Physics Applications of Gaseous Detectors: R&D for ALICE and NA61

RMKI - **E**LTE **Ga**seous Detector
Research and **D**evelopment Group

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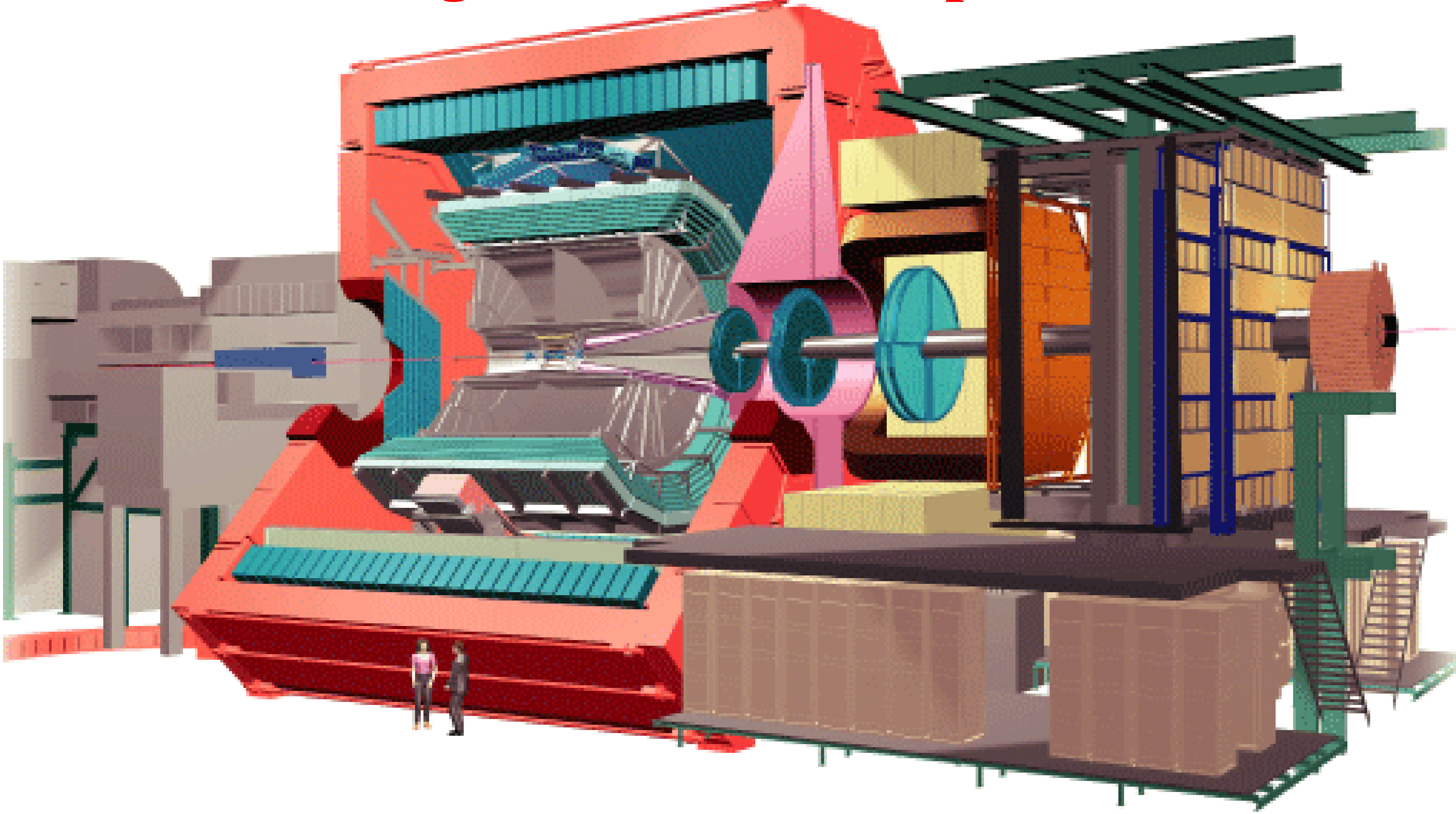
Outline

- **High P_T Trigger Detector for ALICE VHMPID**
  - **ALICE and its PID, VHMPID**
  - **Trigger detector and its requirements**
  - **Gaseous detectors**
  - **HPTD prototypes**
    - **TGEM** **(test beam, analog- digital signals, efficiency, angular smearing, sparking properties)**
    - **CCC** **(applicability, analog- digital signals, angle detection)**
- **NA61 Centrality Detector**
  - **NA61**
  - **Ideas for detecting grey protons**
  - **Test beam at PS**

ALICE

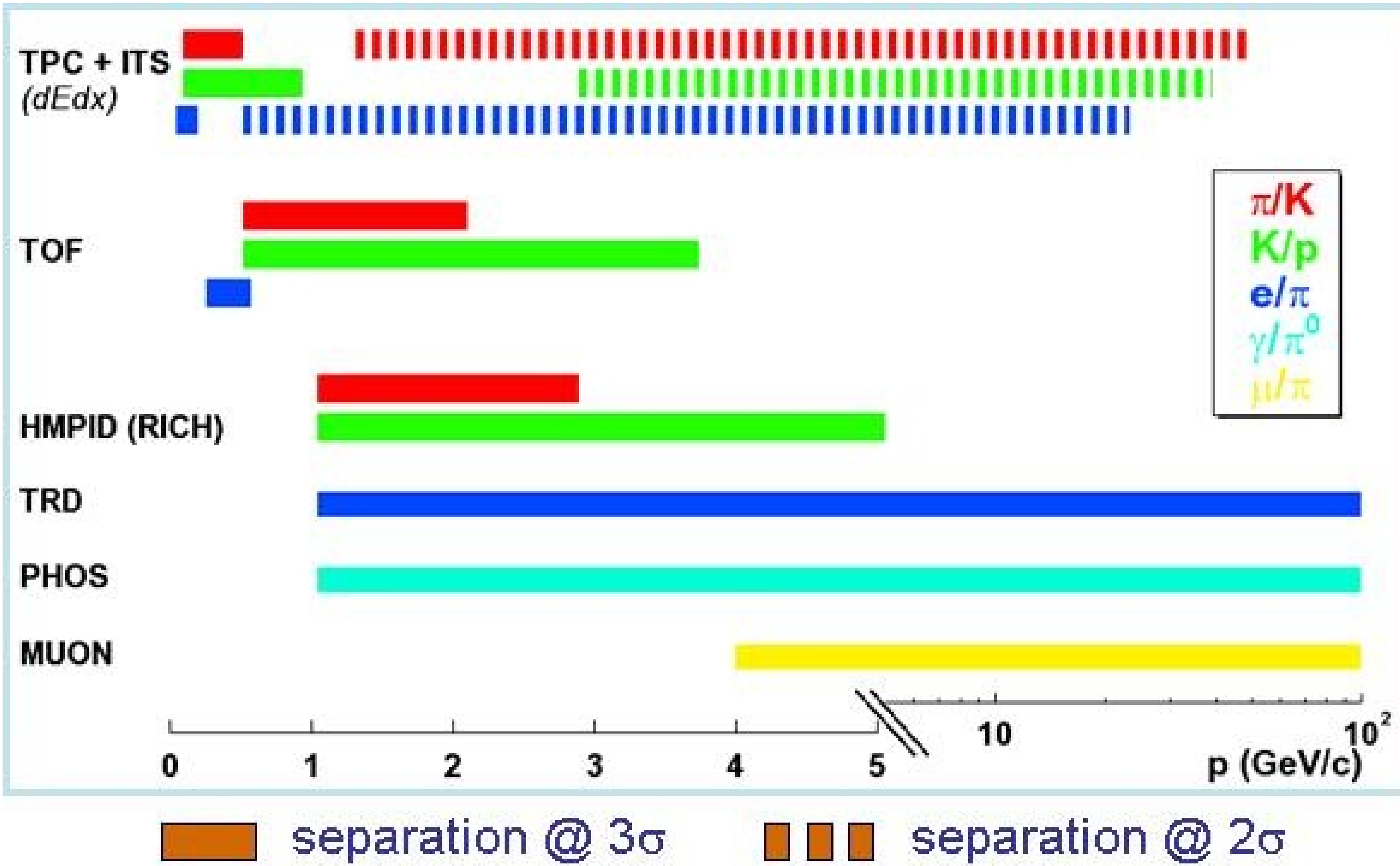
(A Large Ion Collider Experiment)



ITS, TPC, TRD, TOF, Muon Arm,   ZDC, V0, T0,

HMPID, EMCal, PHOS, VHMPID?

PID at ALICE

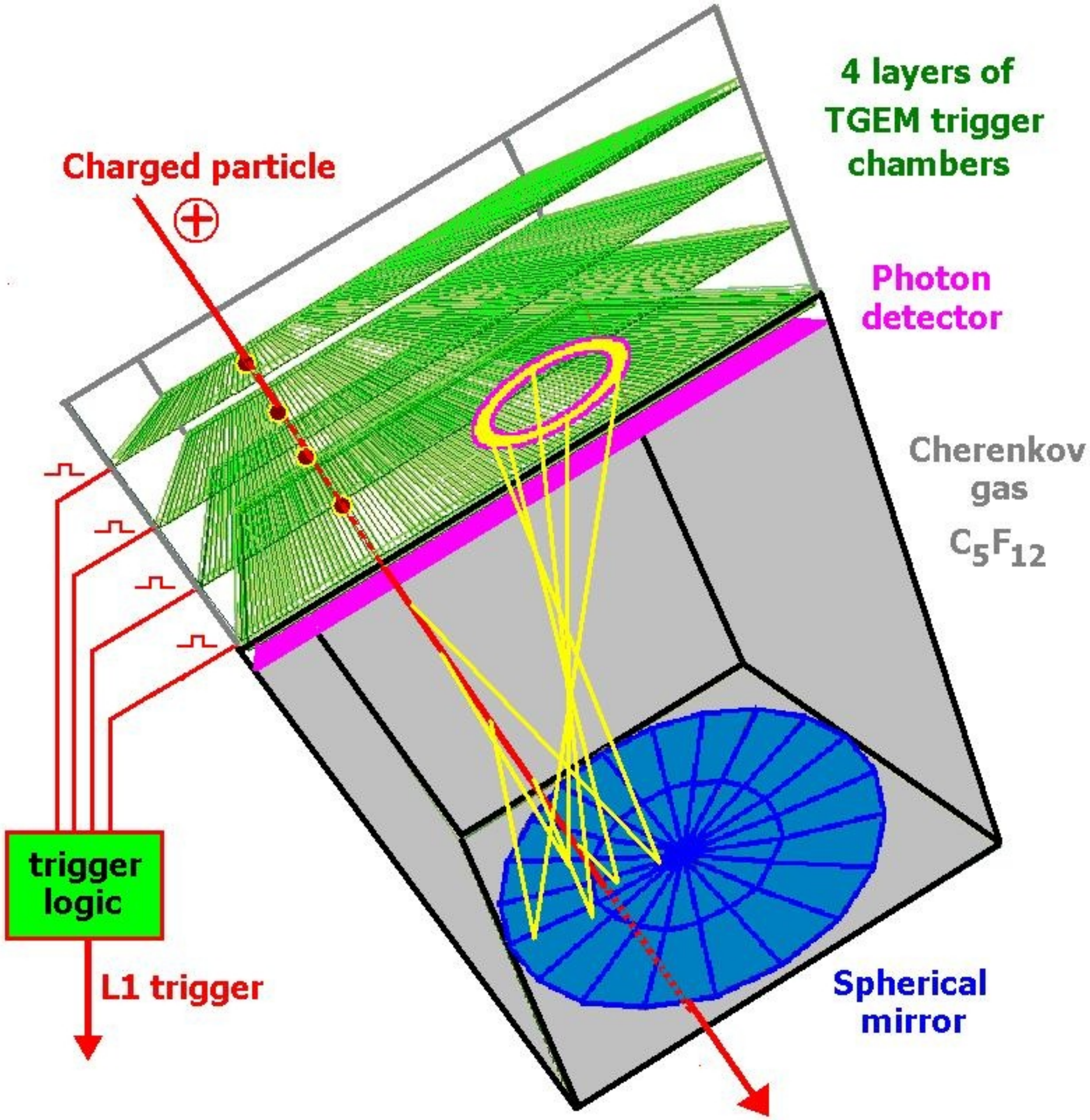


VHMPID: π,K,p separation at 5 GeV < p_T < 15 GeV

Physics motivations

- **π, K, p yields at 5 GeV < p_T < 20 GeV**
  - **P**roton/pion anomaly (~ RHIC)
  - Prticle production mechanisms (thermal,coalescence,pQCD)
  - Fragmentation function at the QGP
  - Jet energy loss, flavour dependence
  - High p_T D- and B-meson and Λ_c, Λ_b-baryon reconstruction
- **Near-side hadron-hadron correlations**
  - B-M (π-p) and B-aB (p-p) correlation (~ RHIC)
  - Di- and Multihadron FF (D_{BM} ?=? D_B*D_M ; D_B*D_{aB} ...)
- **Cooperation with other specail detectors at ALICE**
  - Near-side photon-hadron correlations : PHOS
  - Away-side jet-photon correalations : EMCAL

VHMPID in ALICE

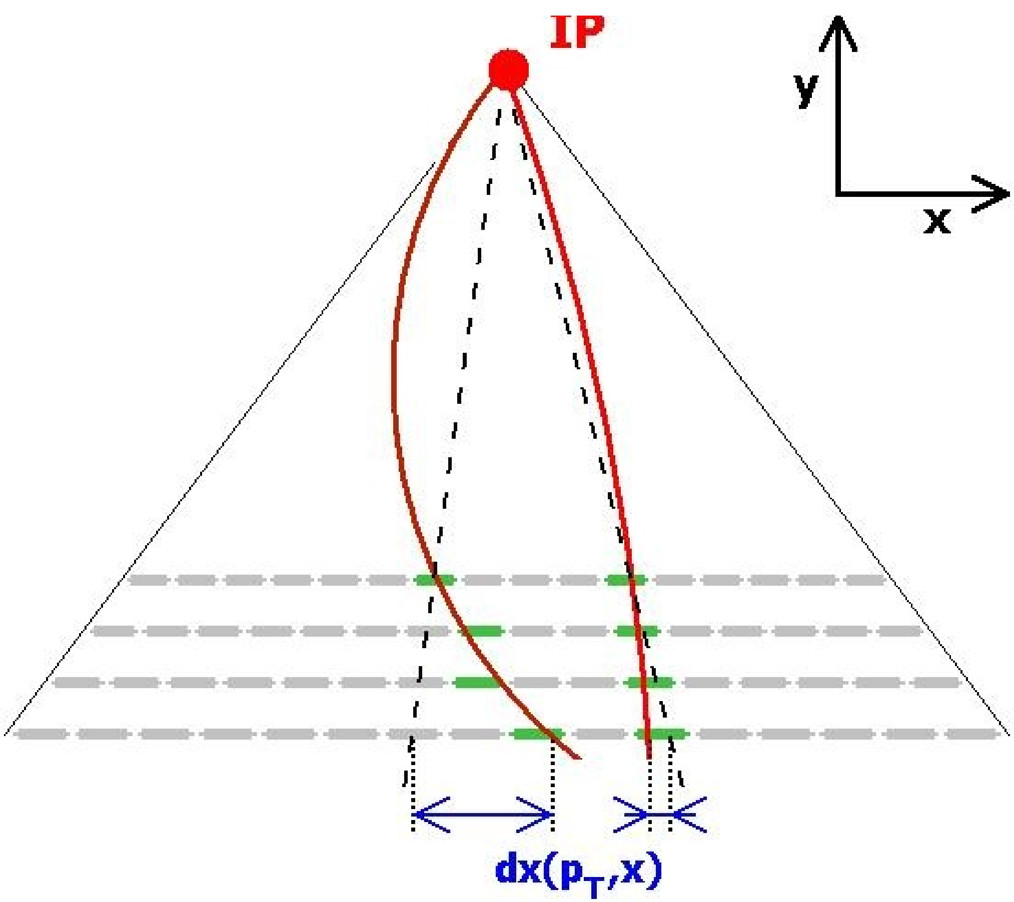


- Event by event analyses
- PID in the region:
  5 GeV/c < pT
- Cherenkov radiation:
  only gas can be used
- Mirror generated circles
- Need for an **L1** trigger:
  within 5 μs

