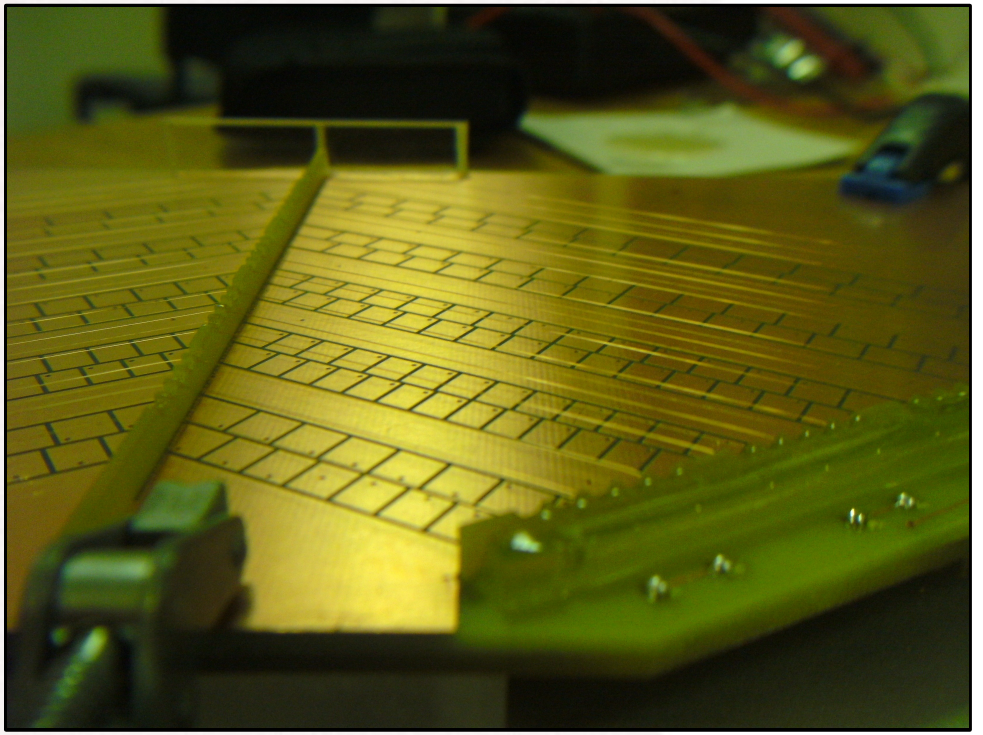
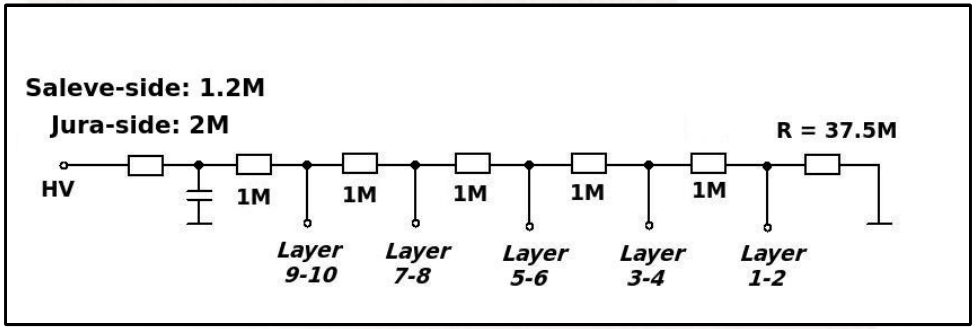


