The ALICE Transition Radiation Detector

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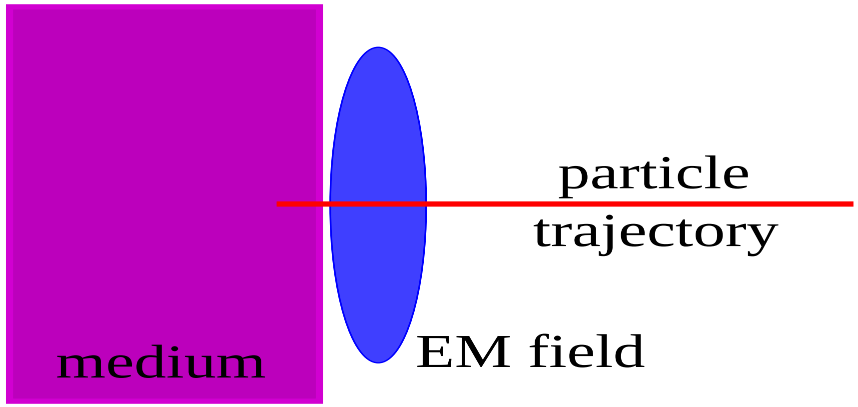
- TR(D) basics
- ALICE TRD characteristics
- Detector physics of TRD (prototype measurements)
  - signal generation, propagation, amplification
  - ...and the associated problems
  - performance
- FEE, DCS, gas system, cooling
- On-going activities

http://www-alice.gsi.de/trd

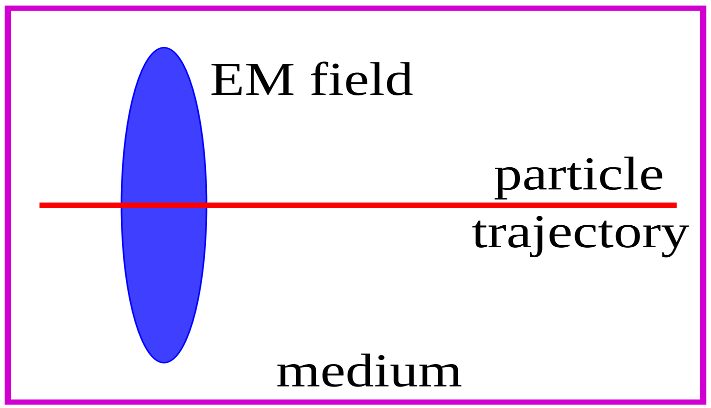
What is transition radiation?

"Transition radiation is *omitted* whenever a charged particle crosses an interface between two media with different dielectric functions." — L. Durand, Phys. Rev. D 11, 89 (1975)

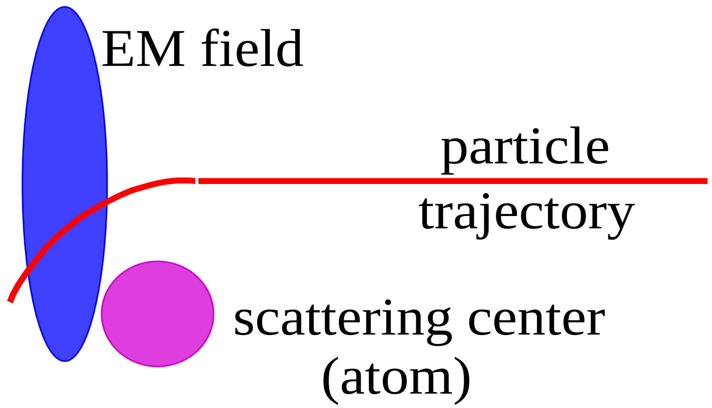
- Predicted: Ginzburg & Frank, 1946
- Observed: Goldsmith & Jelley, 1959 (optical)
- It's sizeable (X-rays) for relativistic particles