Very High Momentum Particle Identification Detector

HPTD in ALICE

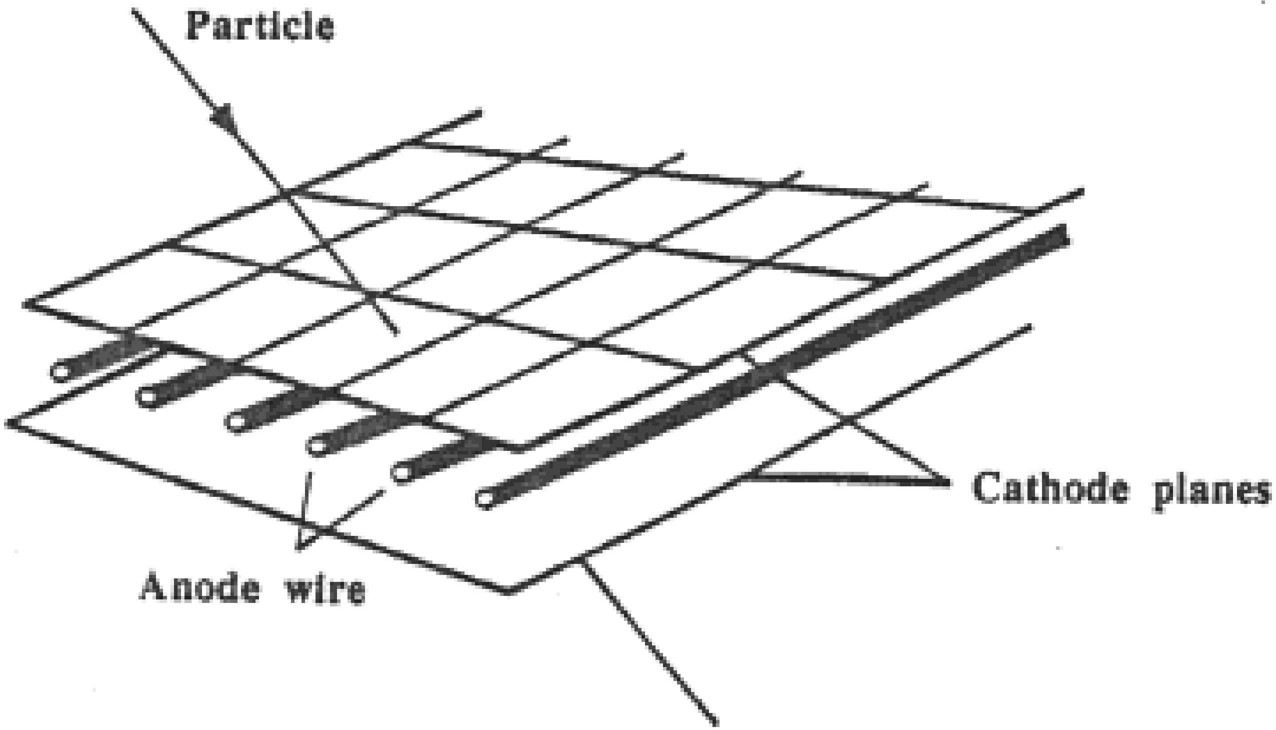
High P_T Trigger Detector



- Simple pattern recognition with FPGAs

- Measure particle inclination
- Good resolution along the direction of bending
- Pad size optimization through simulations (2-5 mm wide)
- Detector requirement
  - high granularity (pads<2cm^2)
  - high multitrack resolution
  - no amplitude meas. needed
  - narrow response function (1 pad/hit)

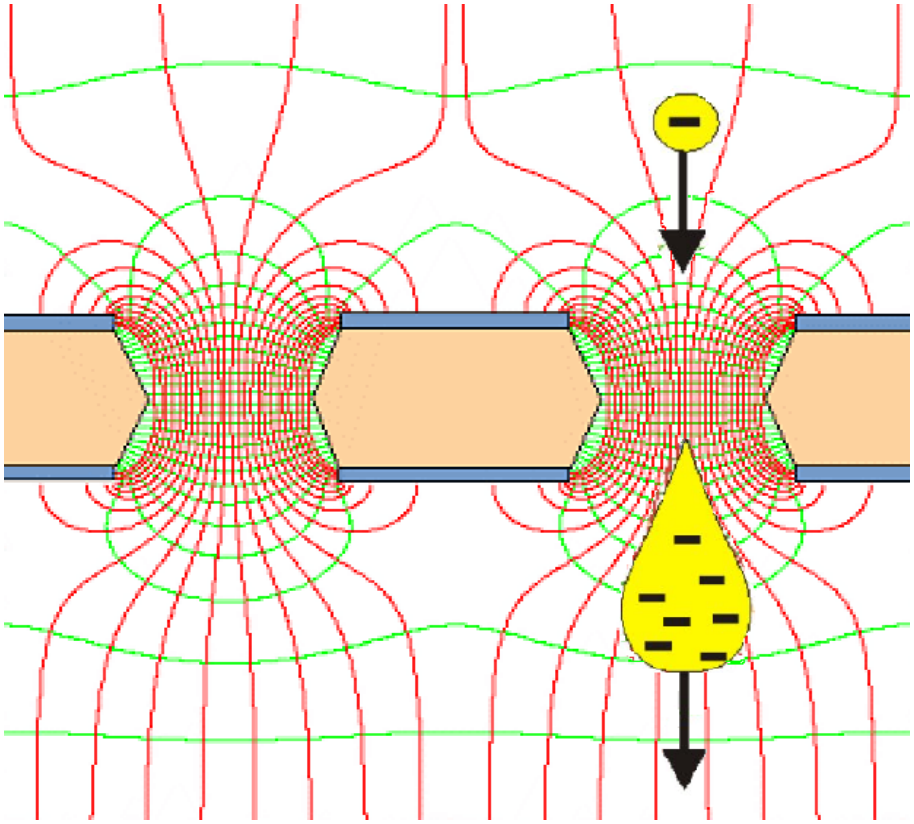
Gaseous chambers

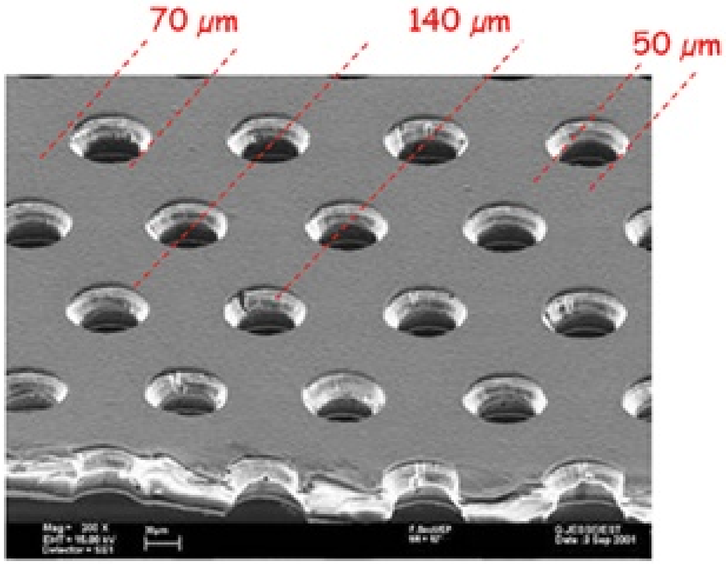


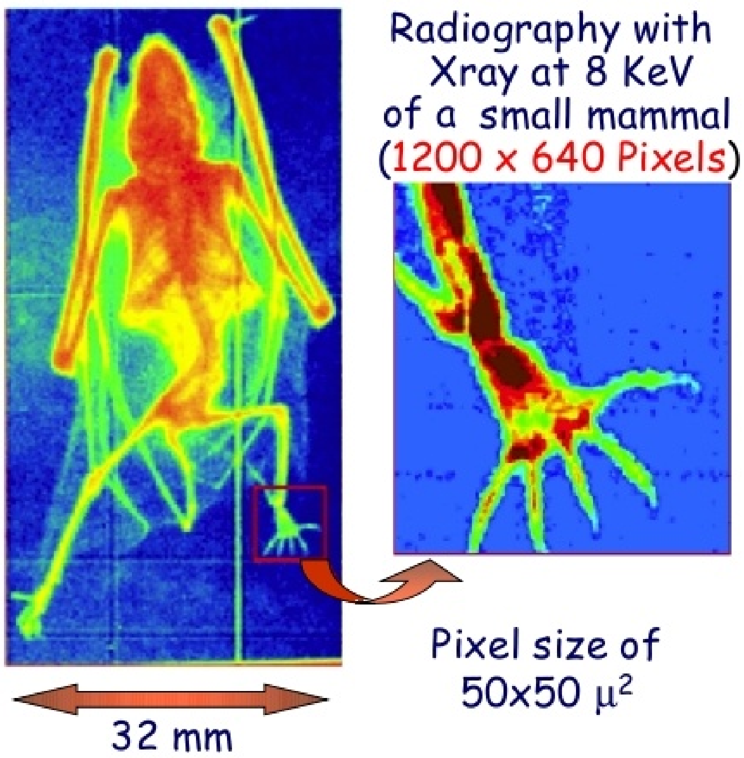
Multi-wire proportional chamber (MWPC)

- Detection of ionizing particles
  - **ionization** – total primary ionization electrons (I_0)
  - high voltage – acceleration of electrons
  - avalanches – **gain** : G electons per primaries
  - $G*I_0$ **detectable** by electronics
  - slow ions – space-charge effect

GEM technology







GEM = Gas Electron Multiplier

GEMs are copper covered kapton foils with plenty of small holes.

Thick GEM, Resistive Thick GEM

Technological possibilities for HPTD

- MWPC
  - \+ stable performance, relatively cheap
  - \- wide response function, difficult construction
- GEM
  - \+ vulnerable (not spark protected), expensive
  - \- good resolution (but we do not need it)
- TGEM, ReTGEM
  - \+ tolerates sparking
  - \- technological difficulties at large area, expensive, sparks
- "Close Cathode" Chamber
  - \+ narrow response function, easy construction, cheap
  - \- still under R&D
- MicroMegash, ...

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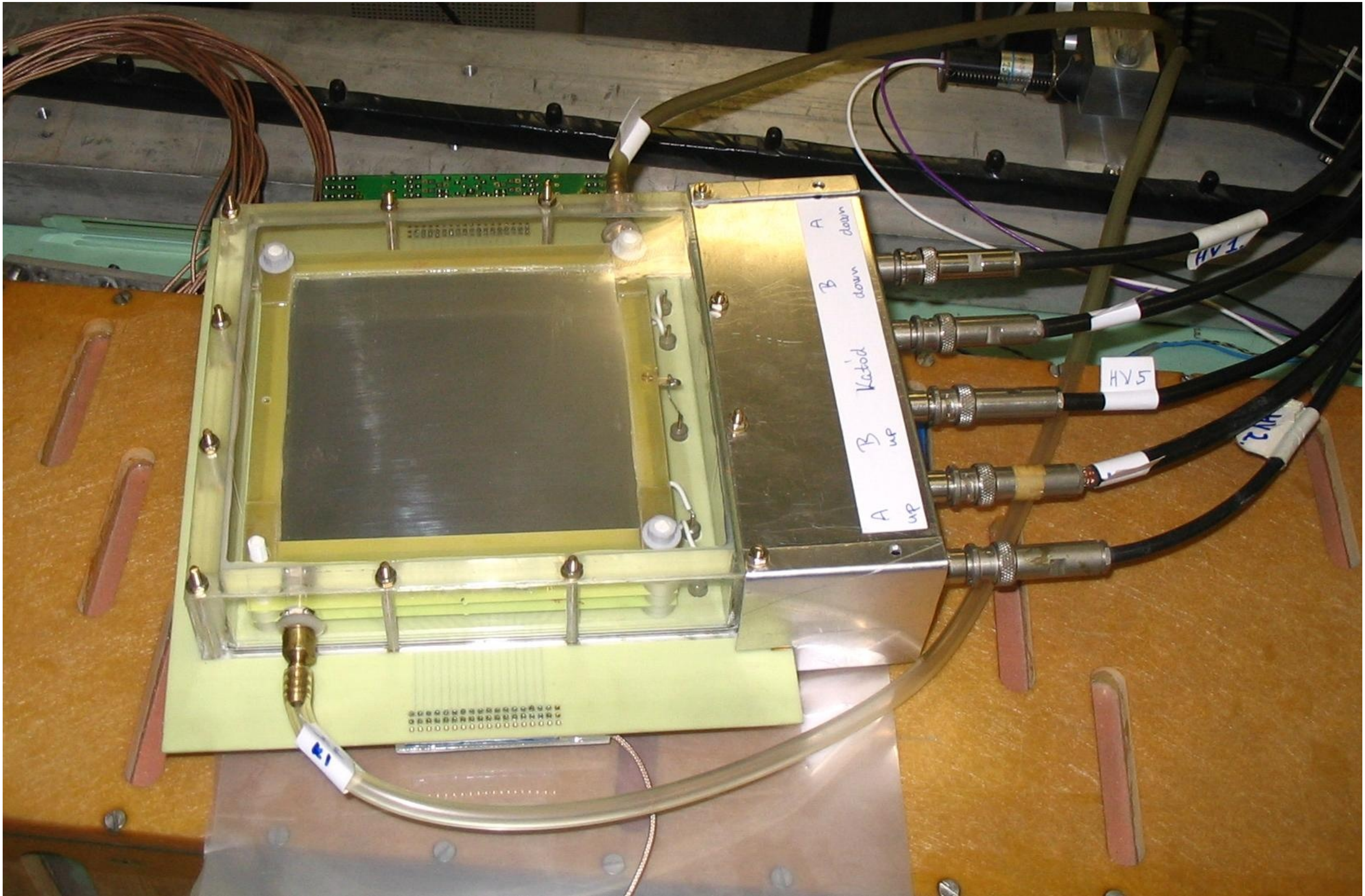
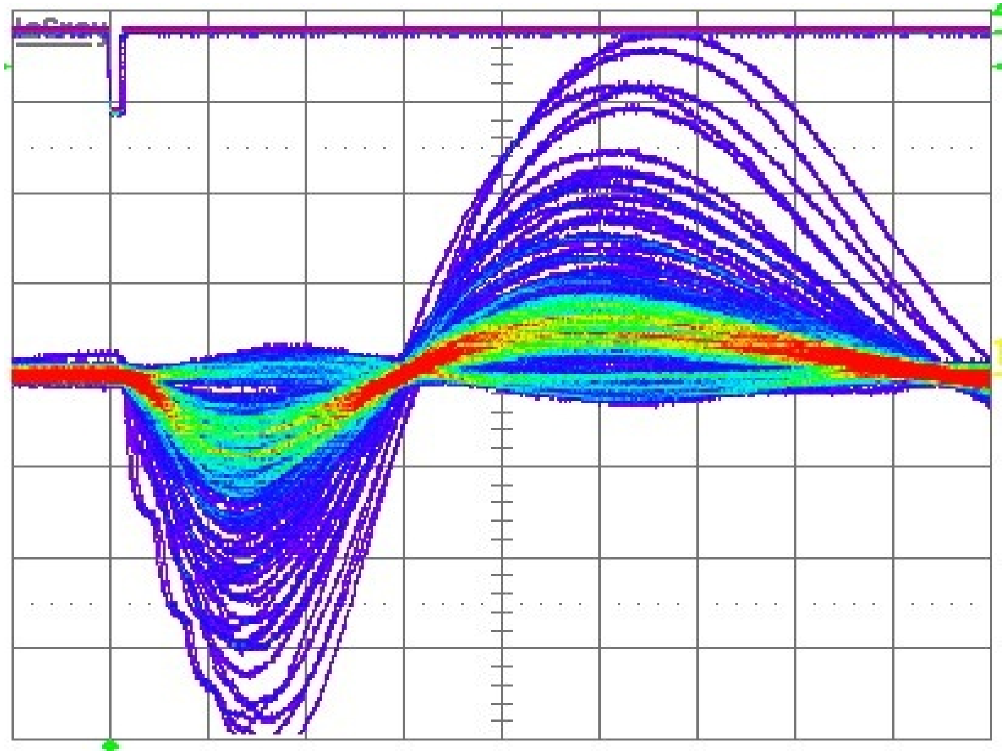
HPTD prototype with TGEMs