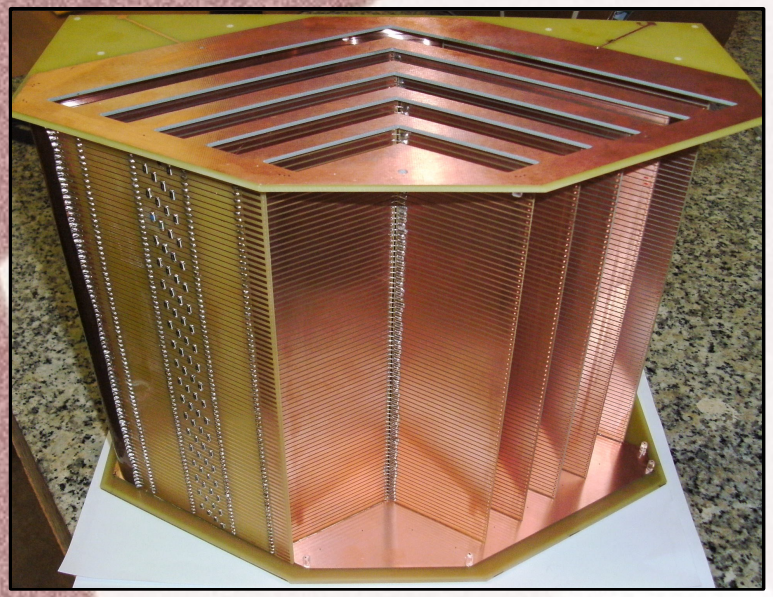


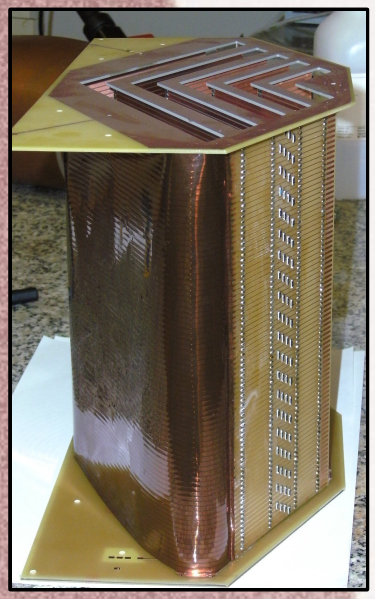
- **Sense wires**: *21 μm*

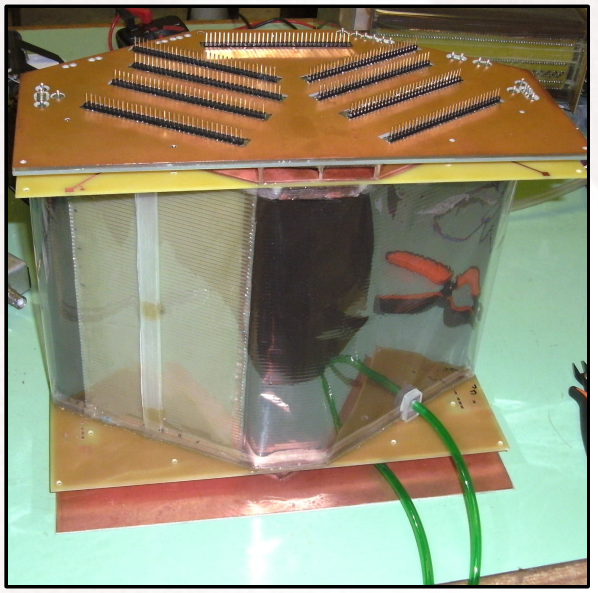
  **Field wires**: *100 μm*
- The gain is far below the “normal” TPC gain due to high ionization: **gating grid is not necessary**
- Follow decreasing ionization due to increasing range → **gradually increasing gain towards outer pad-rows**