Cherenkov

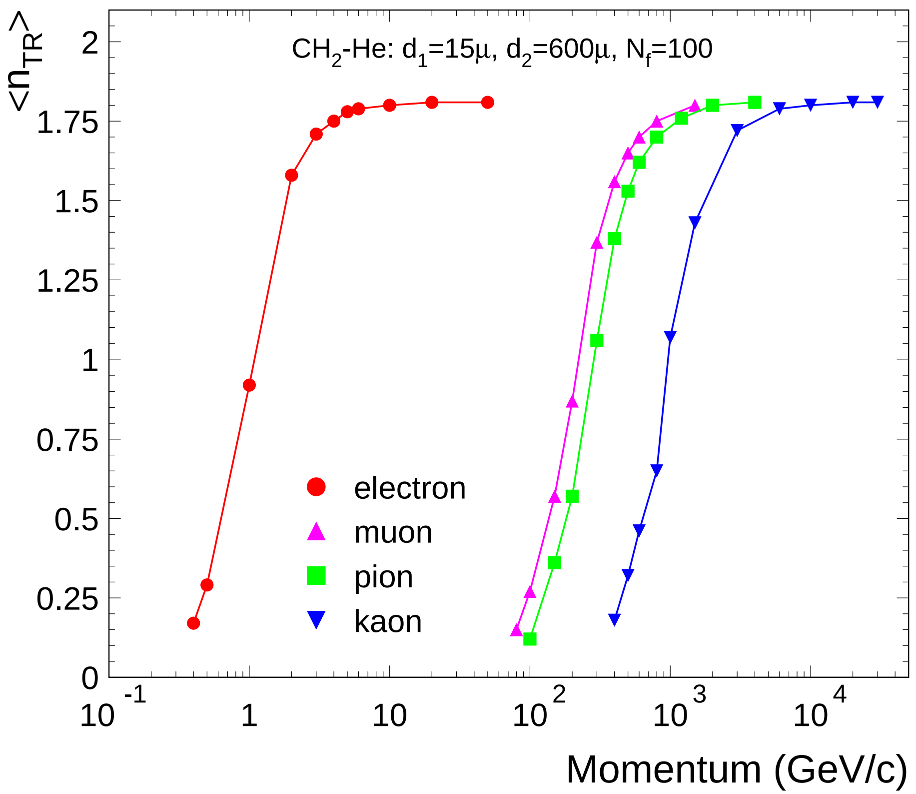


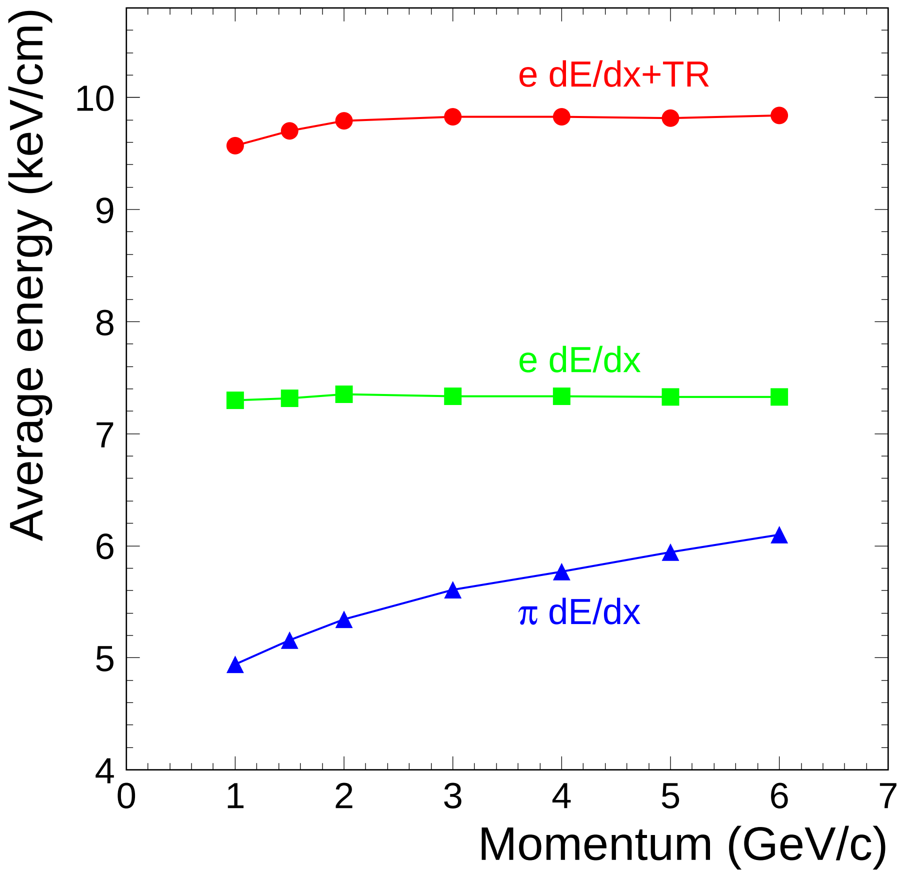
Brehmsstrahlung



How does it work: from TR to TRD

Radiator ... + Detector (Xe) ⟶



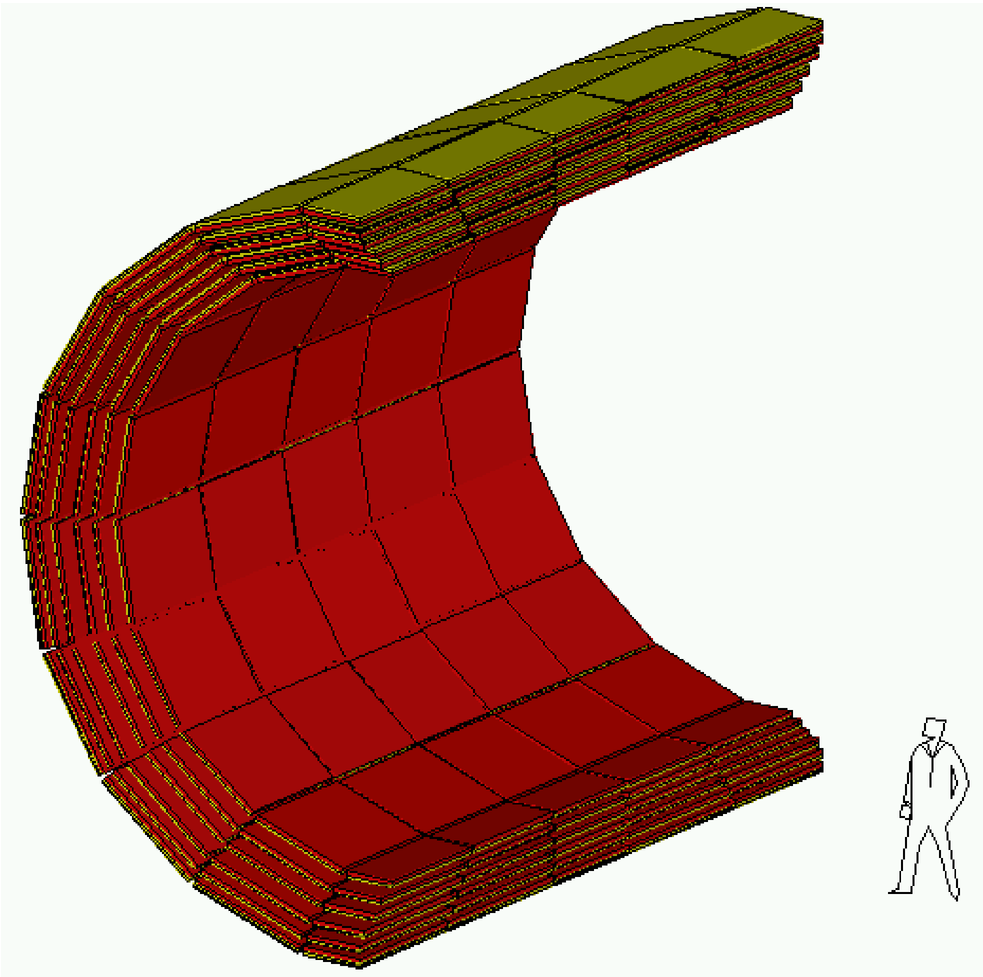


▷ TRDs are not "hadron-blind", they see all charged particles dE/dx

▷ TR gives a much needed boost to dE/dx of electrons

ALICE TRD at a glance

Goal: pion rejection factor of 100, fast trigger for high-p_t electrons and jets



Parameters:

- 540 modules (18×5×6)
- Total area: 767 m^2
- Gas volume: 27 m^3 , Xe,CO_2(15%)
- 1.2 mil. readout chan. (≃20 M pixels)
- 15 TB/s on-detector bandwidth
- Rad. thickness X/X_0: ∼ 22%
- Total weight: 21 tons
- Total power consumption: 70 kW
- 60 persons, 10 institutions

Conditions in ALICE

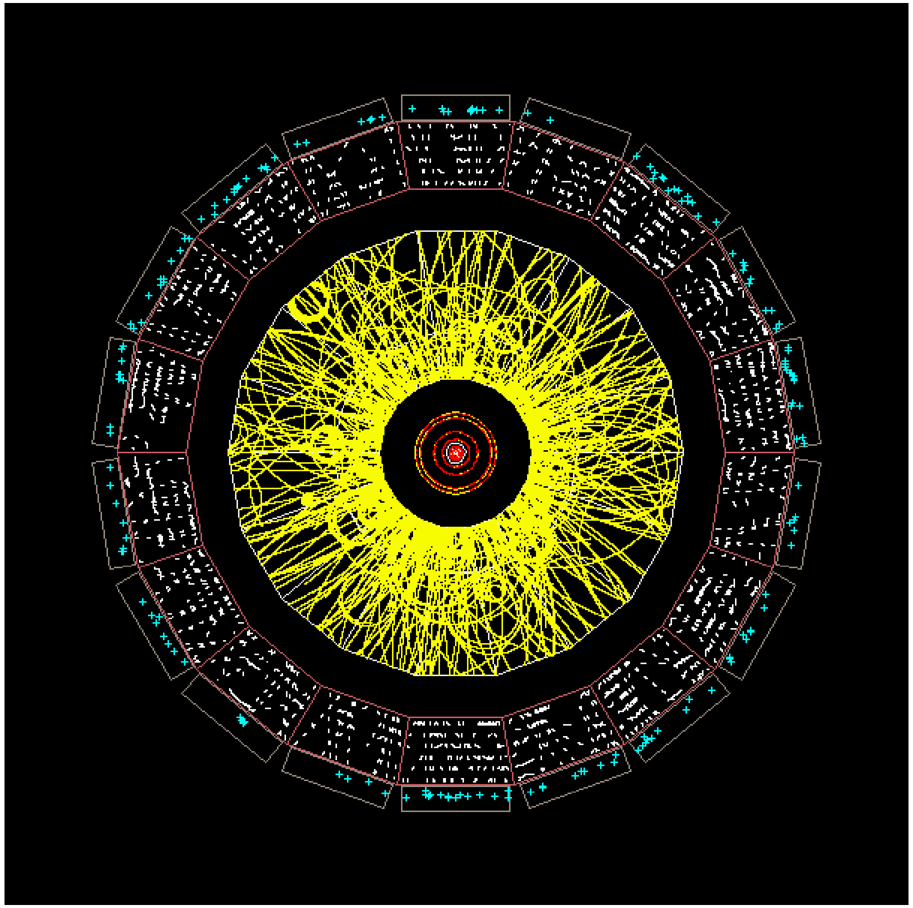
Pb+Pb $\sqrt{s_{NN}} = 5.5$ TeV

- 8 kHz interaction rate (10^{27} s^{-1}cm^{-2})
- dN$_{ch}$/dy=8000 (central collisions)
  1% of a central Pb+Pb event at LHC