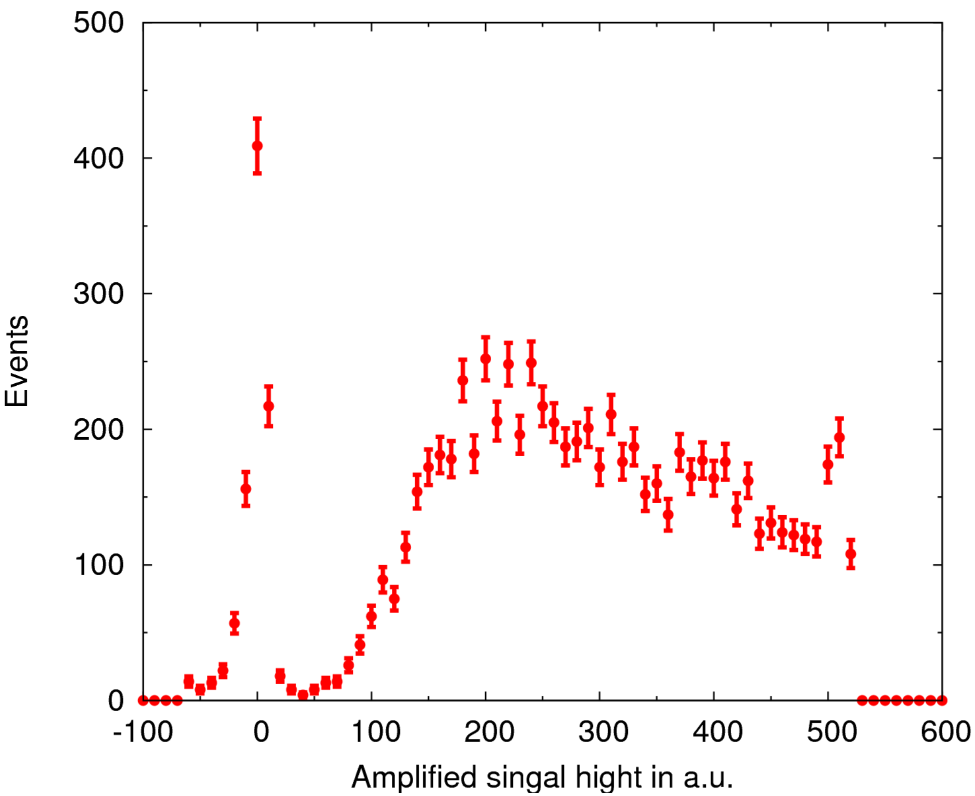
PS test beam main studies

- **Analog vs. 1 bit digitalized multiplex readout**
- **Threshold for the 1 bit digital outputs**
- **Cross talk between the neighbouring pads**
- **Chambers' High Voltage optimization**
- **Angle study (from 0° to 60°)**
- **Absorber study (from 5mm Al to 25mm Pb)**
- **Spark study vs. Rate and HV**
- **Gas mixture study (gas: Ar with 20%,10%,5% CO_2)**

Analog signals

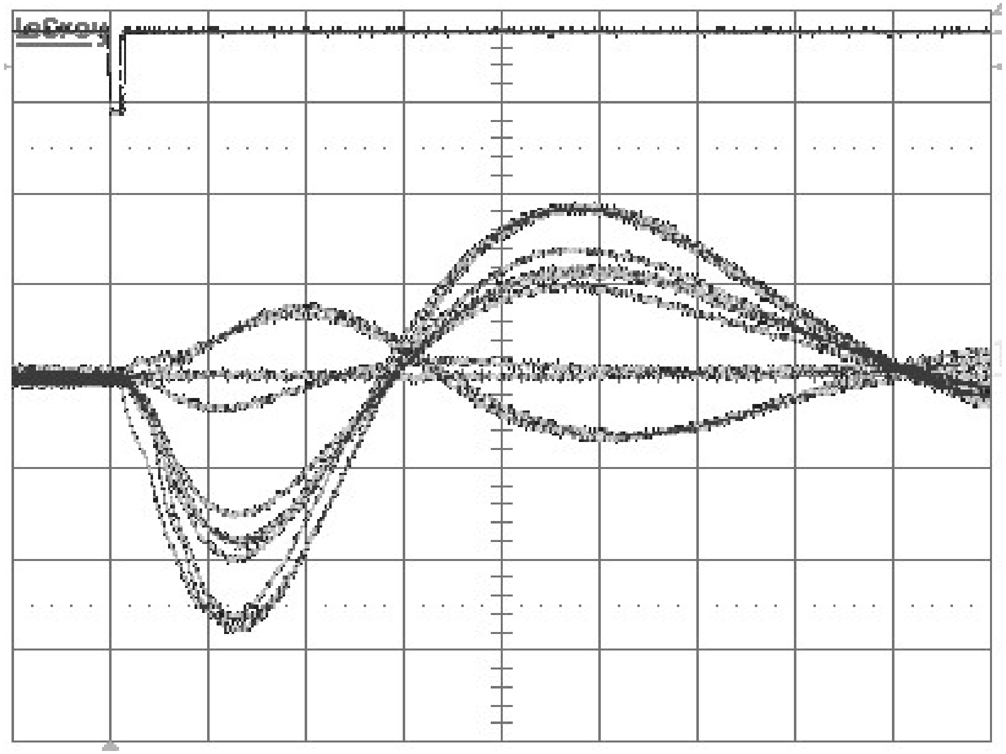


- Pre-amplified signals from the analog readout
- Perceptible signal and noise

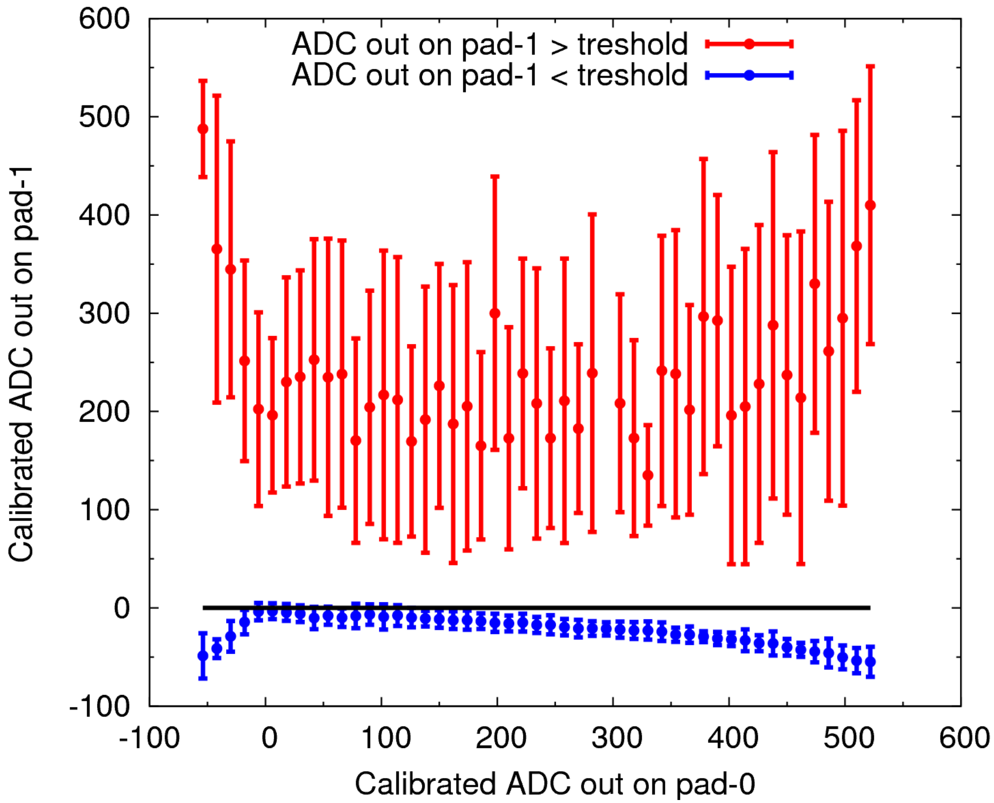


- Noise + Landau
- No need for high dynamic range (discrimination)

Correlations, cross-talk

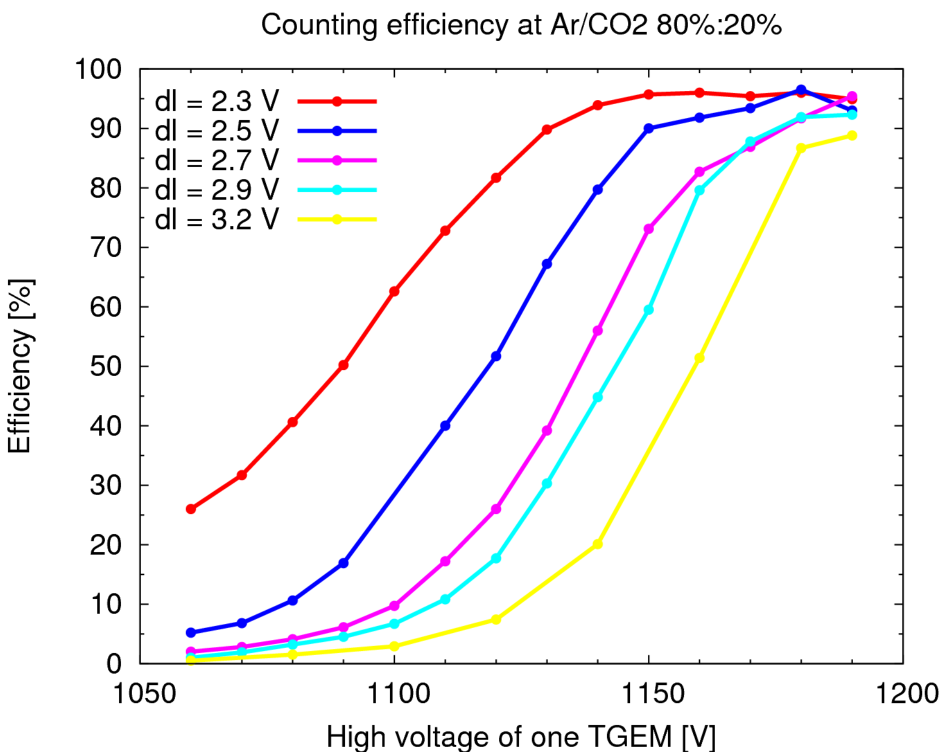


Expected positive correlation:
- **Diffused electron avalanche spreads onto two pads**

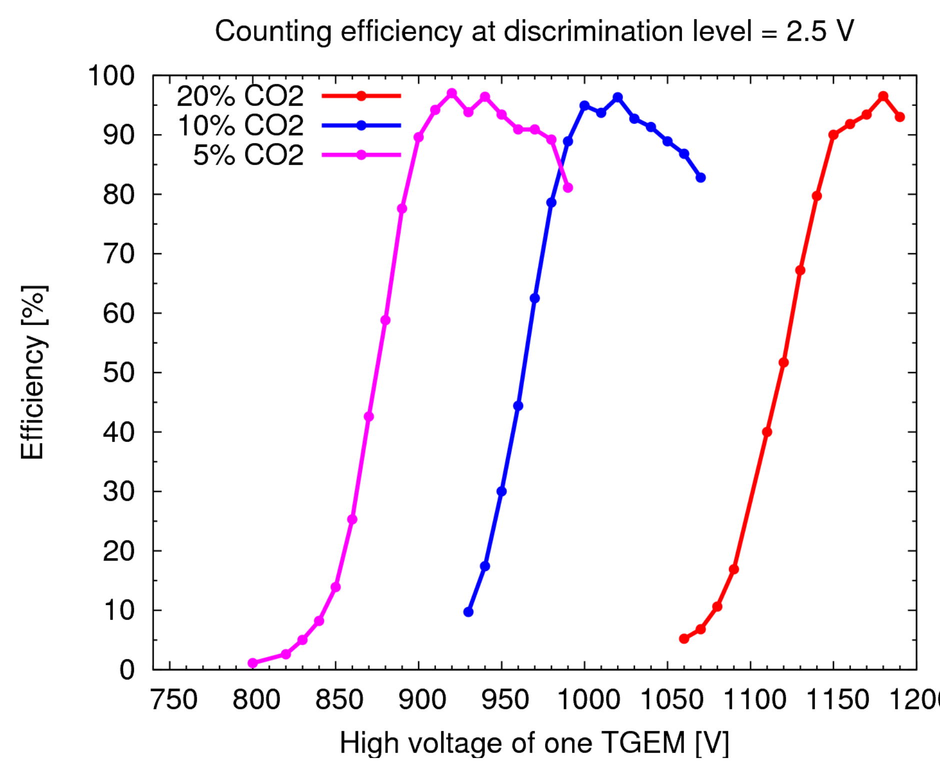


Negative correlation:
- **Capacitive connection between pads, (well measurable)**