# LMPD – Field cage and absorbers

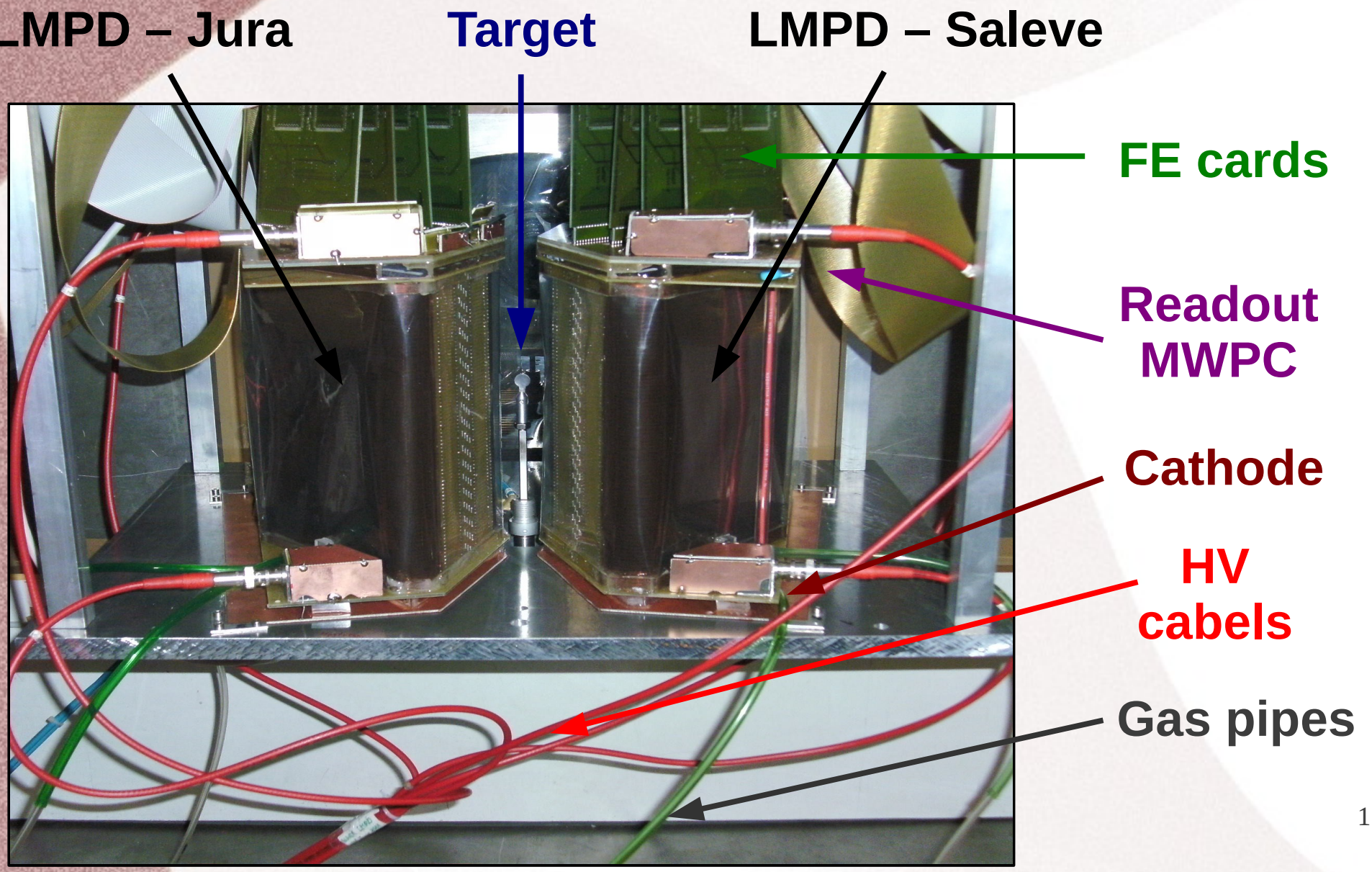




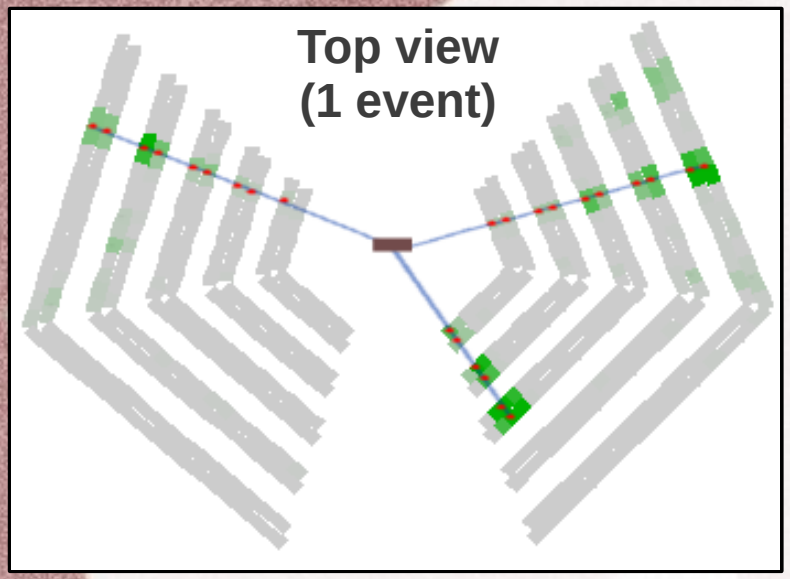


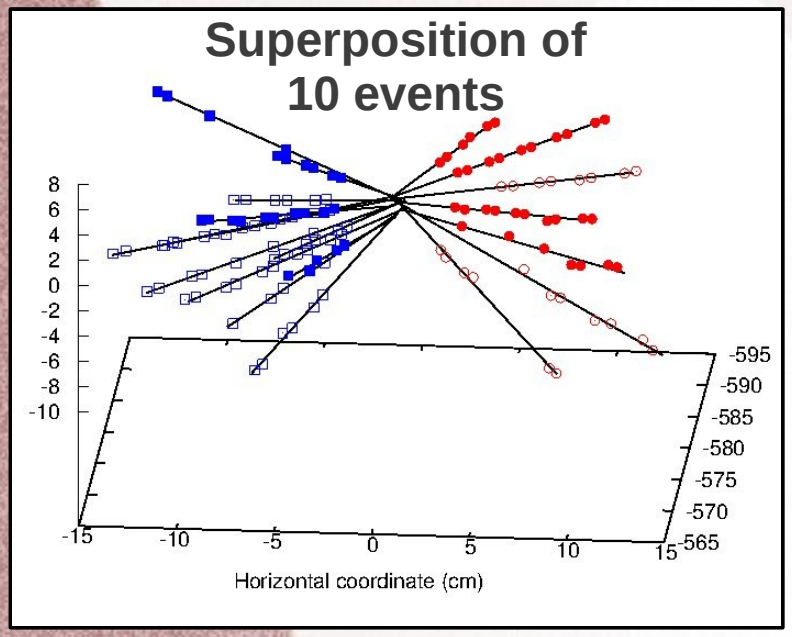
- 4 absorbers (glass-epoxy)
  - 0.5mm, 1mm, 2mm, 2.5mm
  - effective thickness depends on the angle of incidence
- Double wall:
  - Inner: 60 *μm* kapton
  - Outer: 40 *μm* mylar
- **Outer field cage**
  → 60 *μm* **kapton foil** printed with 5 *μm* Cu strips
- **Inner field cage**
  → printed on **absorbers**

# LMPD at NA61


LMPD – Jura
Target
LMPD – Saleve
FE cards
Readout MWPC
Cathode
HV cabels
Gas pipes

# Data taking with LMPD




## 2011

- Standalone data taking at "downstream position" (Pb, Al, C targets)
- Test run in "target position" with full NA61 detector system

## 2012

- Krypton calibration
- p+Pb at 158 GeV/c

**~ 10 million events**

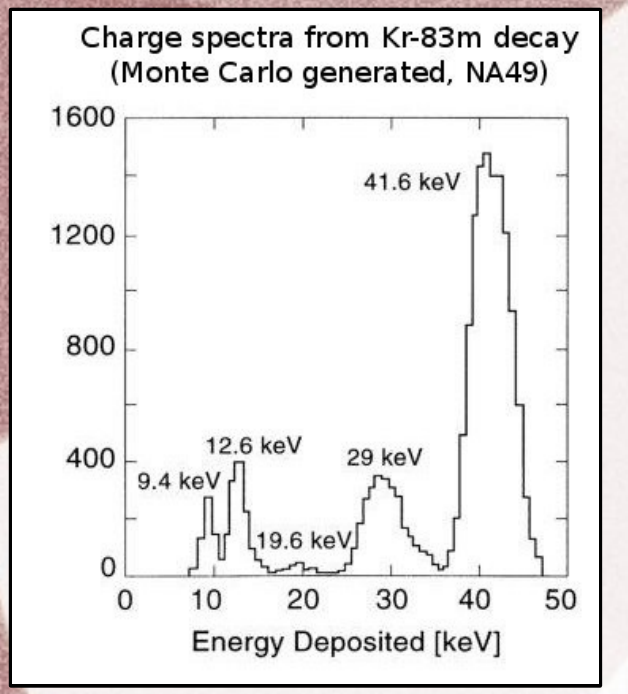
# Data taking with LMPD

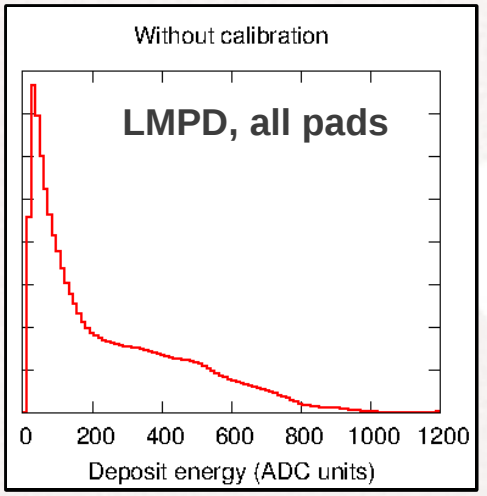
- **HV settings:**
  - *Drift voltage:* -4kV
  - *Field wires:* -400V
  - *Sense wires:*
    - **Kr run** → 970V, without resistor chain (same HV on every SW)
    - **Physics runs** → 1150V, constant voltage drop after each absorber layers