  $\longrightarrow$

  (recent extrapolations: dN$_{ch}$/dy$\simeq$2000)

  need high granularity
- the TRD will work in conjunction with all central detectors
  (TRD+ITS in high-rate pp, C+C)

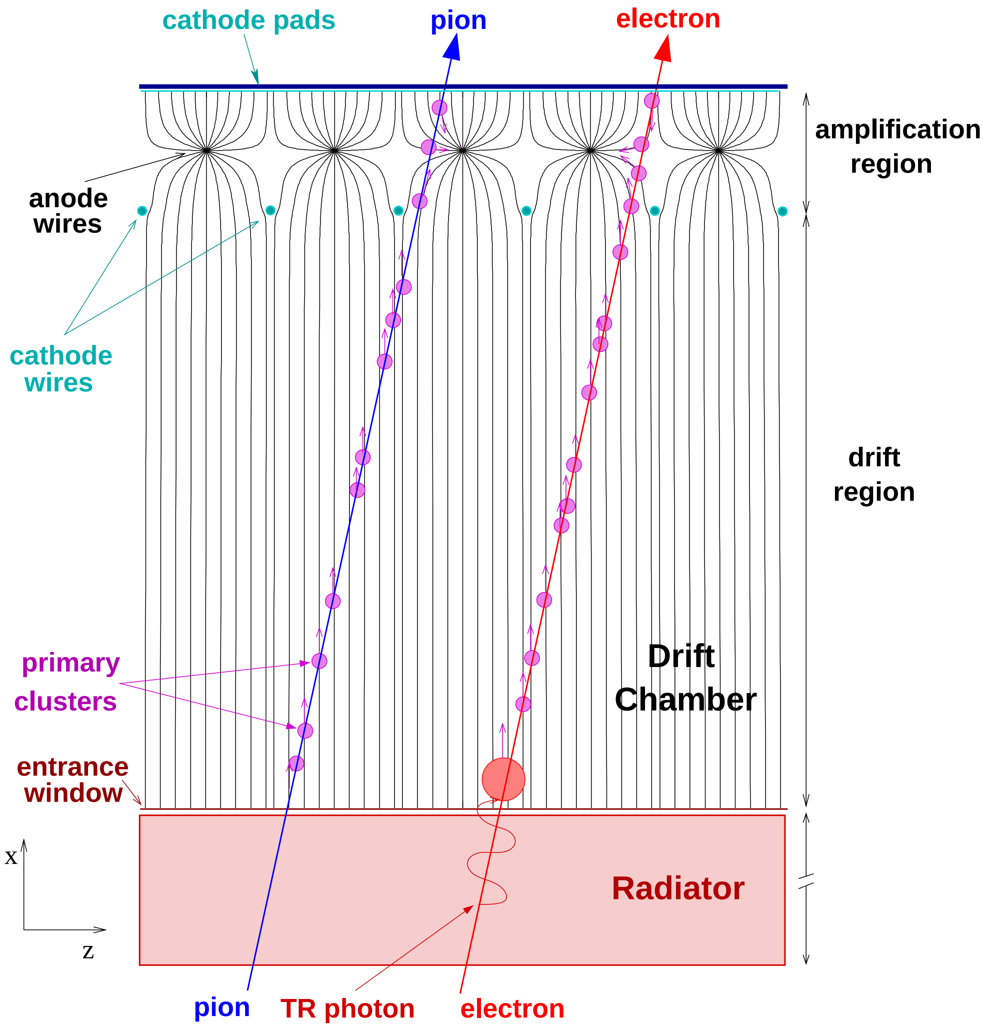


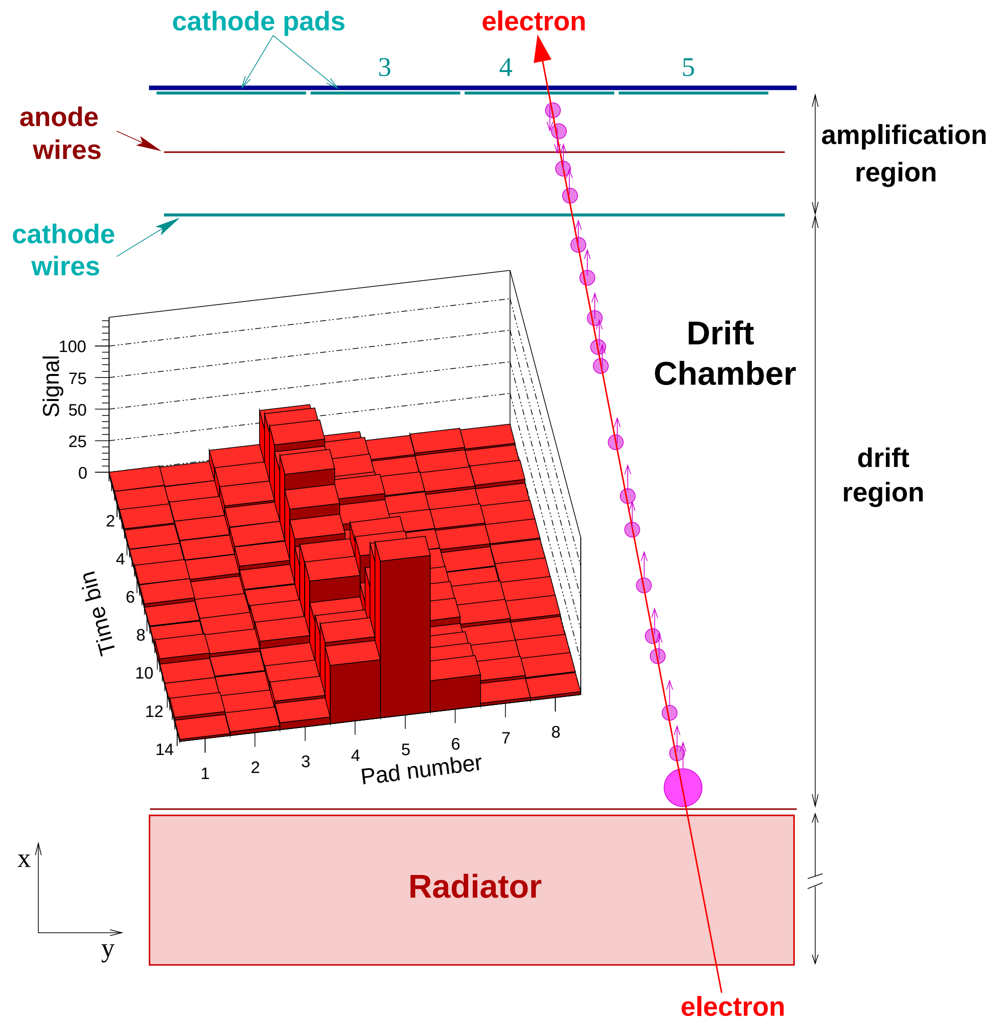
A comparison of TRDs

Experiment	Radiator (x,cm)	Detector (x,cm)	Area (m^2)	N	L (cm)	N. chan.	Method	π_{rej}
HELIOS	foils (7)	Xe-C_4H_{10} (1.8)	0.5	8	70	1744	N	2000
H1	foils (9.6)	Xe-He-C_2H_6 (6)	1.8	3	60	1728	FADC	10
NA31	foils (21.7)	Xe-He-CH_4 (5)	4.5	4	96	384	Q	70
ZEUS	fibres (7)	Xe-He-CH_4 (2.2)	3	4	40	2112	FADC	100
D0	foils (6.5)	Xe-CH_4 (2.3)	3.7	3	33	1536	FADC	50
NOMAD	foils (8.3)	Xe-CO_2 (1.6)	8.1	9	150	1584	Q	1000
HERMES	fibres (6.4)	Xe-CH_4 (2.54)	4.7	6	60	3072	Q	1400
kTeV	fibres (12)	Xe-CO_2 (2.9)	4.9	8	144	∼10 k	Q	250
PAMELA	fibres (1.5)	Xe-CO_2 (0.4)	0.08	9	28	964	Q,N	50
AMS	fibres (2)	Xe-CO_2 (0.6)	1.5	20	55	5248	Q	1000
PHENIX	fibres (5)	Xe-CH_4 (1.8)	50	6	4	43 k	FADC	∼300
ATLAS	fo/fi (0.8)	Xe-CO_2-O_2 (0.4)	31	36	51-108	425 k	N,ToT	100
ALICE	fi/foam (4.8)	Xe-CO_2(3.7)	126	6	52	1.2 mil.	FADC	200