Counting efficiency



- Full efficiency at around gain $2*10^3$
- Discrimination level opimization



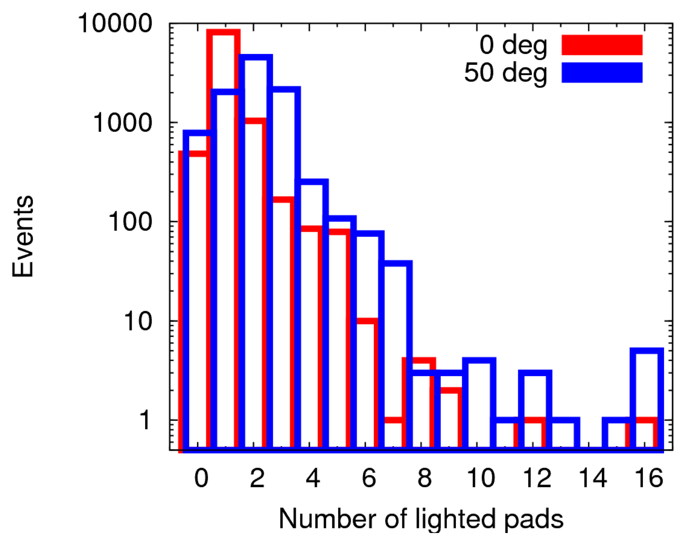
- Efficiency curves for different gas mixtures
- Fall of efficiency at high voltage due to sparking

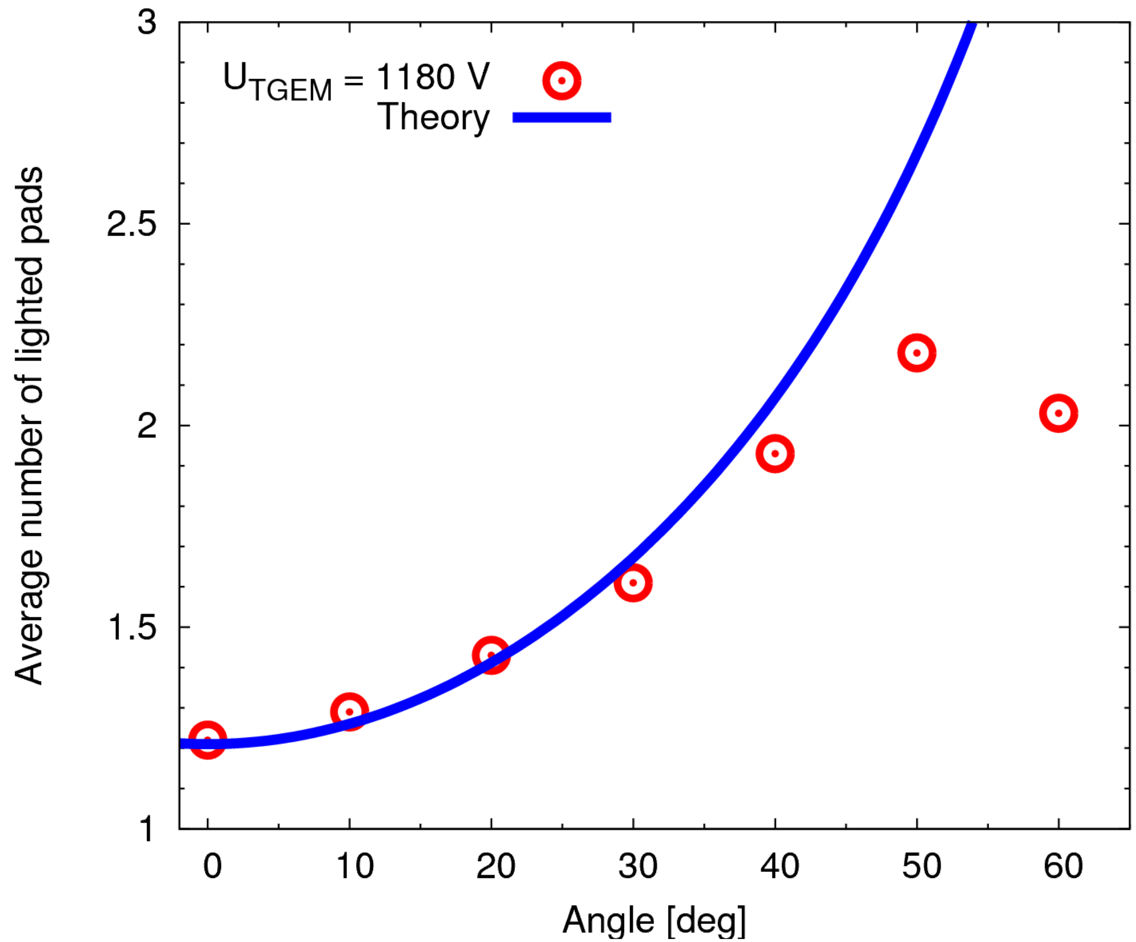
Angular smearing

- The theoretically ideal case smearing becomes

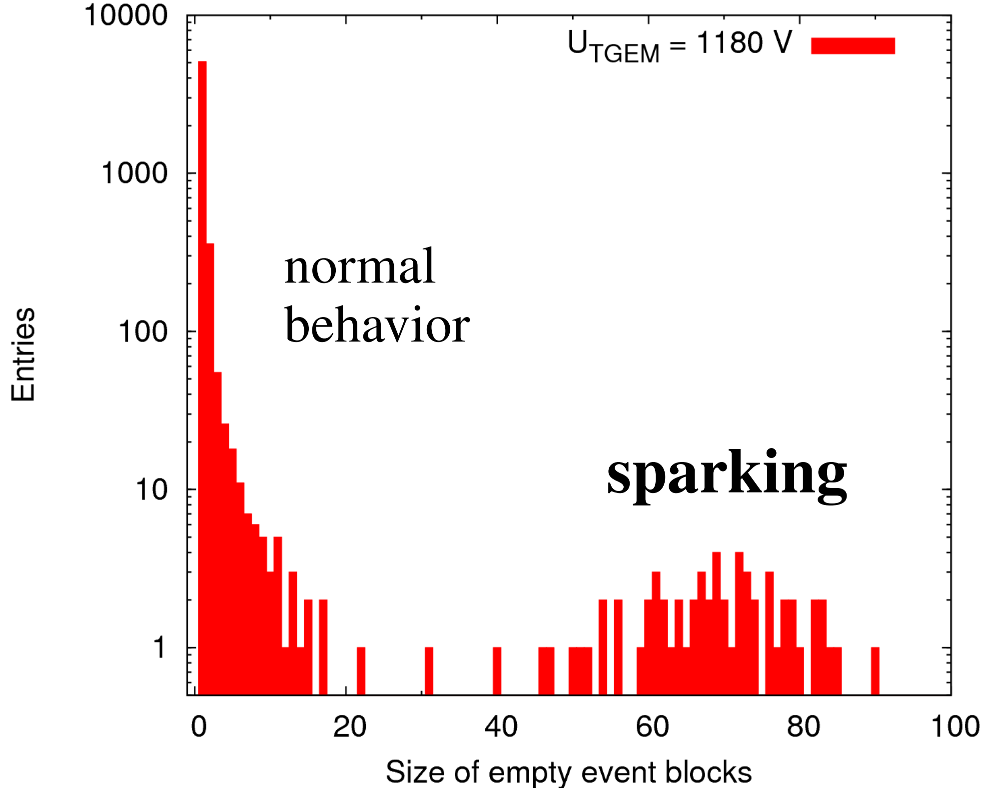
$$\langle n \rangle_{\alpha}^{2} = \langle n \rangle_{0}^{2} + (2 * \tan \alpha)^{2}$$