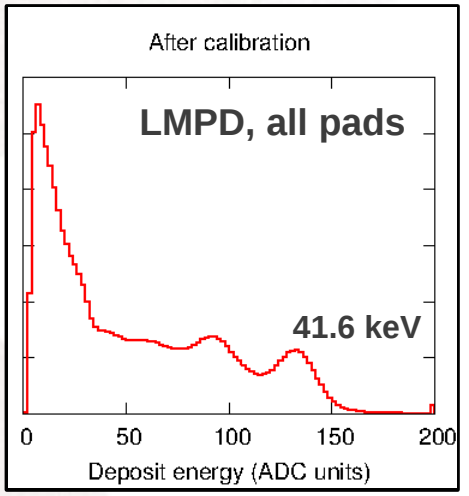
| | *Jura* | *Saleve* |
|---|---|---|
| HV | 1150 V | 1150 V |
| Layer 9-10 | 1072 V | 1092 V |
| Layer 7-8 | 1046 V | 1066 V |
| Layer 5-6 | 1020 V | 1040 V |
| Layer 3-4 | 995 V | 1013 V |
| Layer 1-2 | **970 V** | 987 V |

- **Gas-mixture:** 85% Ar + 15% $CO_2$

# Krypton calibration

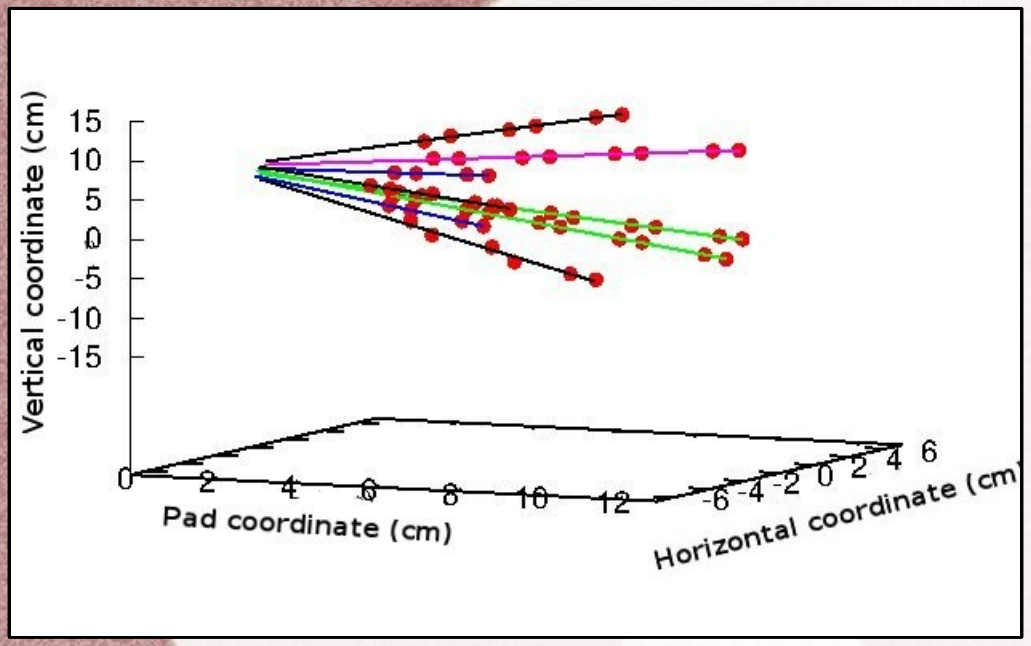


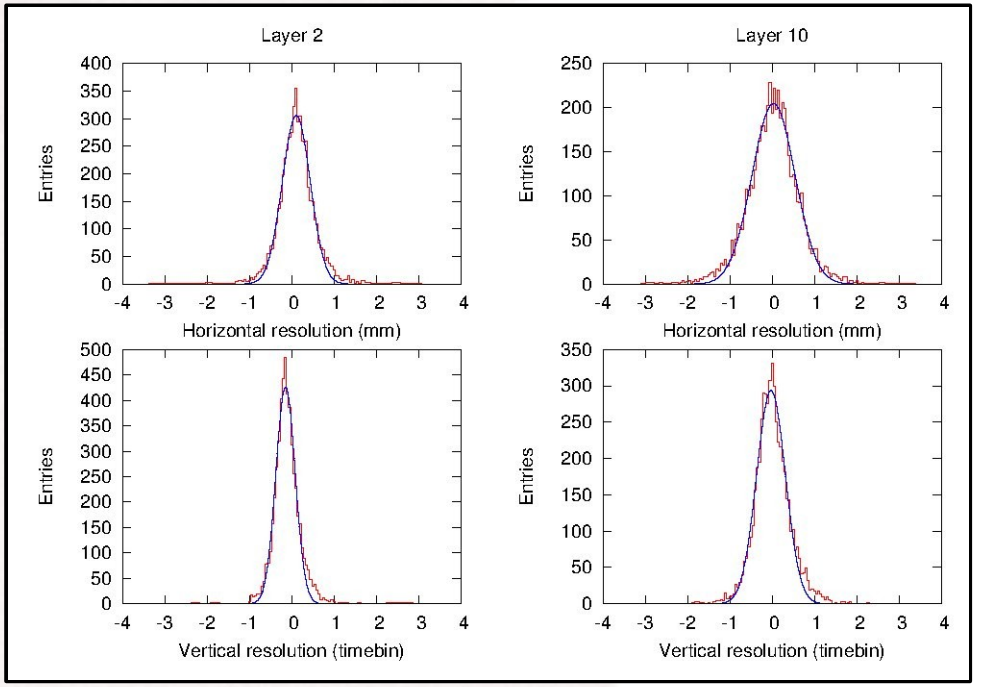




- **Relative gain calibration of the pads**
  → random trigger events with $^{83}$**Kr** source
  → $^{83}$**Rb** foil into the existing gas system via a bypass line
    - Short lifetime of $^{83m}$**Kr** gas
      → the chambers could be operated normally after few half-lives
      → no disposal of radioactive gas was necessary
- **Charge distribution** of Kr clusters on all pads in LMPD → peaks are visible after the calibration