all radiator material CH_2

ALICE TRD – The principle

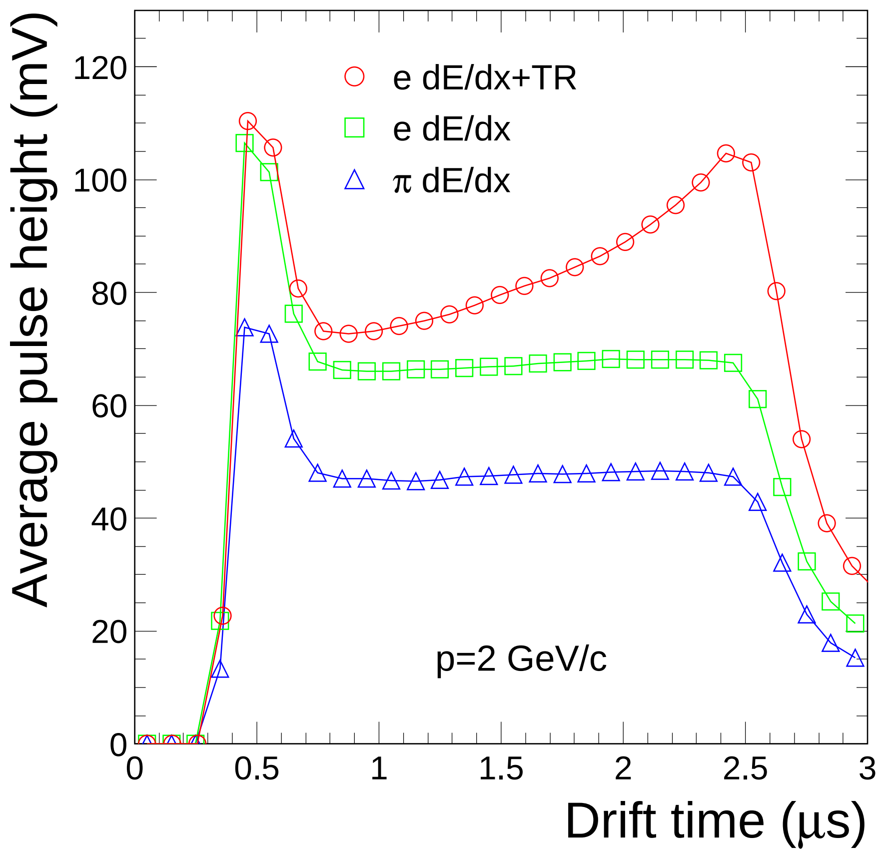




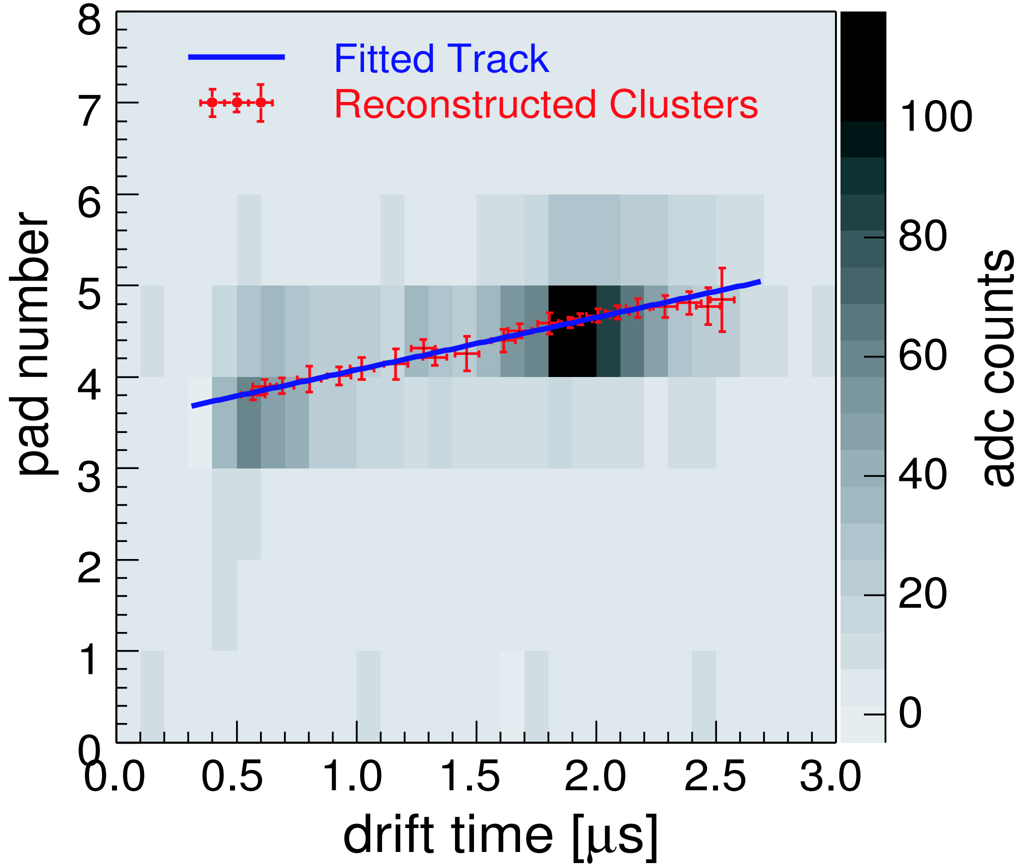
wires: Au-W 20μm, Cu-Be 75μm; pads: $\simeq 7\times 80$ mm^2