- At large angle
  - ΔE/pad decreases
  - efficiency falls

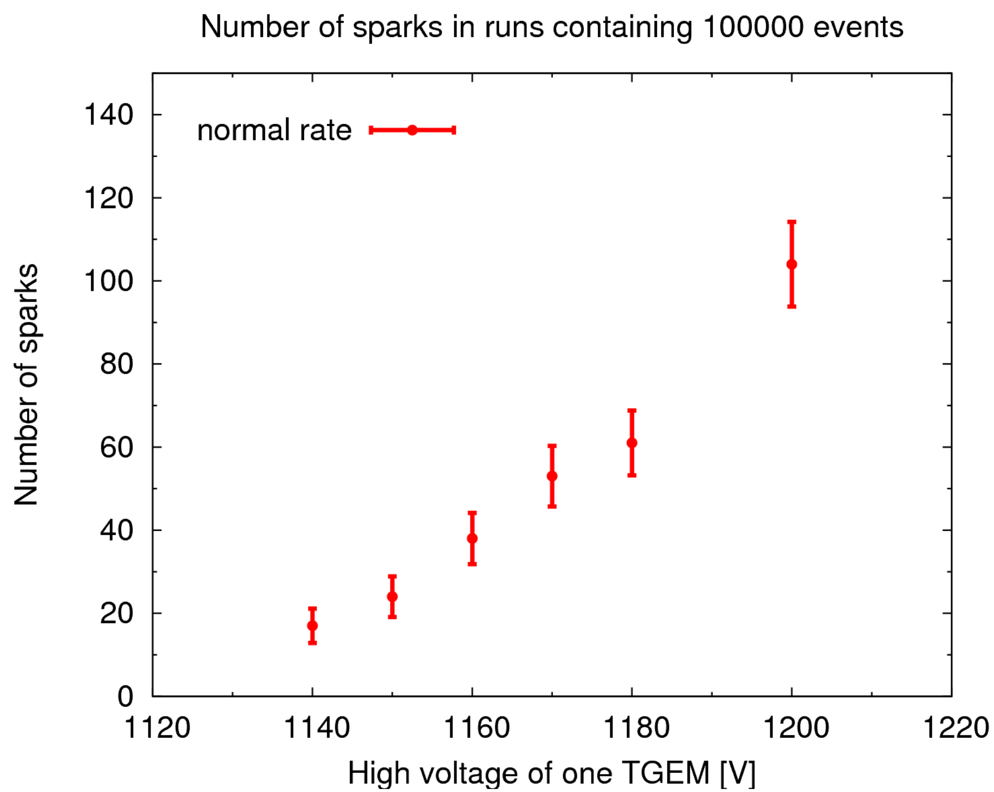




Spark study

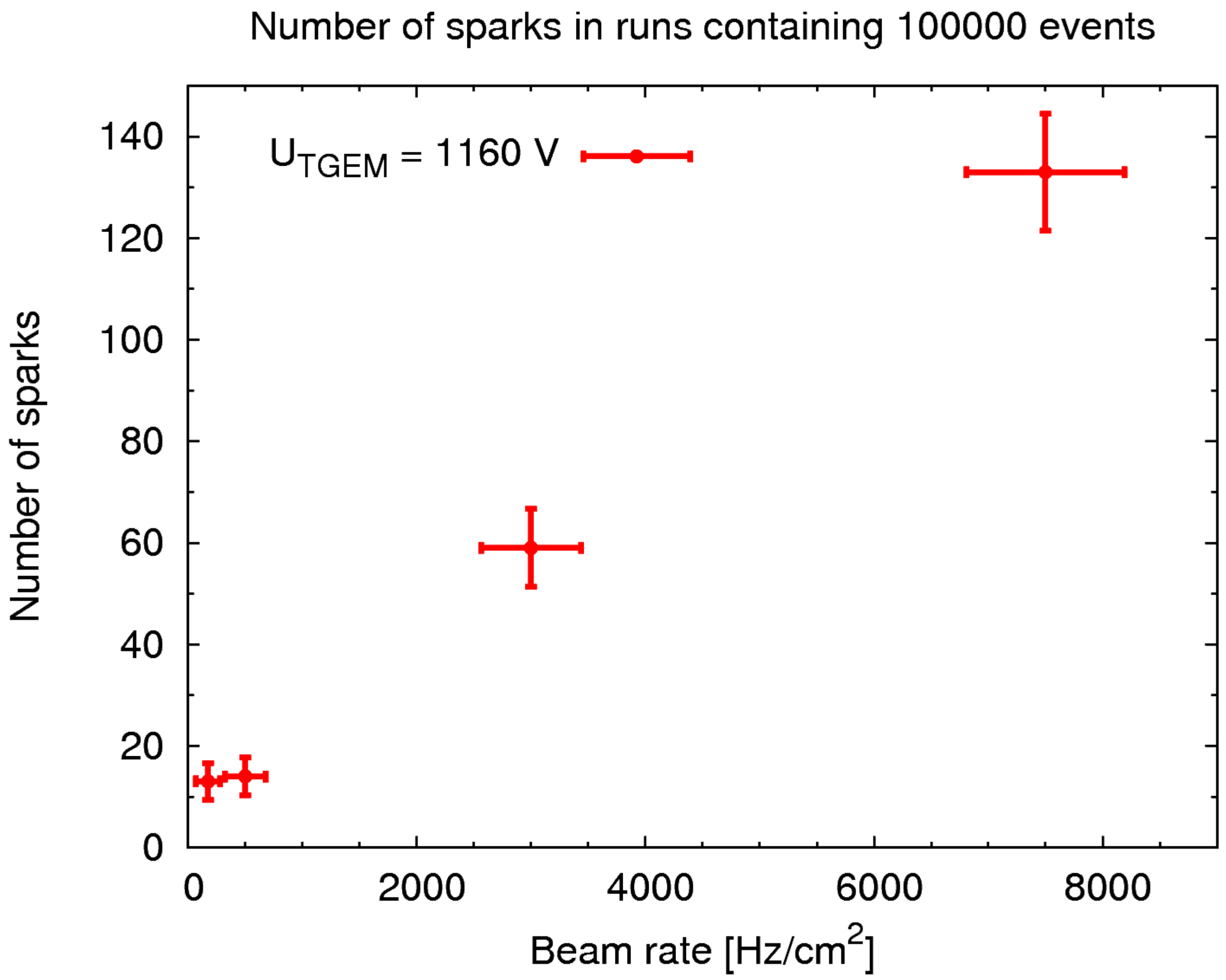


- "Offline" spark observation as long sequence of empty events



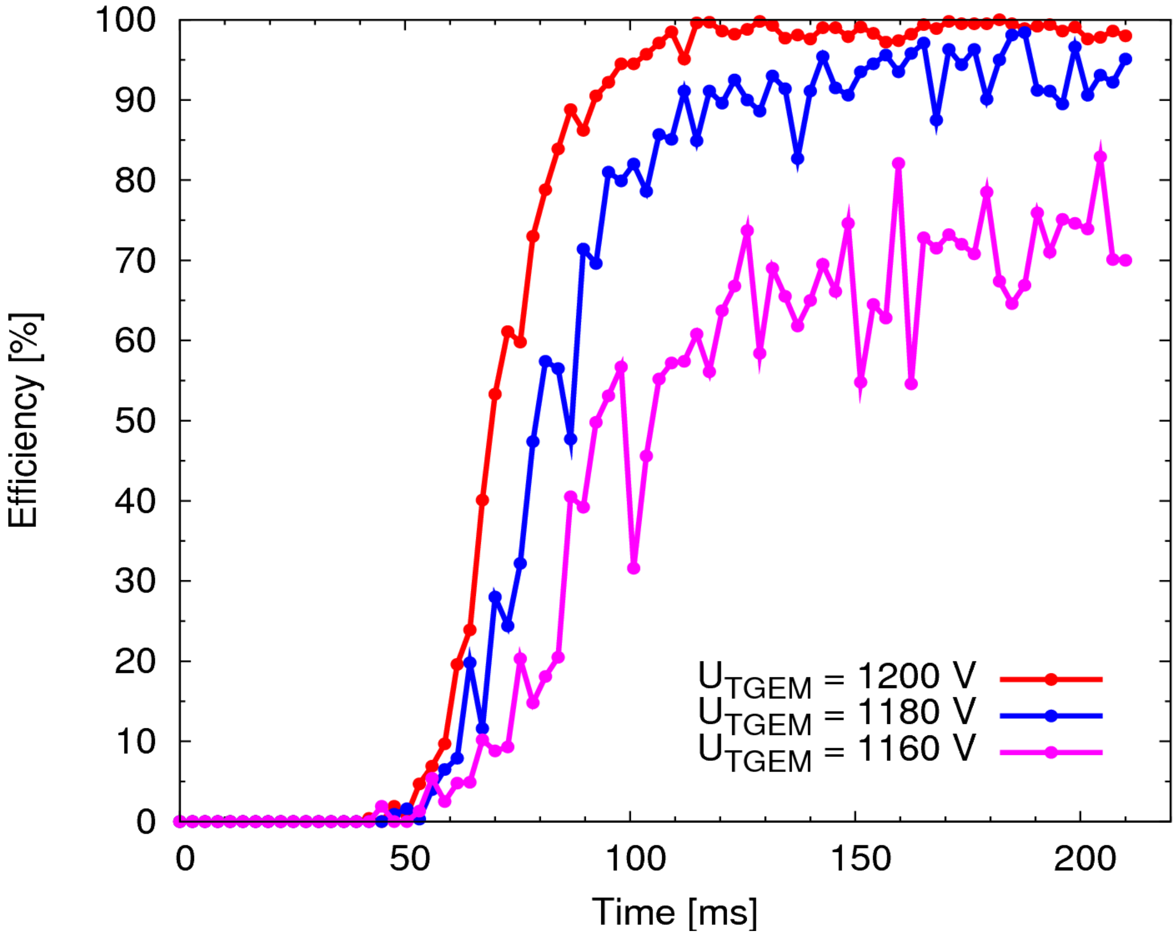
- Sparking probability correlated to gain (known from earlier studies)

Spark study



Sparking probability proportional to rate (gain = $2*10^3$)

Recovery after sparking



- 10 MOhm resistors in HV divider chain,
  1 nF TGEM capacitance => 10 ms timescale
- 100 ms total recovery time

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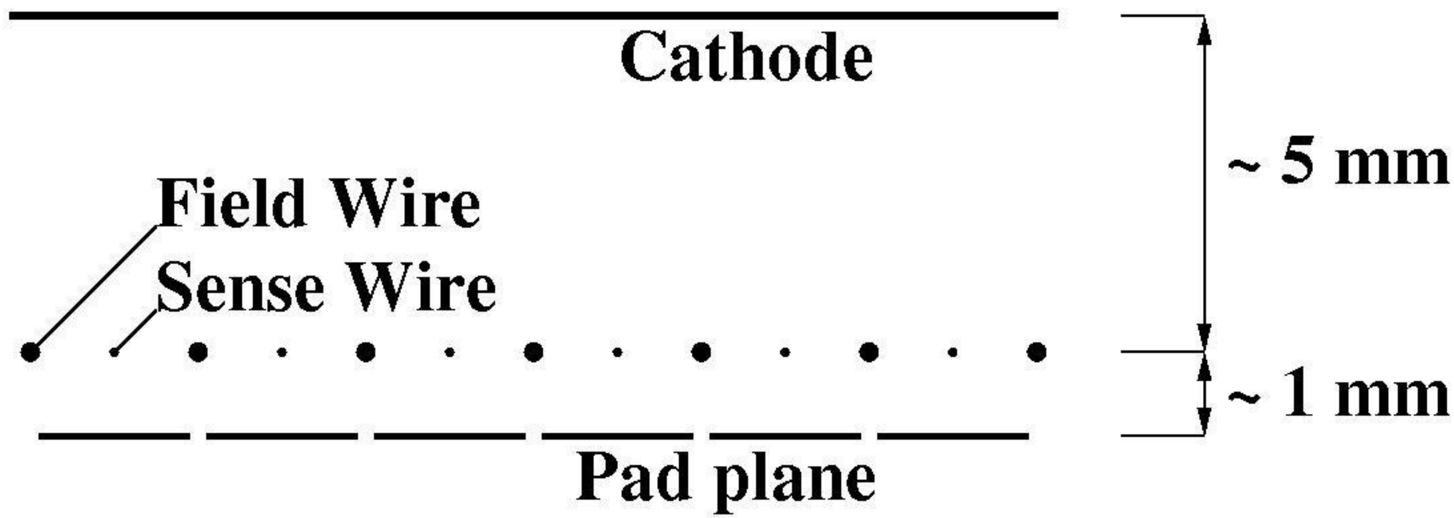
Close Cathode Chamber

New development of the ELTE-RMKI Collaboration

(proposed by D.Varga)

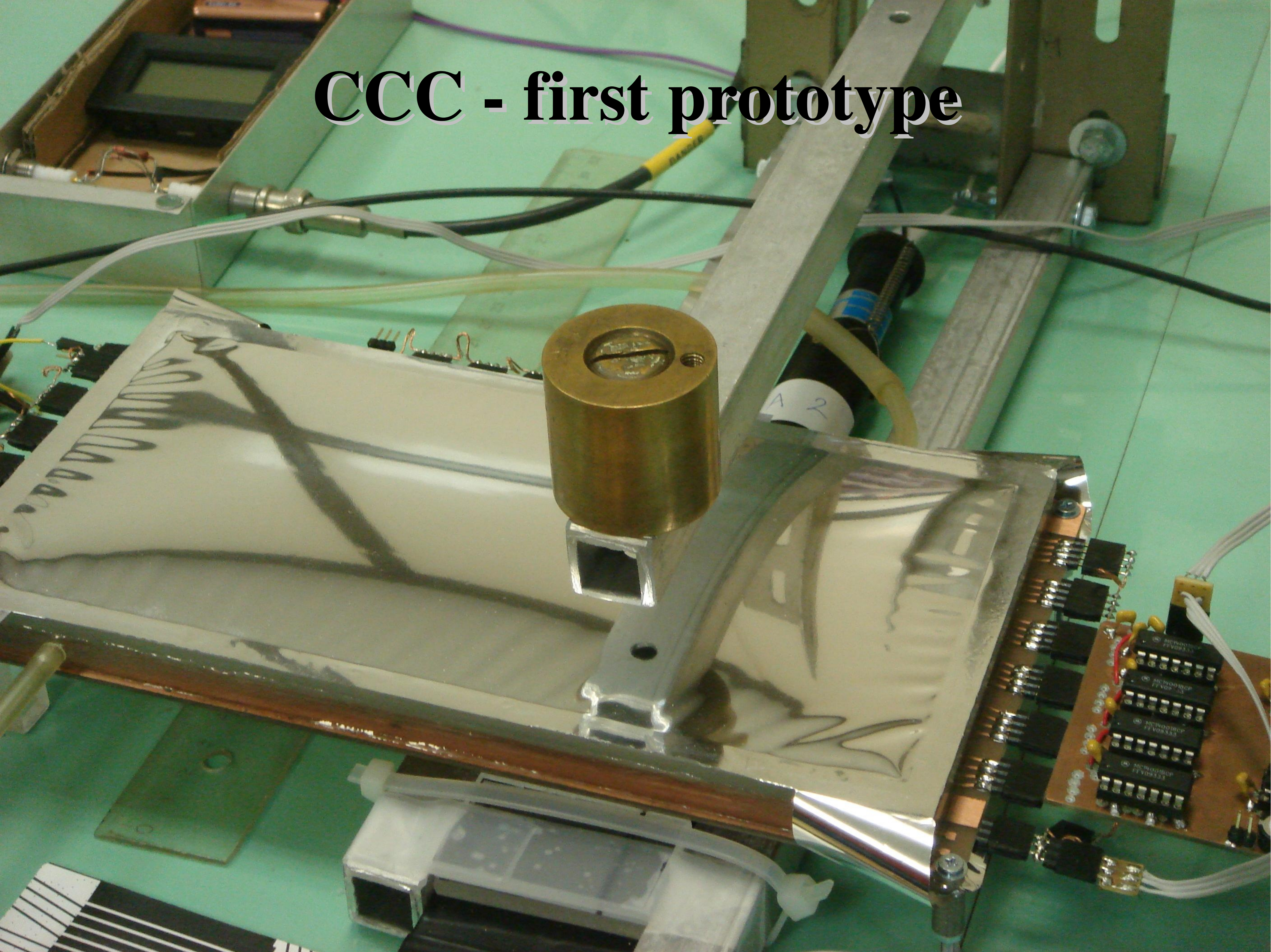


- Main parameters:

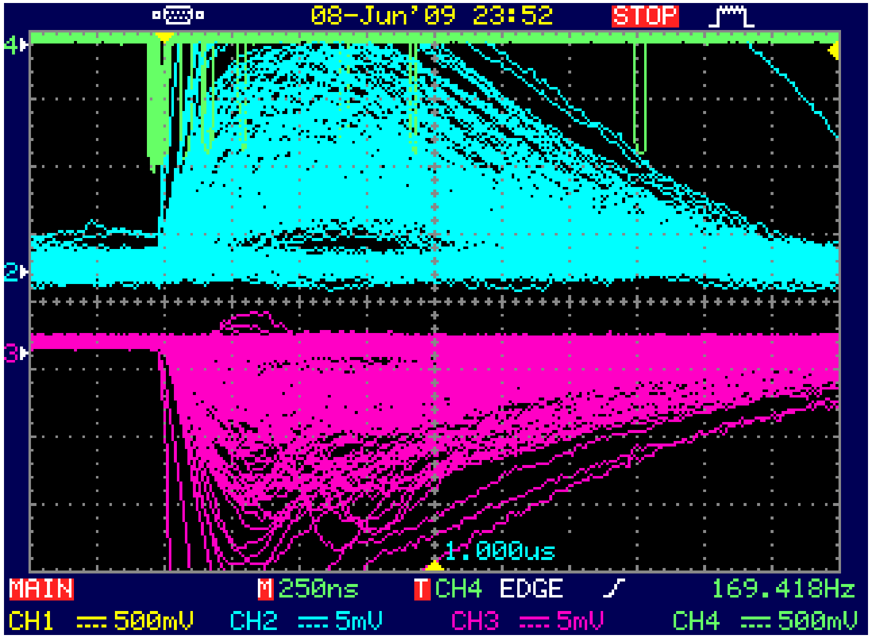
Sense Wire ~ +1200 V
Field Wire ~ -600 V
Cathode ~ -600 V
Pad plane ~ 0 V

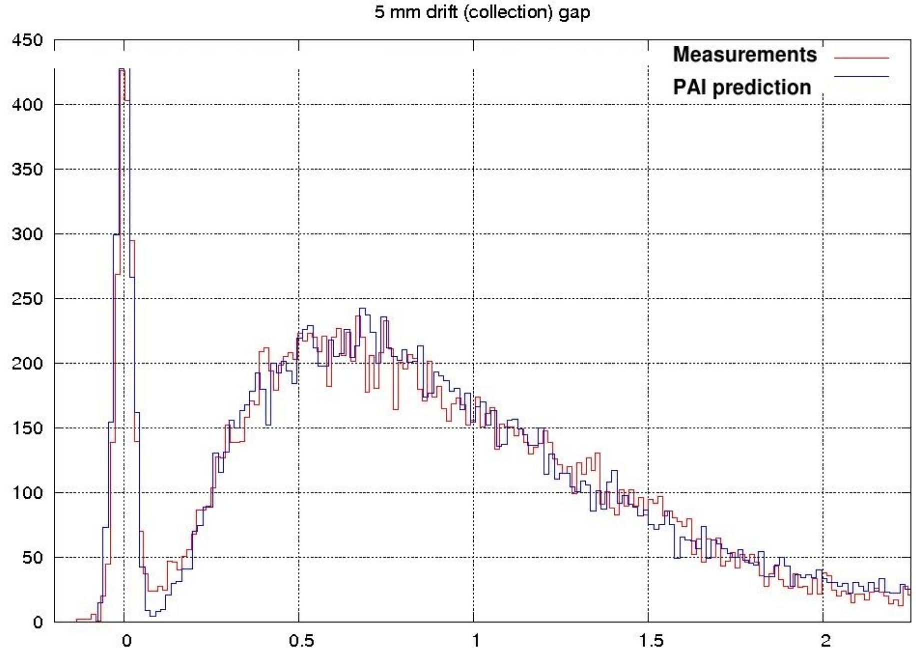
Gas mixture : Ar/CO_2
Pad size typically 2-4 mm
Wire distance typically 1-2 mm