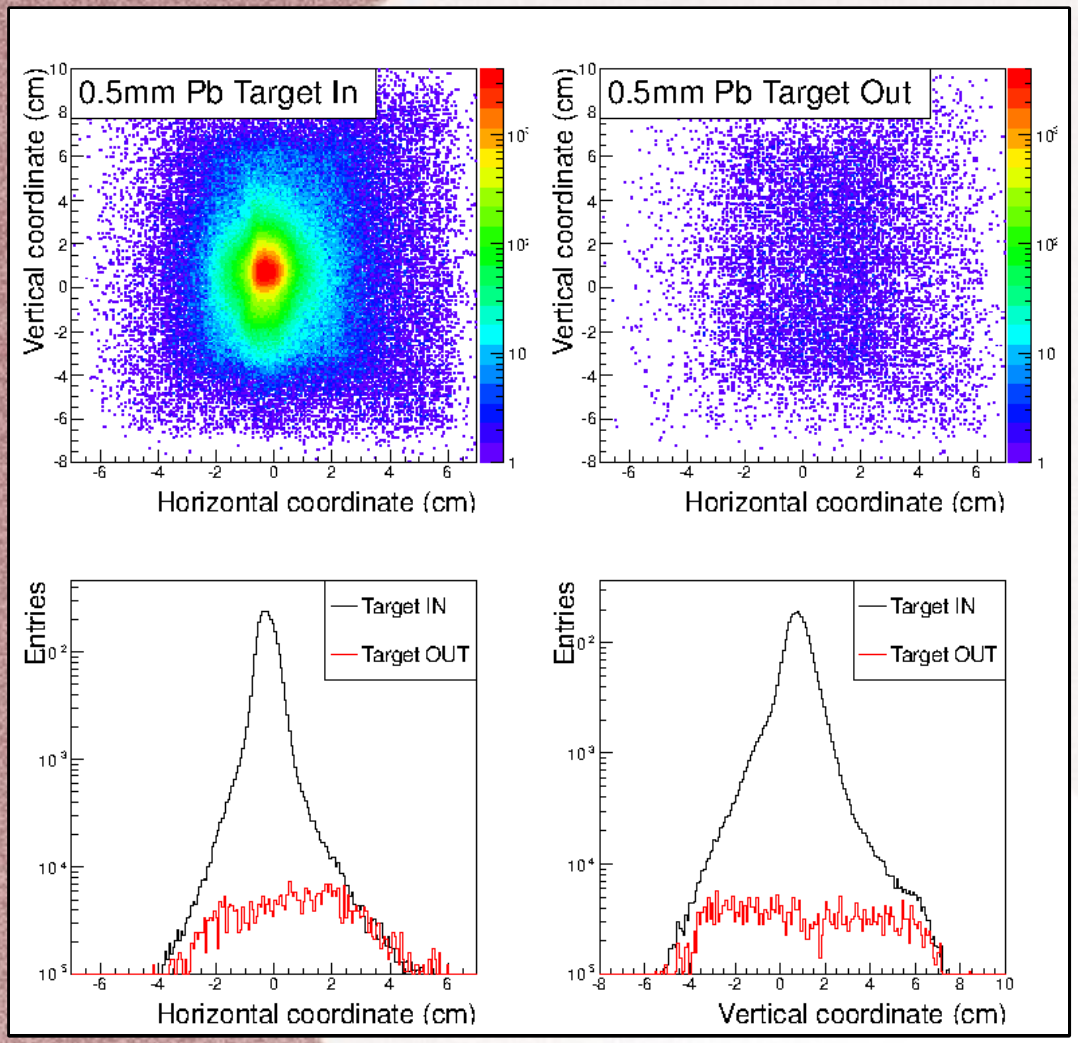
# Event reconstruction and performance




- First step → **cluster** reconstruction
- Second step → **track** reconstruction
  - **Combinatorial** track finding → *position resolution* (~1mm)
  - **Hough transformation**, combined with maximum likelihood principle

# Main vertex distributions



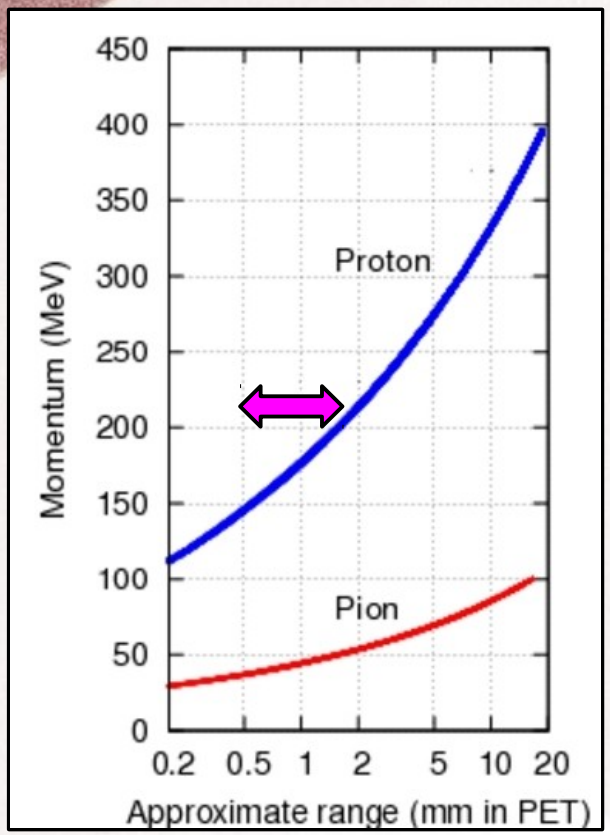

- Fitted tracks → extrapolation to the Z = const plane (intersecting with the target)