ALICE TRD – What do we measure

pulse height

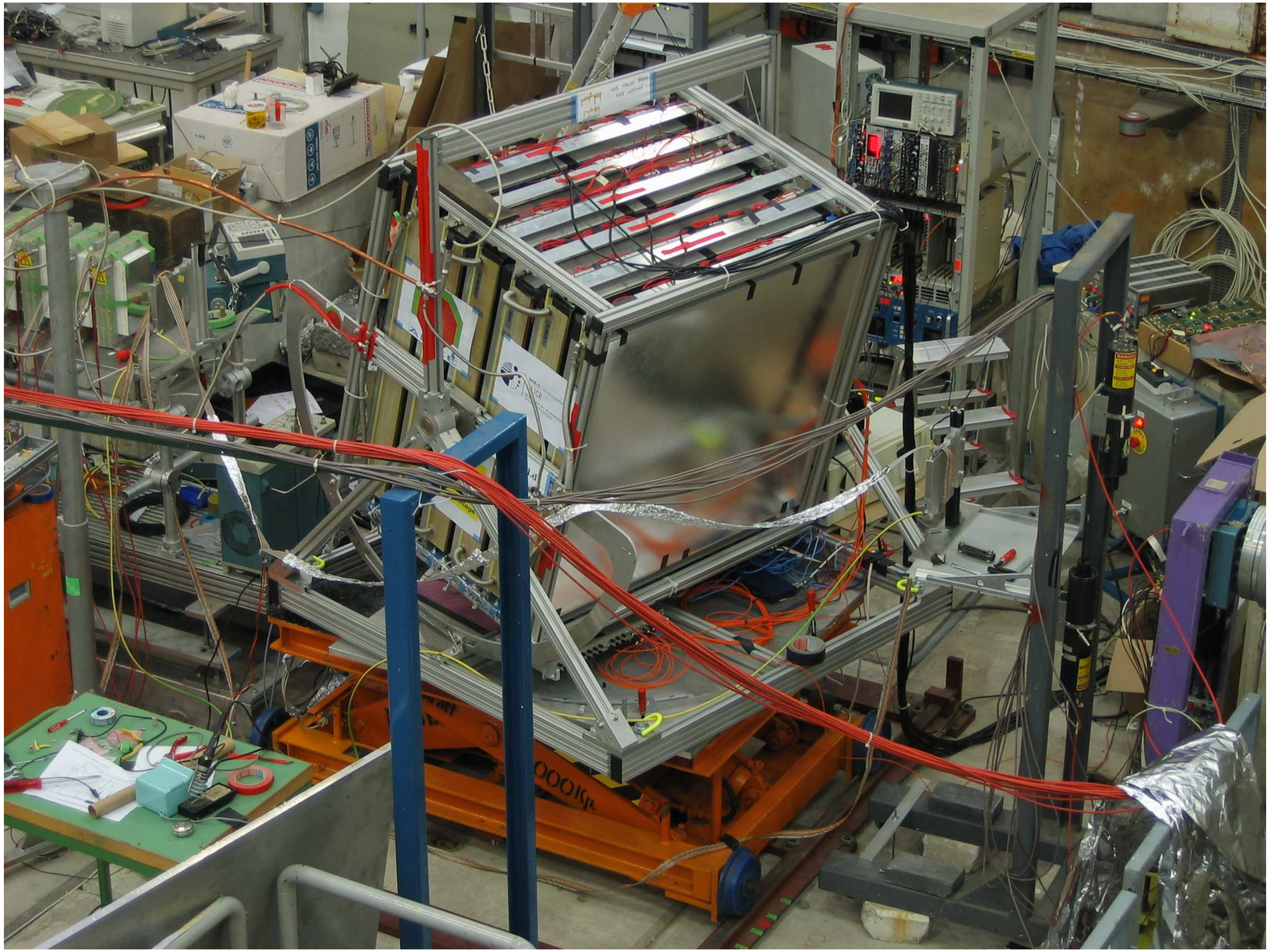


charge sharing



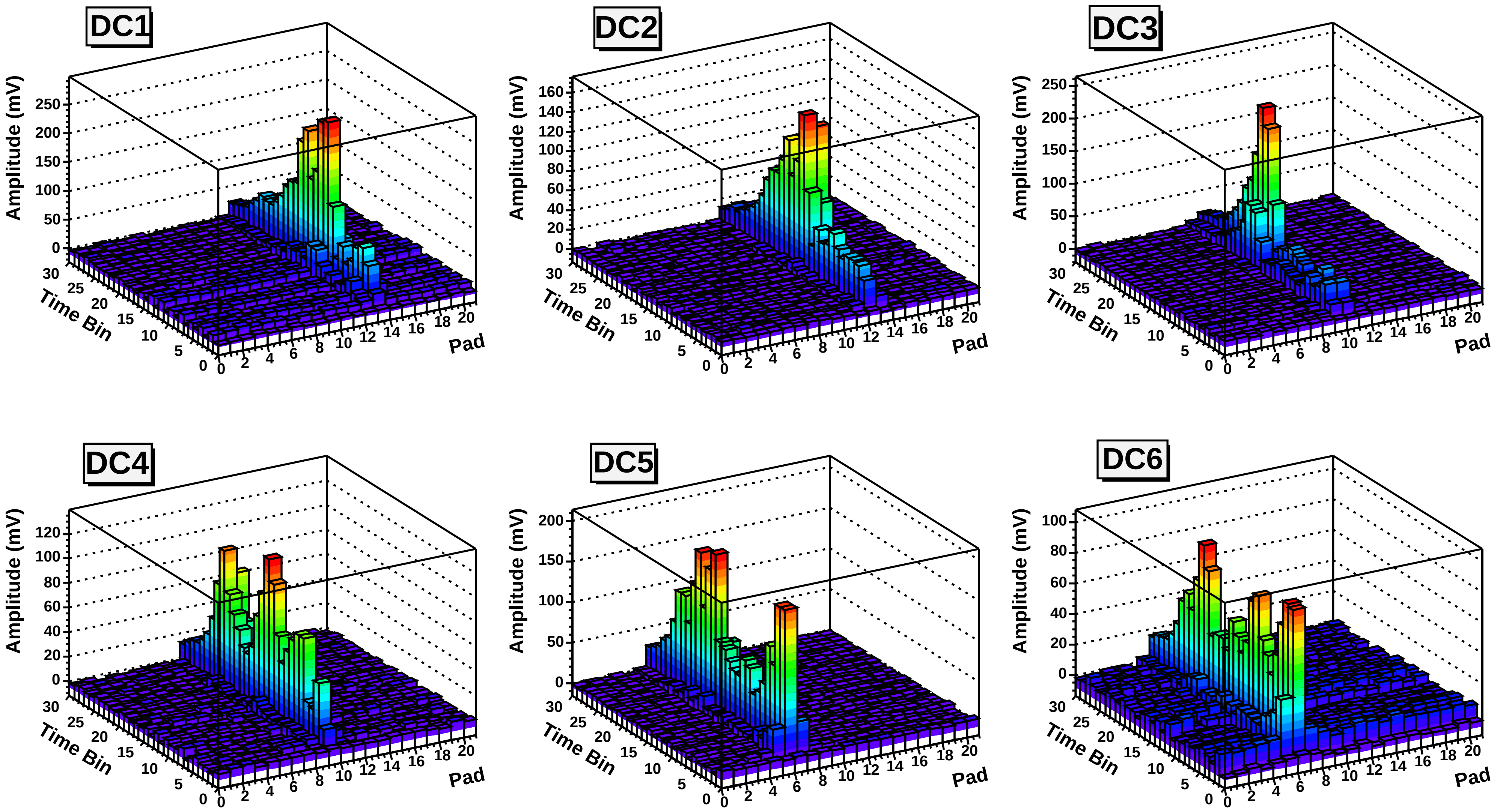
ADC: 10 bit, 10 MHz sampling, 2 V dynamic range; Noise: ≃1.3 LSB