CCC - first prototype



CCC – in operation

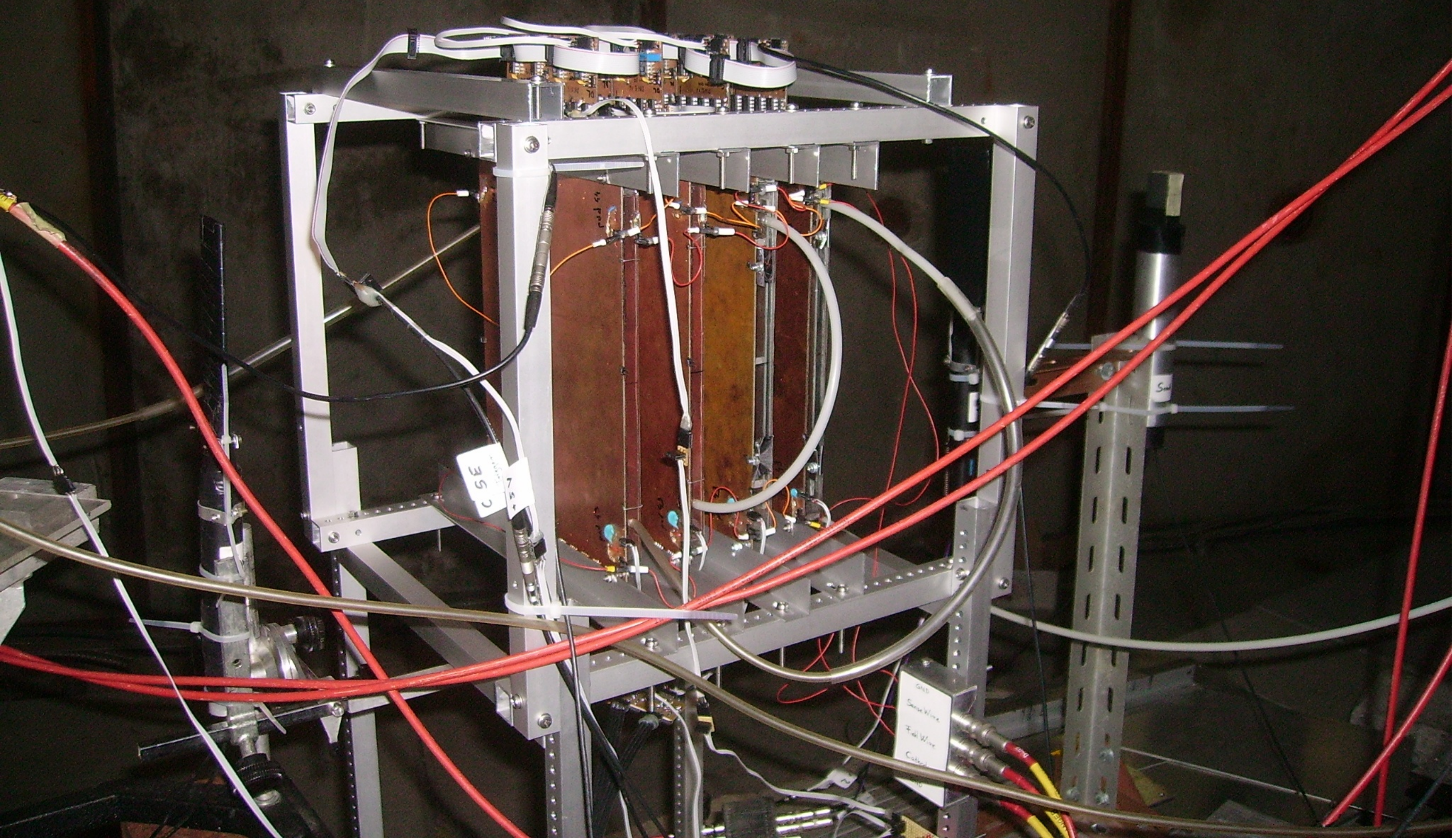




- Oscilloscope screeenshot of multiple signals on the Sense Wires (top) and on a pad (bottom)

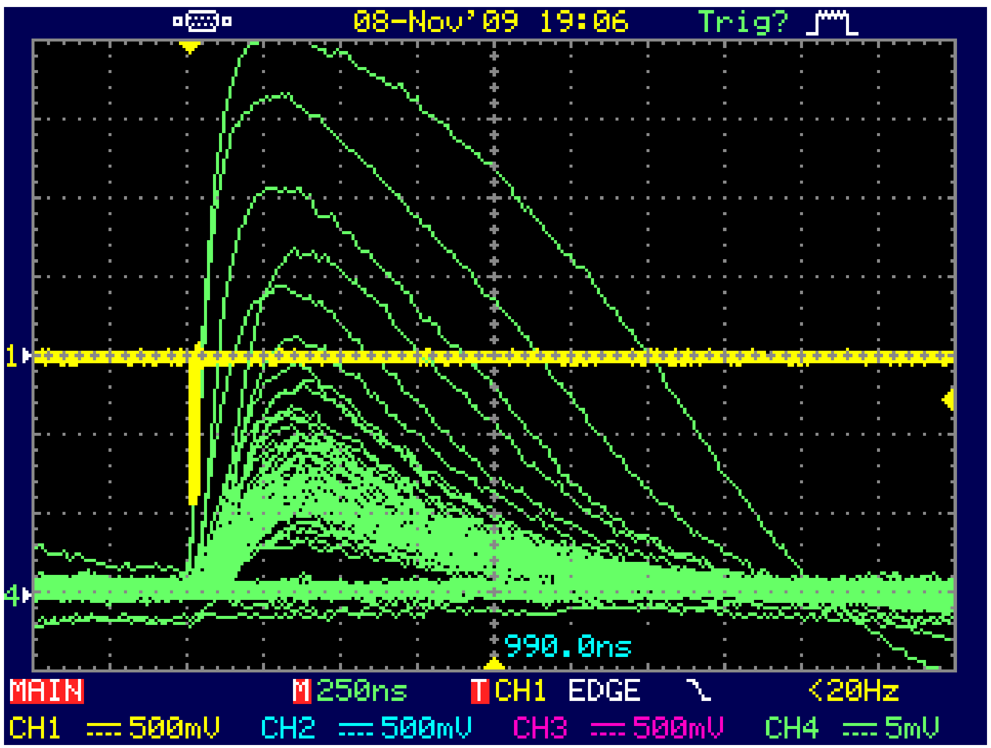
- Comparison of the measured and PAI predicted energy loss distributions

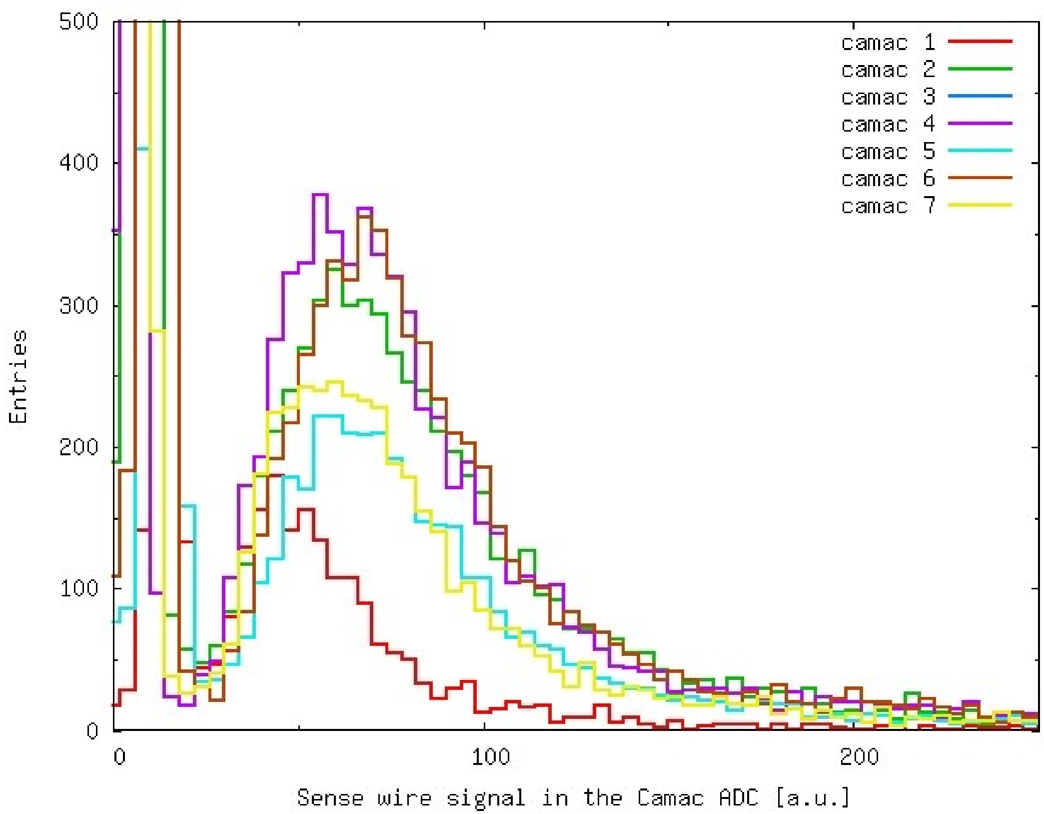
HPTD prototype with four Close Cathode Chambers



Analog signals

from sense wires





- Oscilloscope picture
- Charge distribution

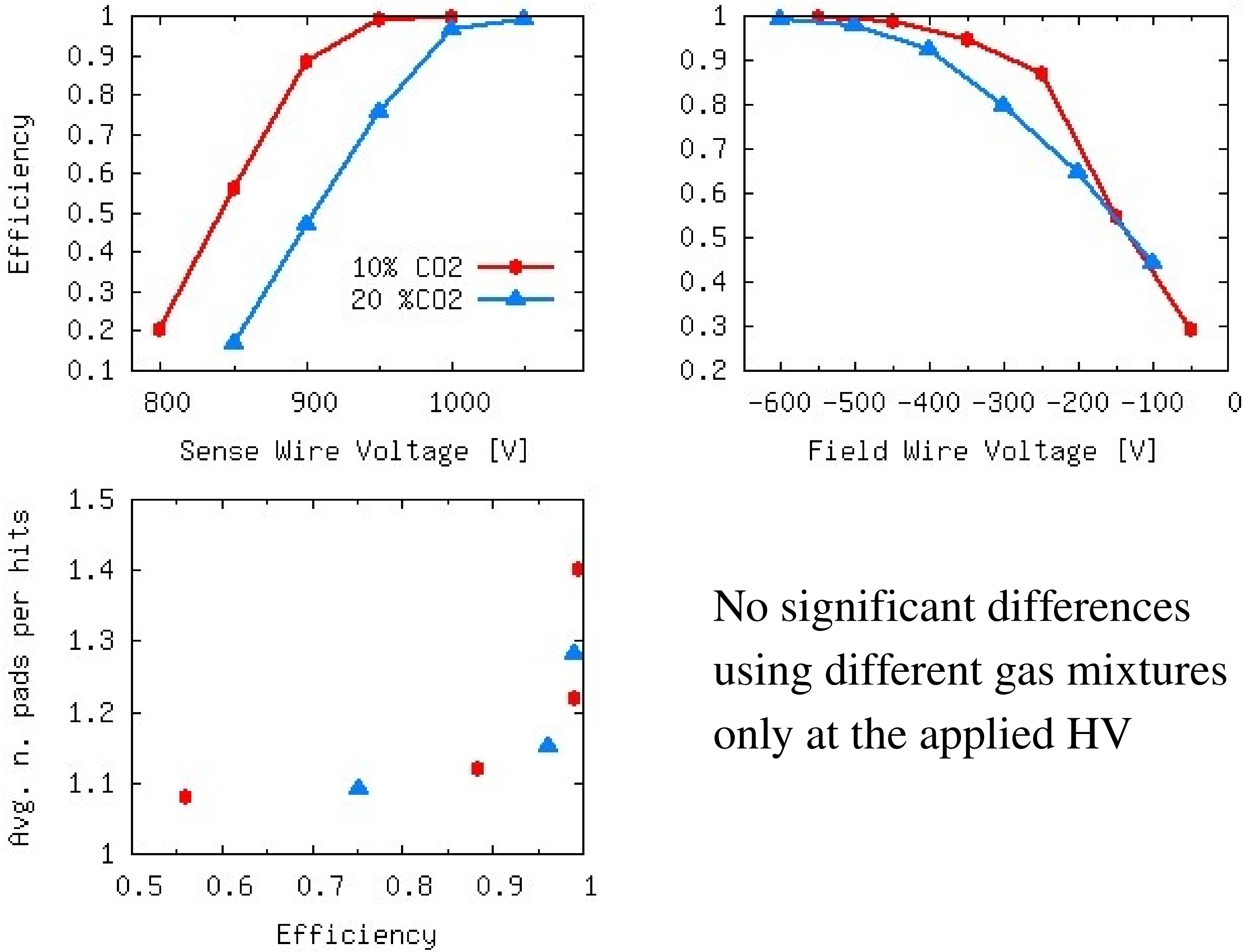
Digital readout

(example screenshot)

```
event   505 -      1333 us -
                                  ....X...........................
                                  .......XX.......................
                                  ..........X.....................
                                  .............XX............... -
event   506 -      1434 us -
                                  .......XX.......................
                                  ..........XX....................
                                  ..............X.................
                                  .................XX........... -
event   507 -      1716 us -
                                  ..............X.................
                                  .........X......XXX.............
                                  ....................XX..........
                                  ........................X..... -
event   508 -      1093 us -
                                  ..........XX....................
                                  ............XXX.................
                                  .................X..............
                                  ....................X......... -
event   509 -      1192 us -
                                  ...X............................
                                  ......X.........................
                                  .........X......................
                                  ............XX................ -
```

particles coming in 15 degrees (3.2 GeV at ALICE)

Preliminary Results



No significant differences using different gas mixtures only at the applied HV

Preliminary Results

- Final results after the offline data analysis

- **Preliminary!** :
  - Efficiency: above 99% was reached for each layers
    in the complete setup
  - Occupancy: average 1.2-1.4 pads hit per particle;
    that is, occupancy is limited by pad size
  - Position resolution: from straight line fit on tracks,
    the position is precise well within +/- 1 pad
    (as expected by design)

  - In the present setup: 10 GeV track corresponds to 3 pads displacement
    between top/bottom layer -- practically usable precision
    for triggering (trigger cut sharpness and modest bias)