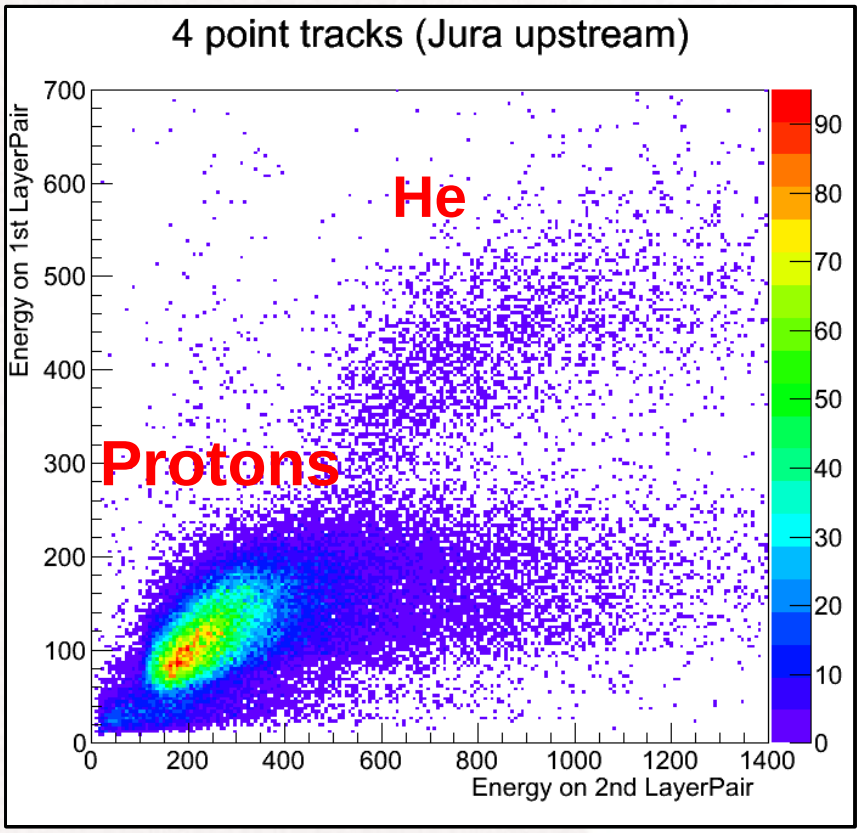
- Distributions of intersection point coordinates for “target in” and “target out” data

  → Target is clearly visible

  → empty target contamination is less than 1%

# Particle identification with LMPD




- Particle identification with LMPD → simultaneous measurement of **dE/dx** and **range**
- Particles with range *0.5 mm < r < 1.5 mm* stop in 2nd absorber
- 2D energy distribution → **proton** peak is clearly visible

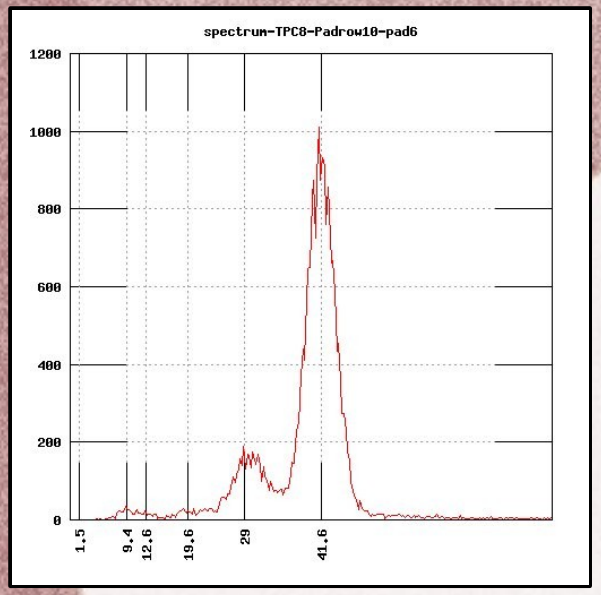
# *Summary*

- **NA61/SHINE** → fixed target experiment at CERN SPS
  → p+p, p+A and A+A collisions
- **p+Pb interactions** → centrality classes can be determined from the number of "gray" protons
- **Low Momentum Particle Detector**
  → TPC with absorber layers
  → identification of slow particles from dE/dx and range
  → *Centrality Detector* in p+Pb collisions
  → 2012: ~10 million events @ 158GeV/c
  → **data taking will be continued in the end of 2014**