Prototype tests

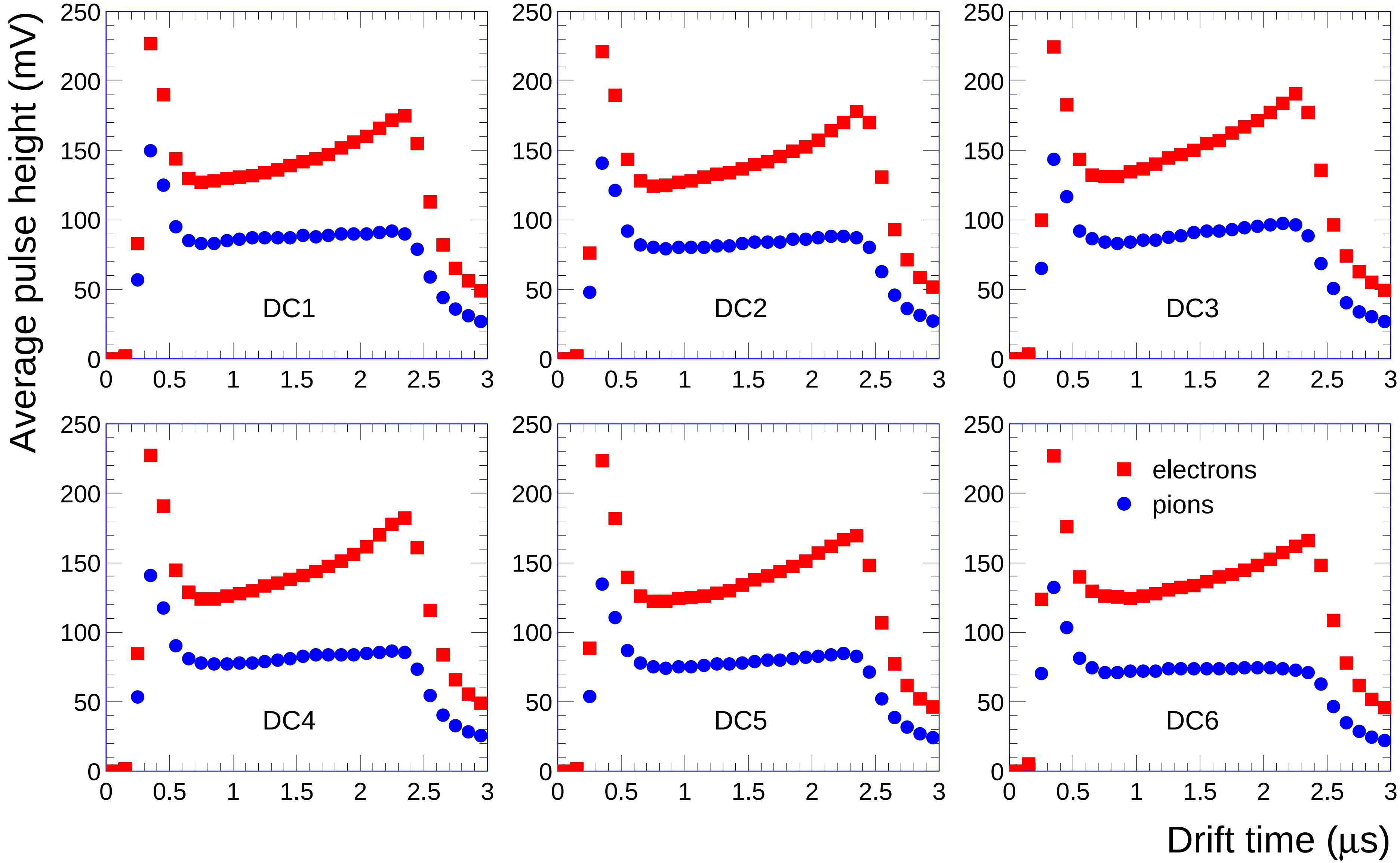


- beams: e,π 1-10 GeV/c
- GSI, CERN 1998-2004

One track, p=4 GeV/c



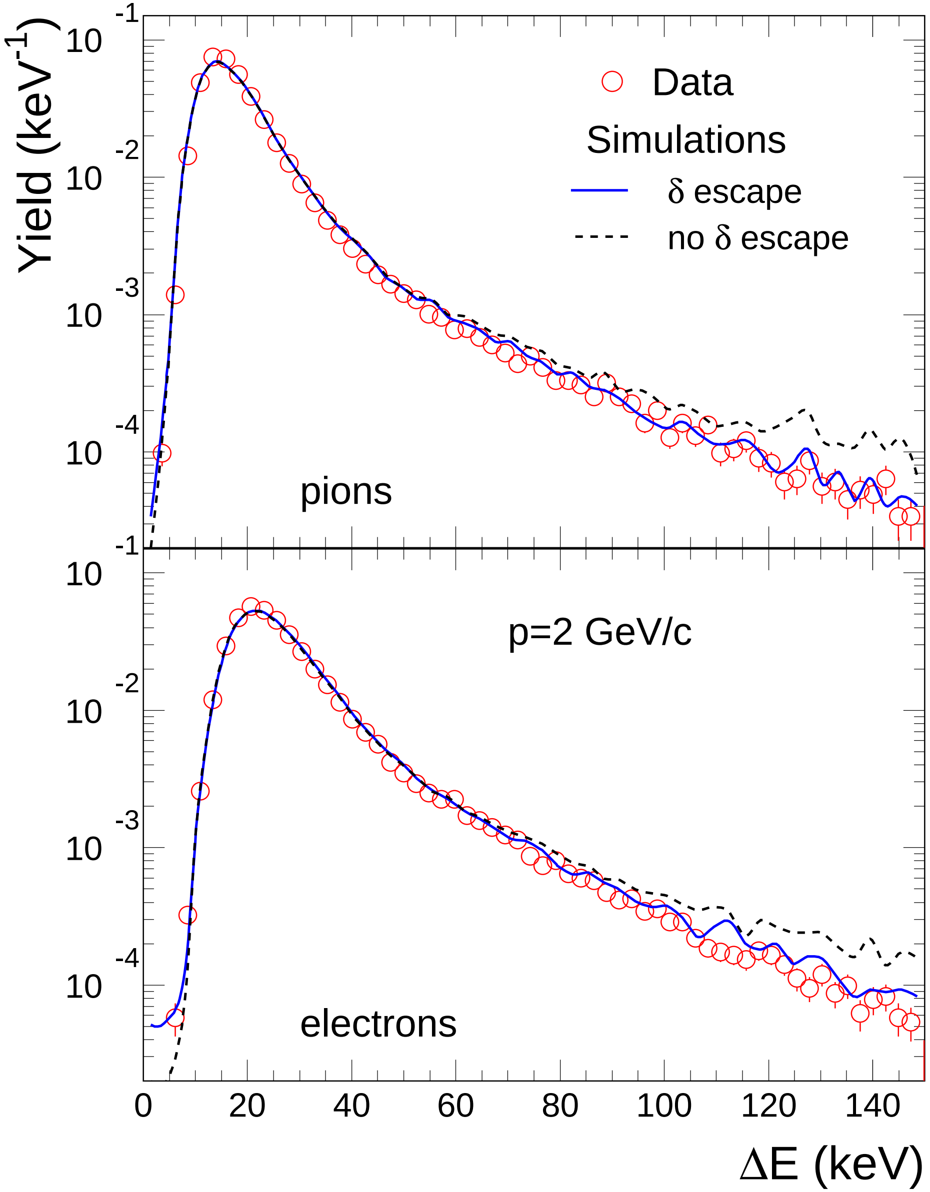
Average signals (p=4 GeV/c)