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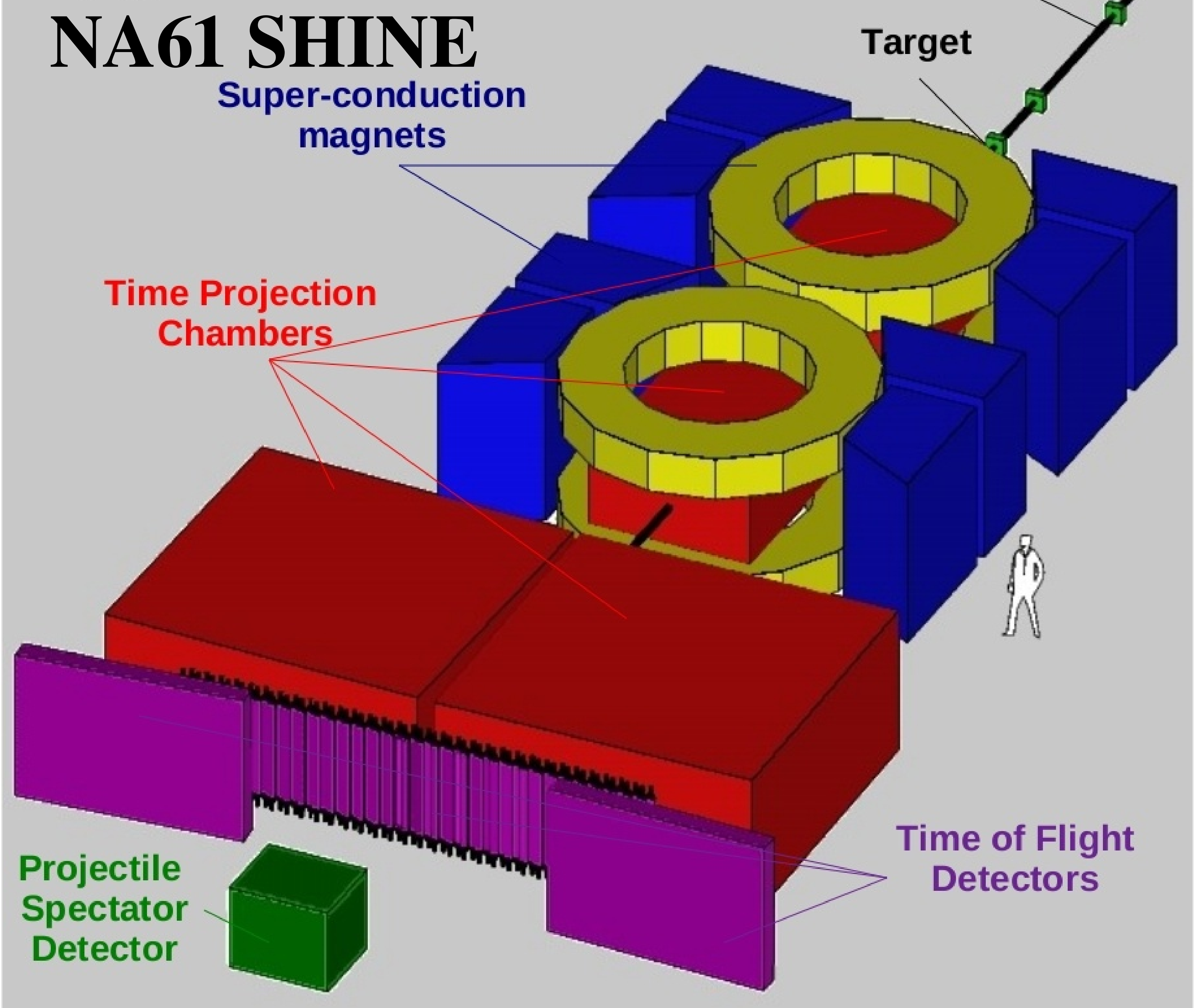
NA61 SHINE

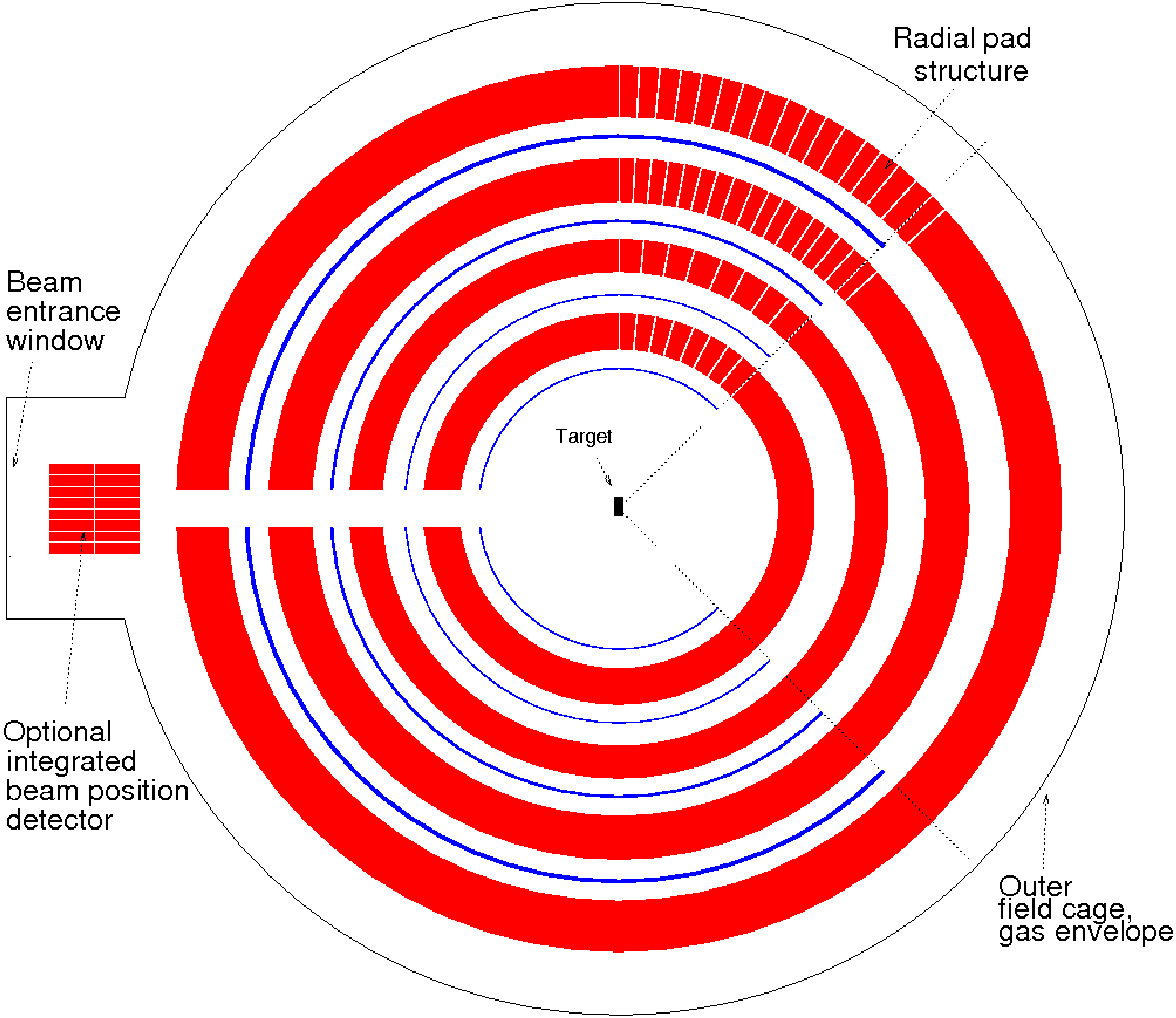

Target
Super-conduction magnets
Time Projection Chambers
Projectile Spectator Detector
Time of Flight Detectors

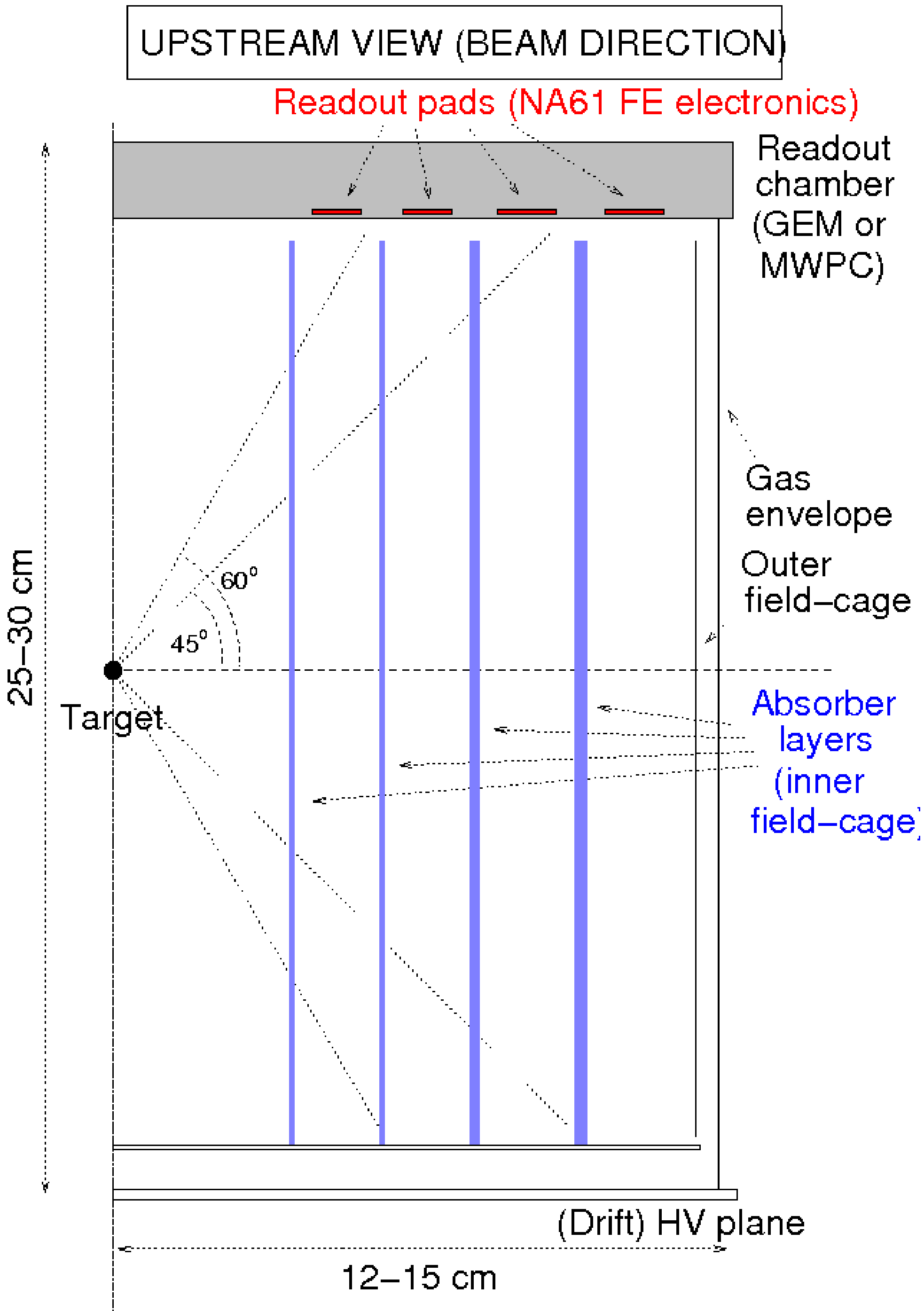
NA61 Centrality Detector via Low Momentum Multiplicity and Identification detector

- h+A interactions: low momentum (gray) particle measurement: energy and identification.
- Centrality measurement, transition from “black” evaporation component to “gray” knock-on protons
- A+A interactions: backward multiplicity

(centrality or forward-backward correlation)

Cylindrical structure



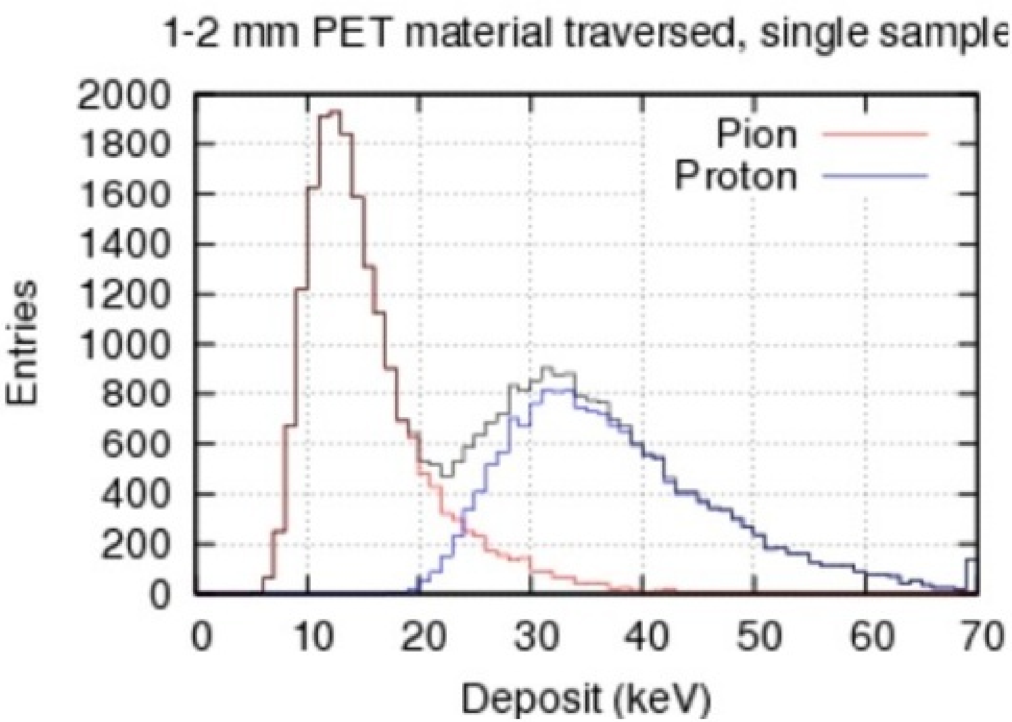


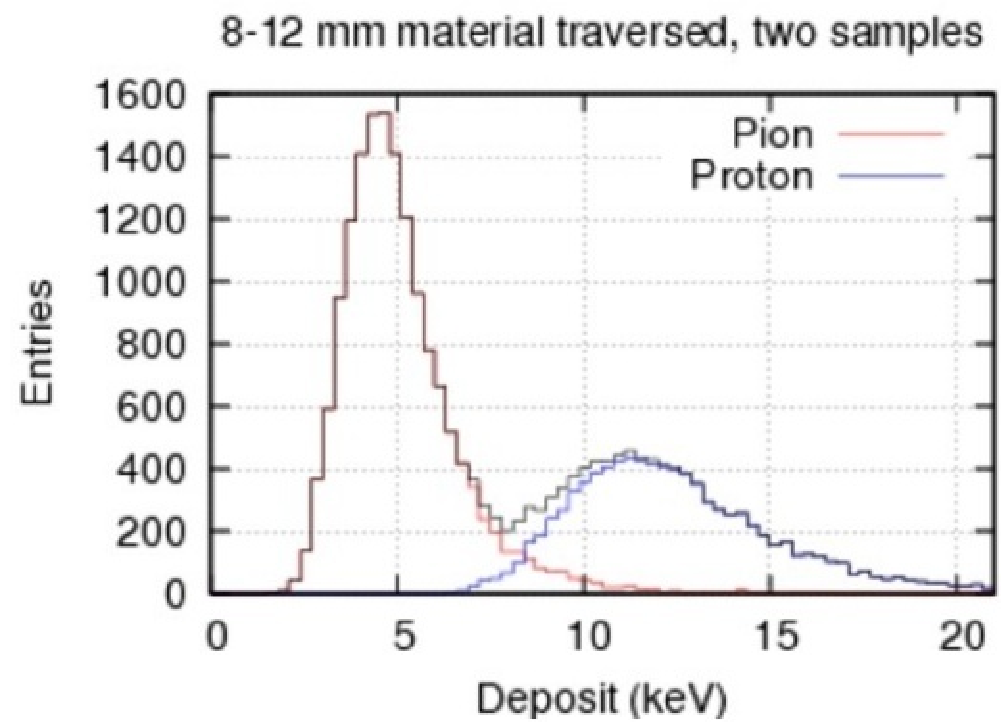
Principle of operation

- Simultaneous measurement of **dE/dx** and **range**: energy and identification
- Intervals in particle range defined by absorber layers (constant thickness to be traversed)
- dE/dx measured over order of 1 cm in a small TPC (field cage printed on absorber)
- Electronics: same as for NA61!