***Thank you for your attention!***

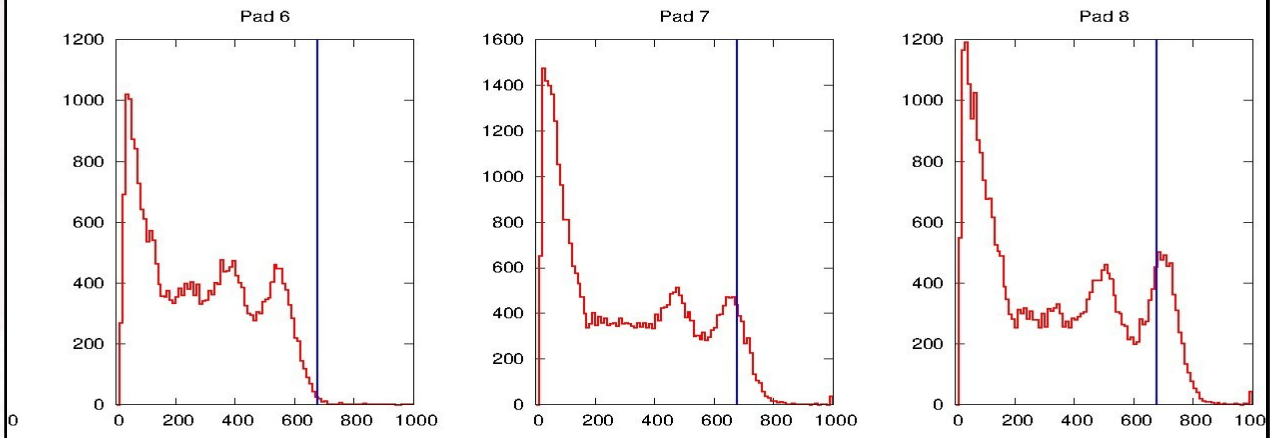
# Backup

# Kr calibration

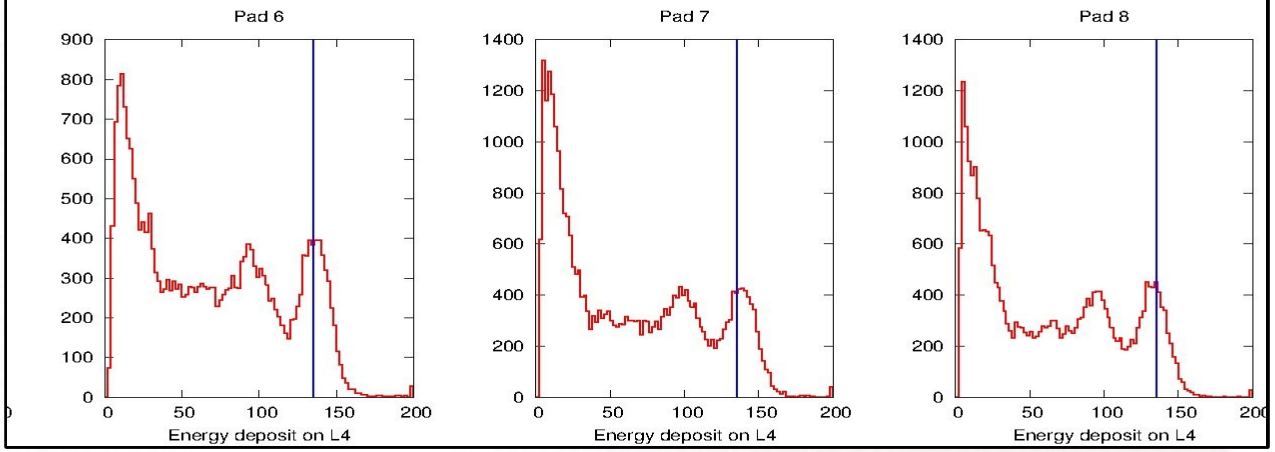



**Kr spectra in LMPD on 1 pad (3D cluster finder)**

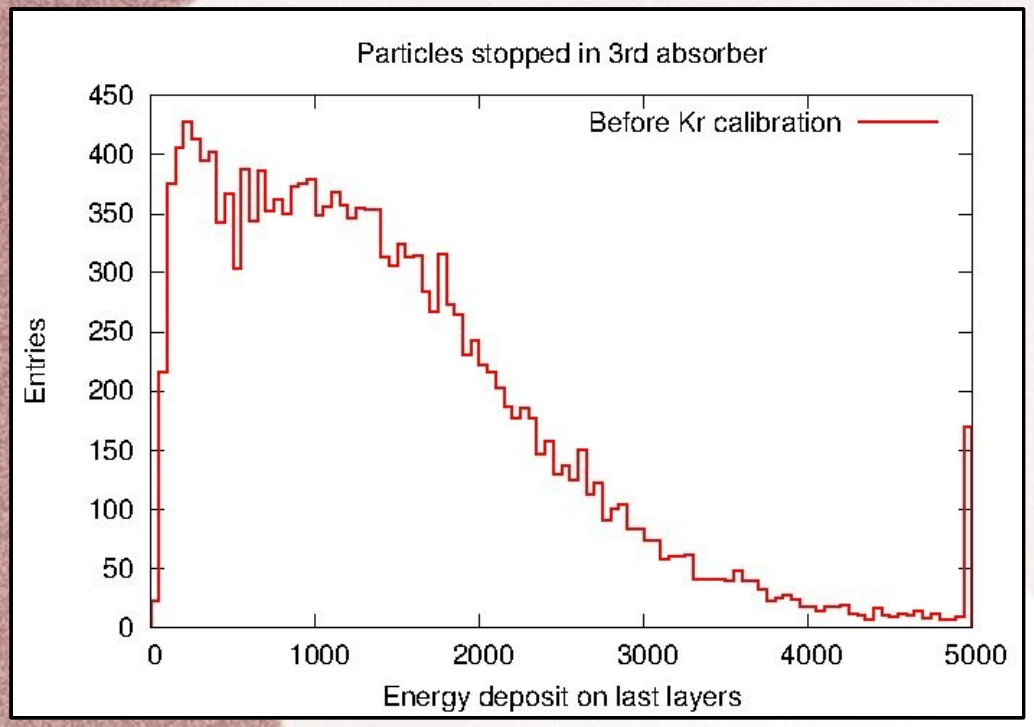
***Without calibration (1 pad, 2D cluster finder)***