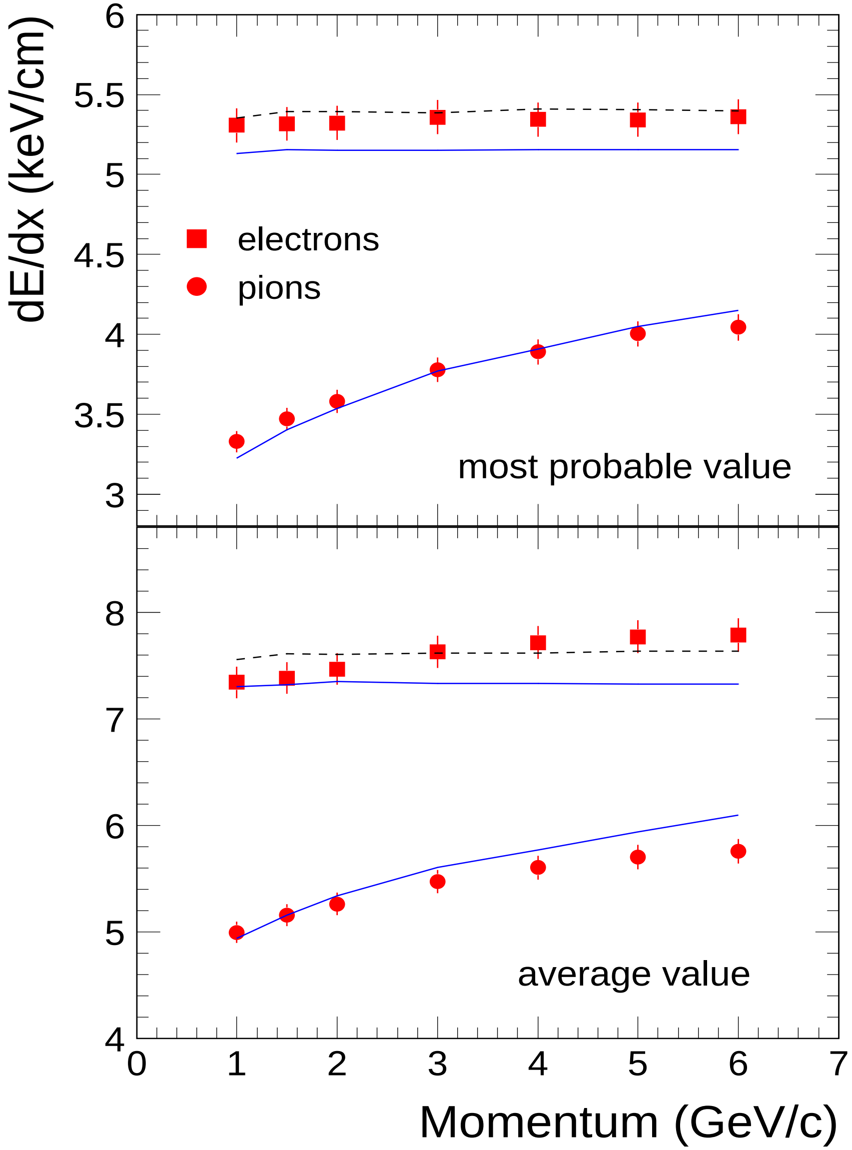
dE/dx: spectra

NIM A519(2004)508 [physics/0310122]

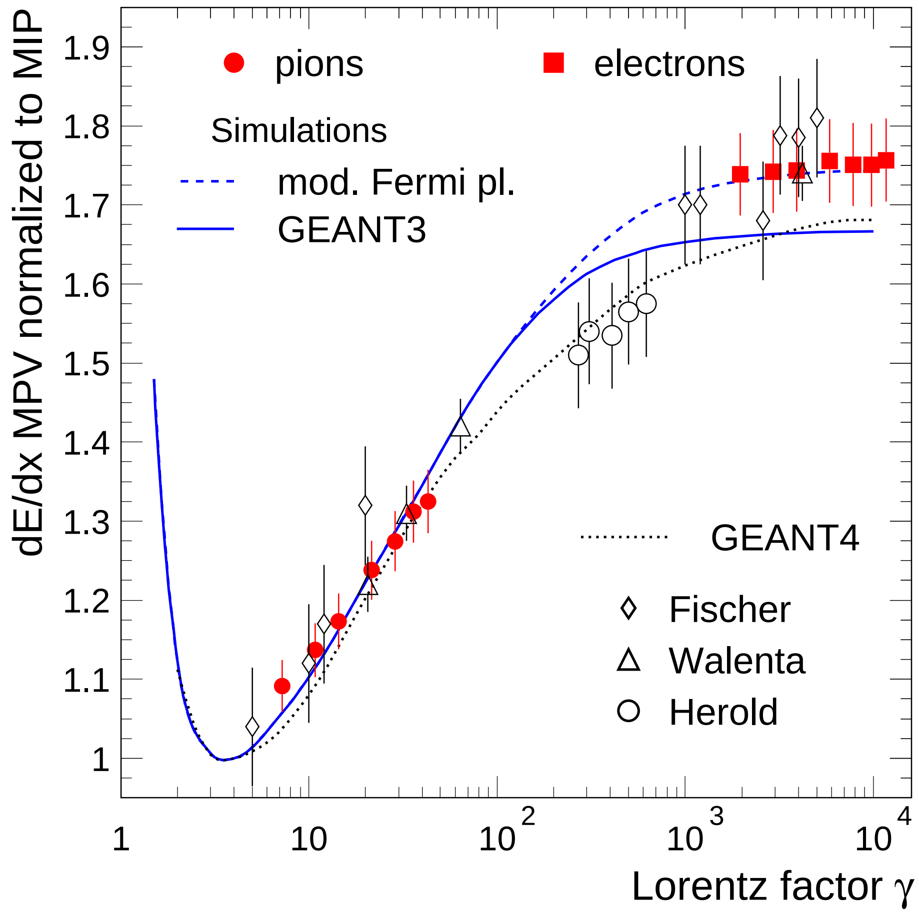
- Landau distribution
- Basic quantity for particle id.
- ...and for tracking (S/N)
- Needs to be well understood (simulations; GEANT3)
- Details (δ-rays) matter



dE/dx: momentum dependence



NIM A519(2004)508 [physics/0310122]



dE/dx: do we understand all?

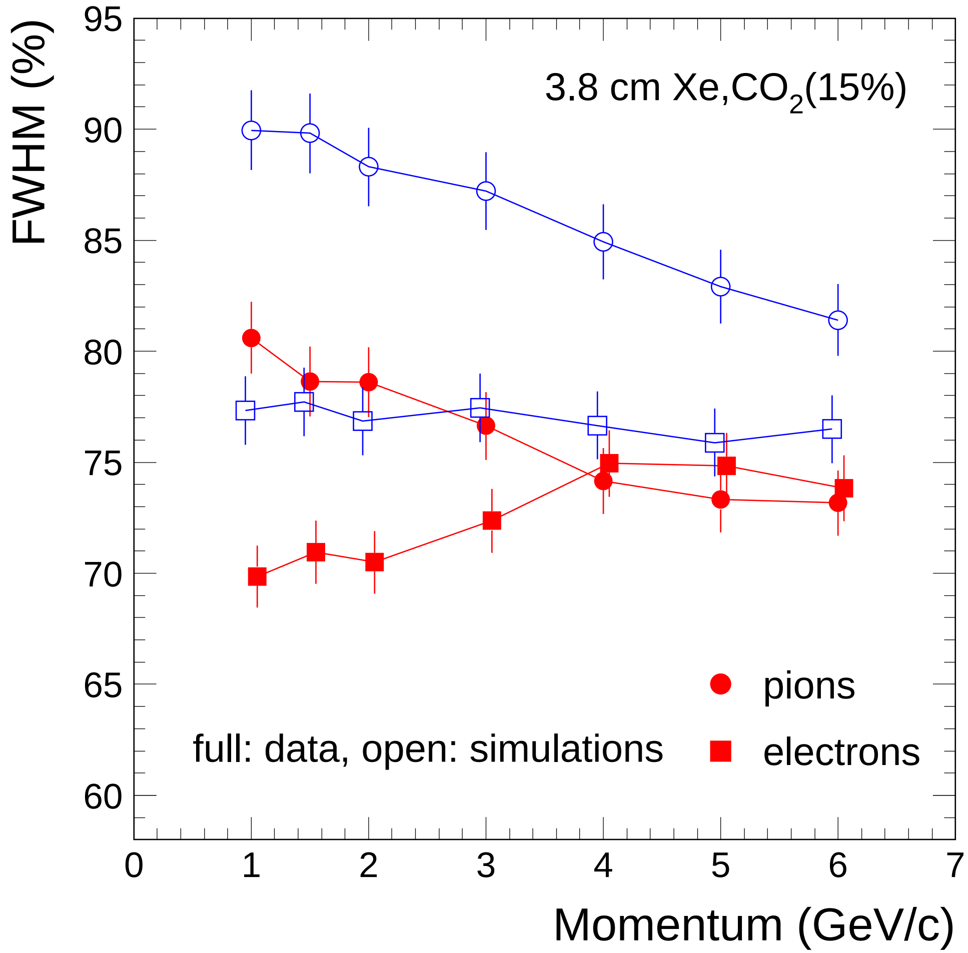
NIM A519(2004)508 [physics/0310122]

Almost, but not all...