Operation principle: Simulation

- Preliminary! PAI (Fermi-) model of ionization
- Below: deposit distribution in range intervals

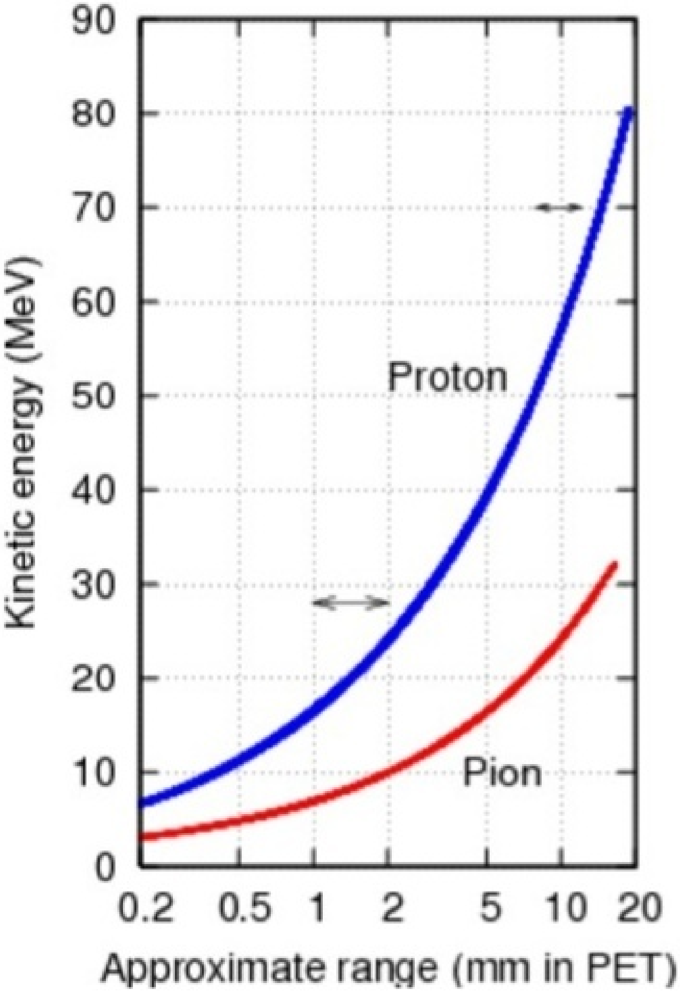


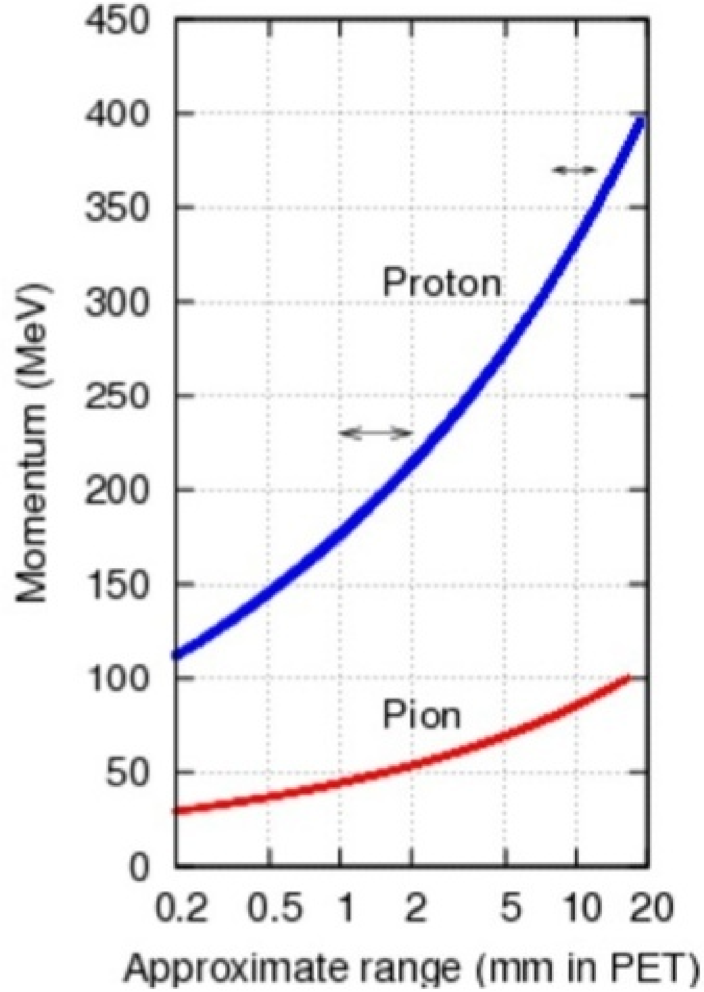


- Clearly identified proton and pion peak!

Momentum (energy) – range relation

- Useful range: 0.5 – 20 mm in PET (shorter in heavier material, e.g. Cu); minimal target thickness needed.

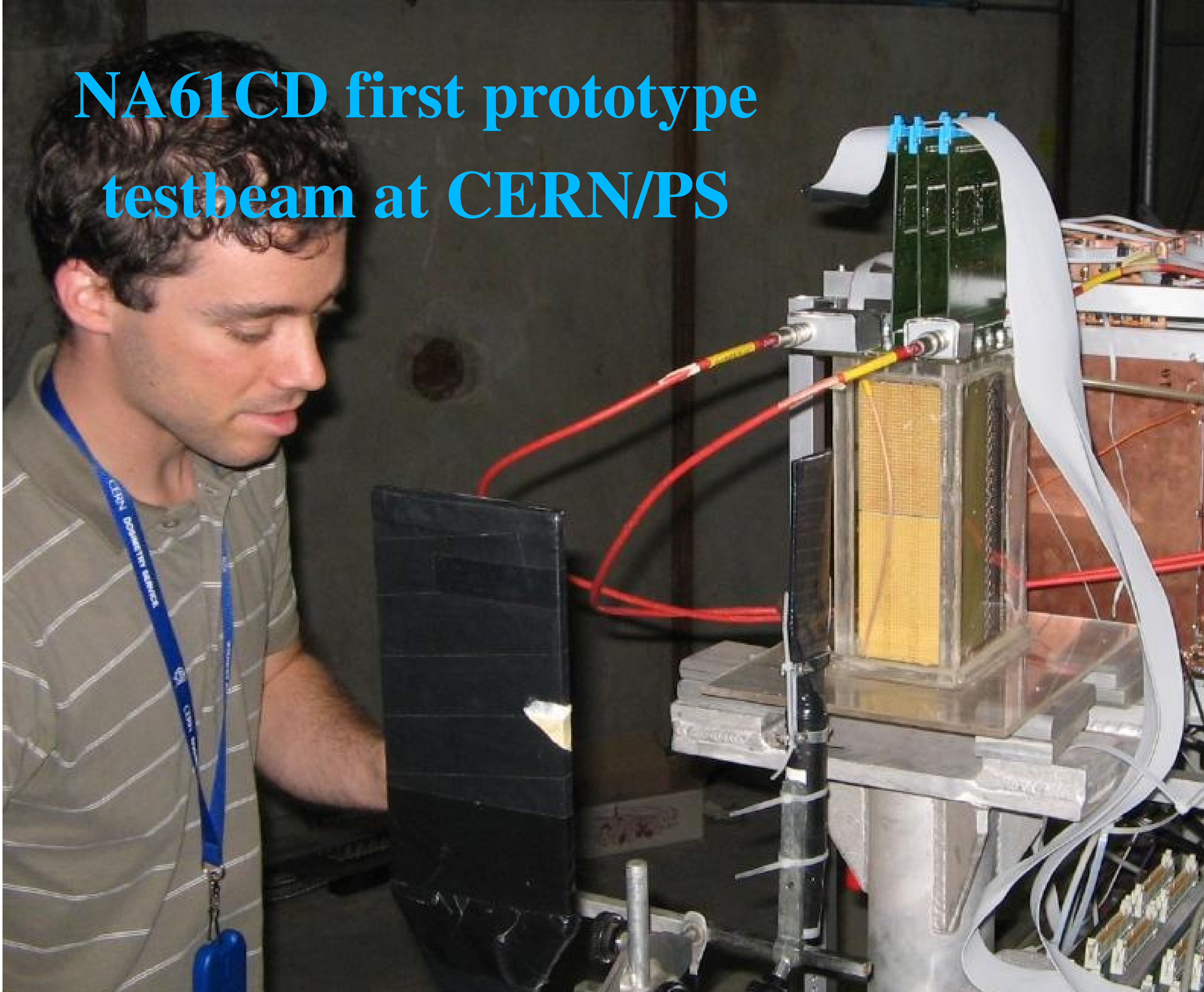




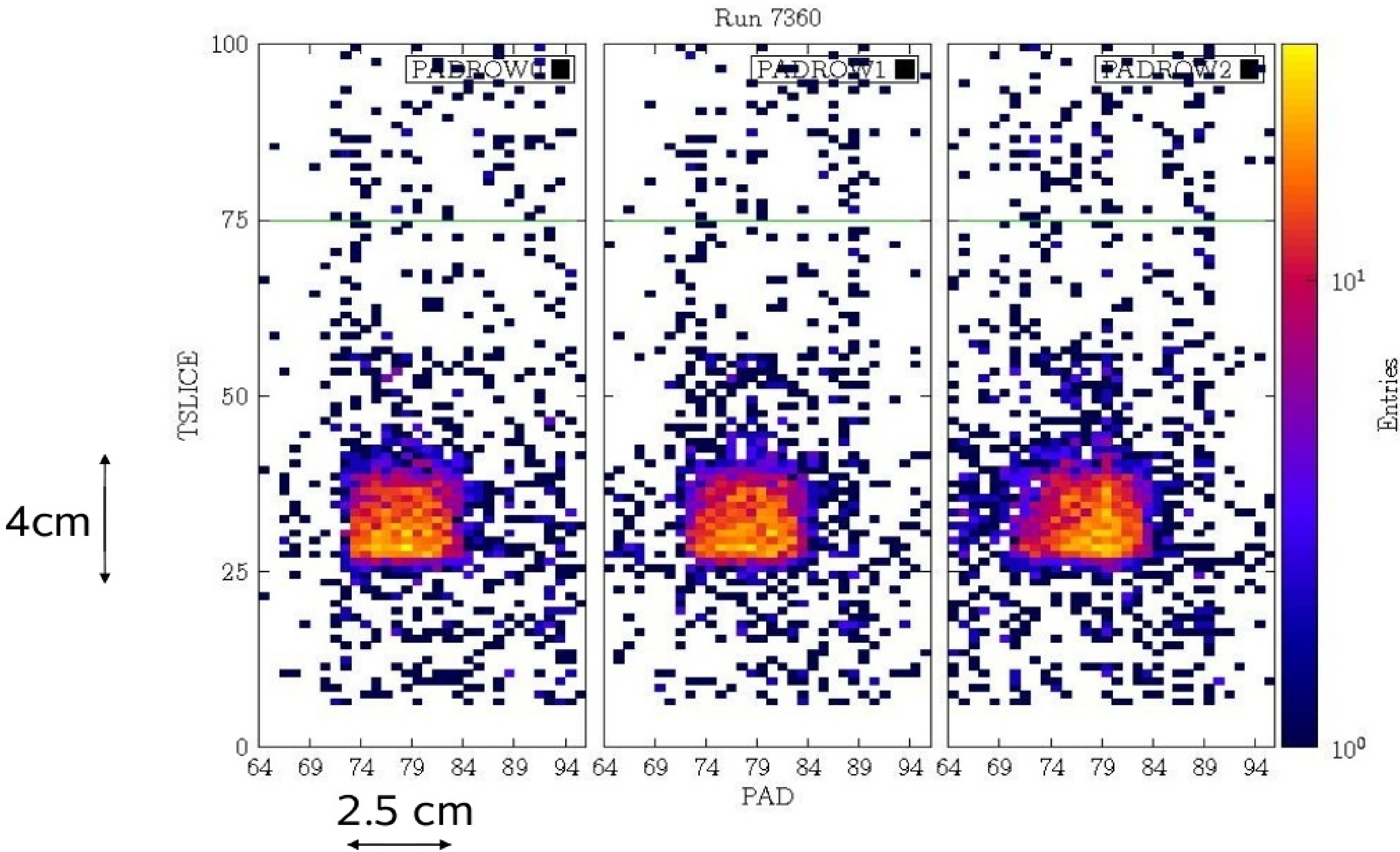
Arrows indicate the ranges on figures before

Hadronic effects to be considered in refined analysis!

NA61CD first prototype testbeam at CERN/PS



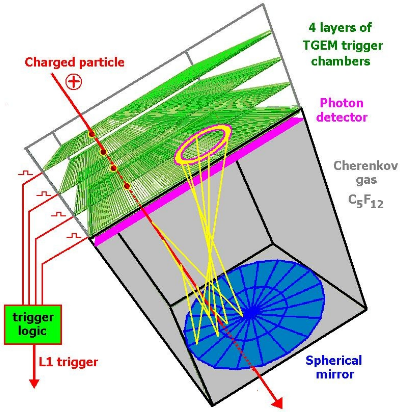
NA61CD testbeam



Cluster population: Scintillator of 2.5 cm width, 4 cm height

Summary

- High P_T Trigger Detector for VHMPID
  - VHMPID: new R&D for ALICE
  - Need for a trigger : HPTD
    tested: TGEM and CCC technology
  - Fast, high granularity, narrow response, 1bit digitalization, pattern recognition.



- NA61 Centality Detector
  - Detecting grey protons via range and dE/dx
  - Field cage on absorbers
  - Slow protons, wide dE/dx range, geometry embraces the target, NA61 electronics