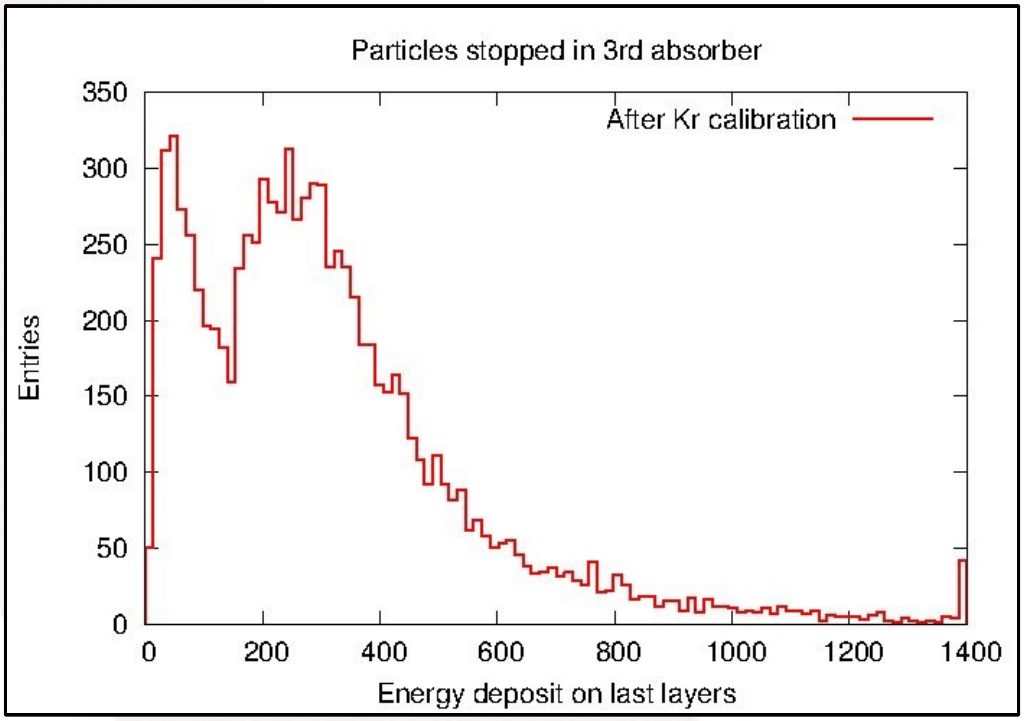



***With calibration (1 pad, 2D cluster finder)***



# Energy deposit distribution for particles stopped in 3rd absorber

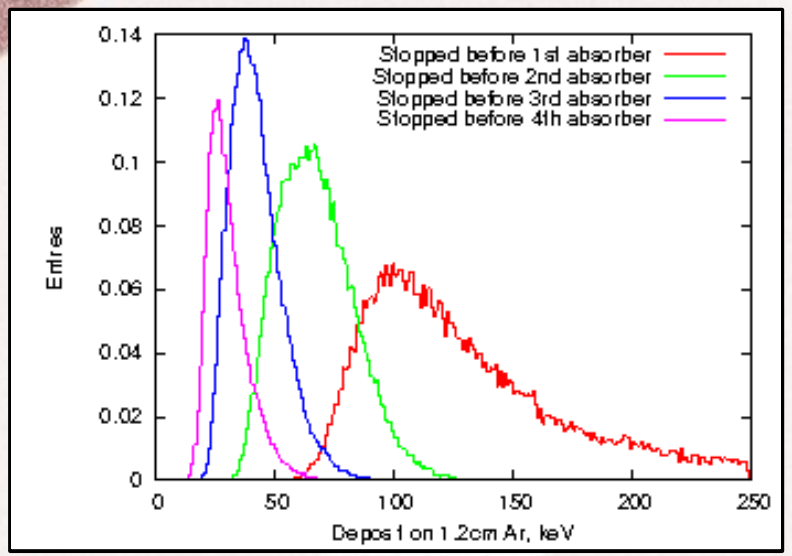


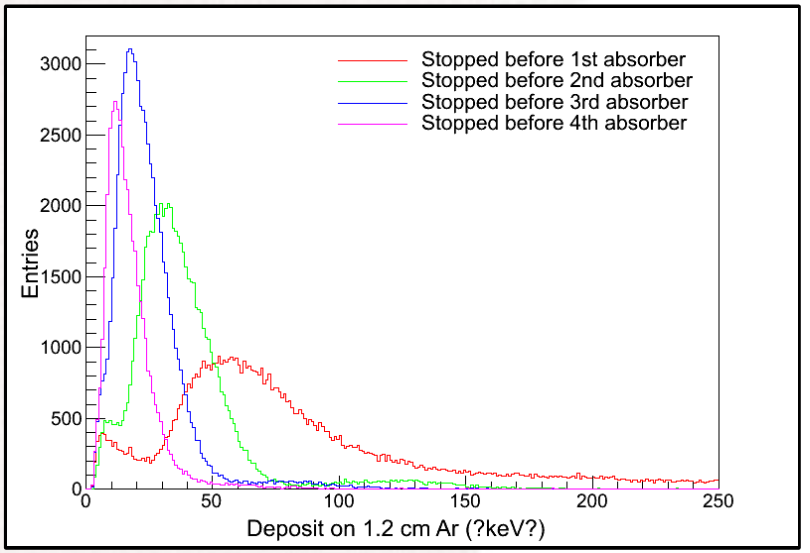




**Before Kr calibration**

**After Kr calibration**

# Comparison with PAI simulation




| Absorber number | Thickness (mm) | Thickness (g/cm2) | Cumulative thickness (g/cm2) | Momentum cutoff (MeV) | Most probable ionization |
|---|---|---|---|---|---|
| 1 | 0.5 | 0.106 | 0.106 | 127 | 100 |
| 2 | 1.0 | 0.213 | 0.319 | 171 | 63 |
| 3 | 2.0 | 0.425 | 0.744 | 216 | 38 |
| 4 | 2.5 | 0.532 | 1.276 | 250 | 26 |

**Absorber thicknesses, approximate momentum ranges and ionization (in 1.2cm Ar) for perpendicular incidence**