Example: width of dE/dx spectrum

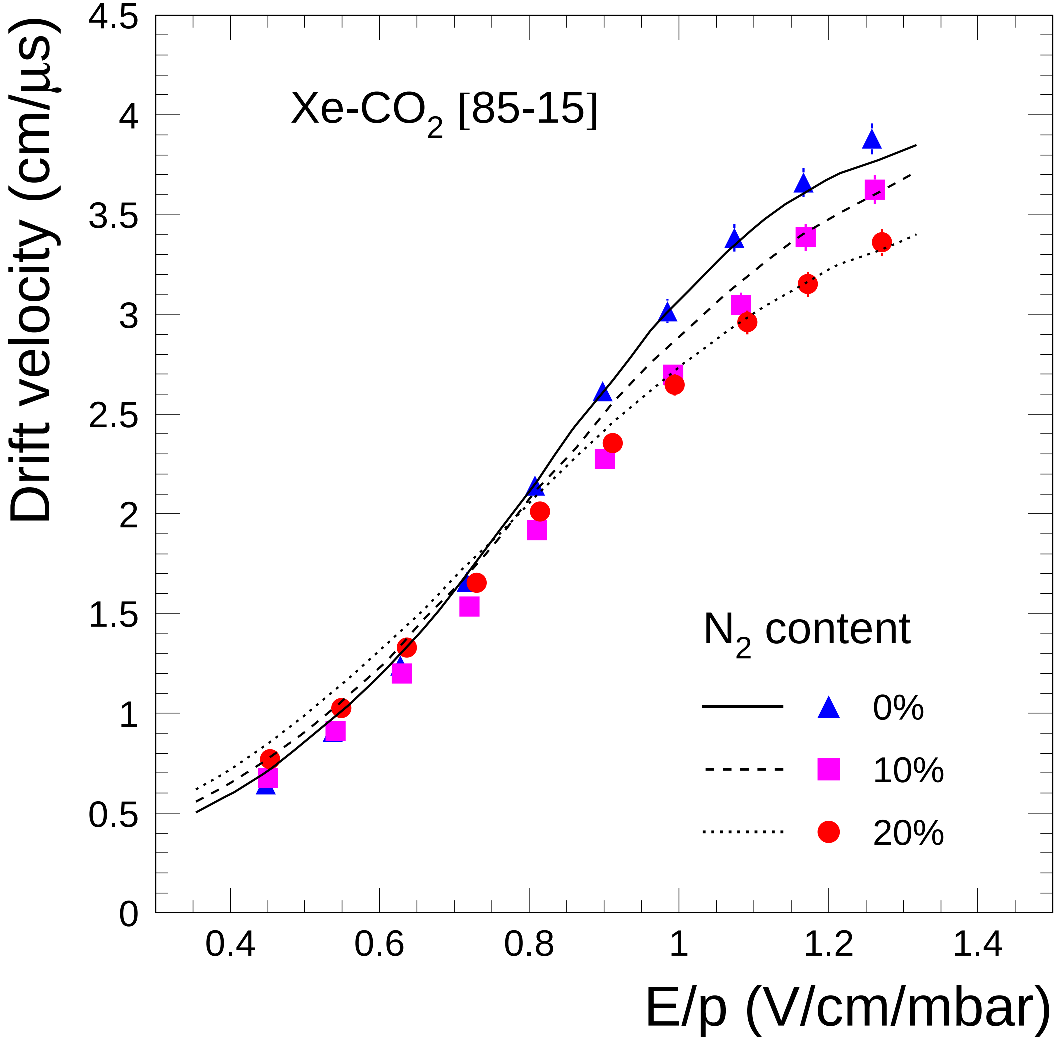
- determines PID quality
- is determined by $\langle N_{prim} \rangle$

  ...too small in GEANT3

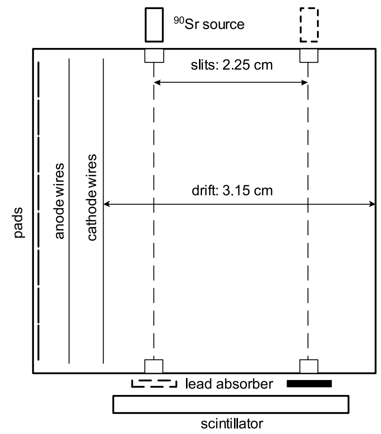


Drift velocities

NIM A523 (2004) 302 [physics/0402044]

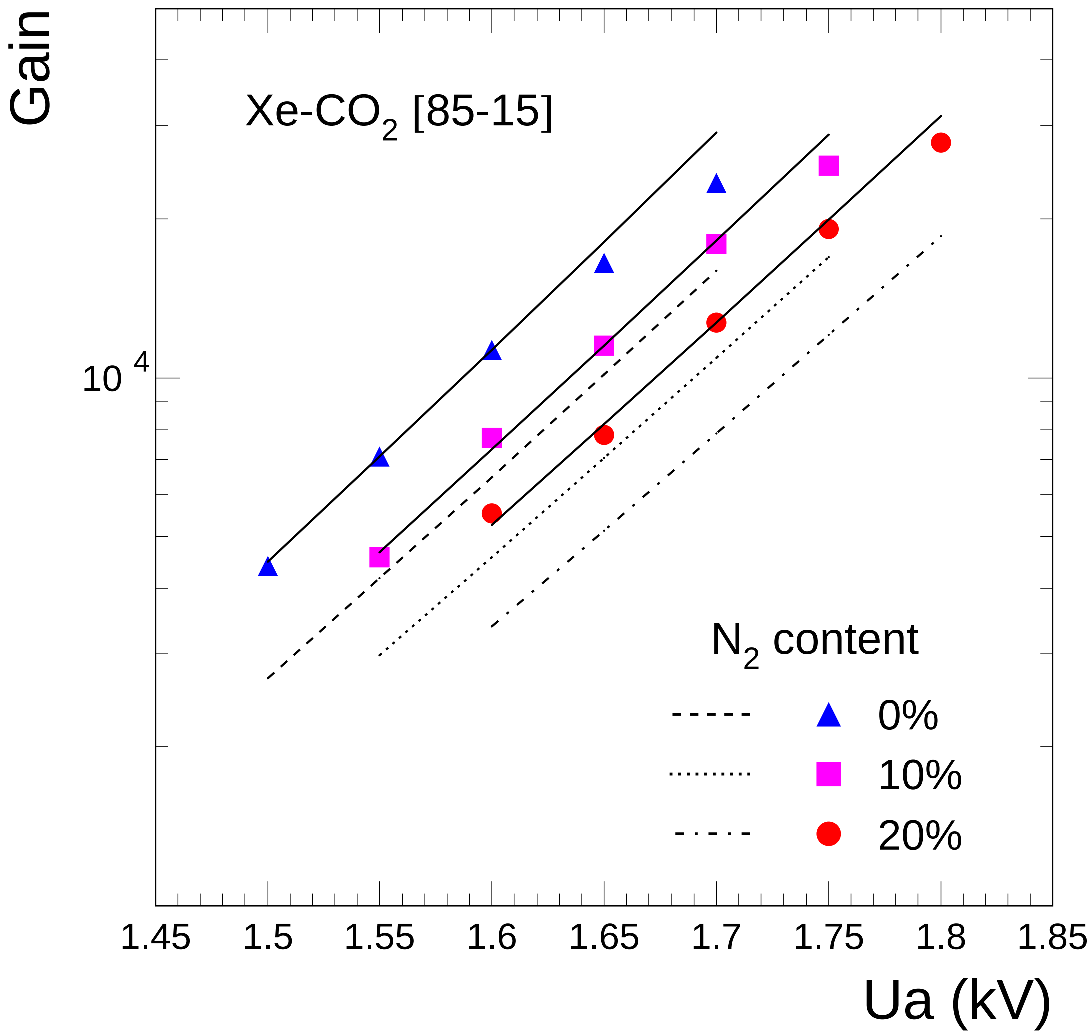


- measured using a drift MWPC



- measurements (symbols) and calculations (MAGBOLTZ, lines) agree well
- N_2 due to buildup (via leaks) from atmosphere (O_2 and water are filtered out)

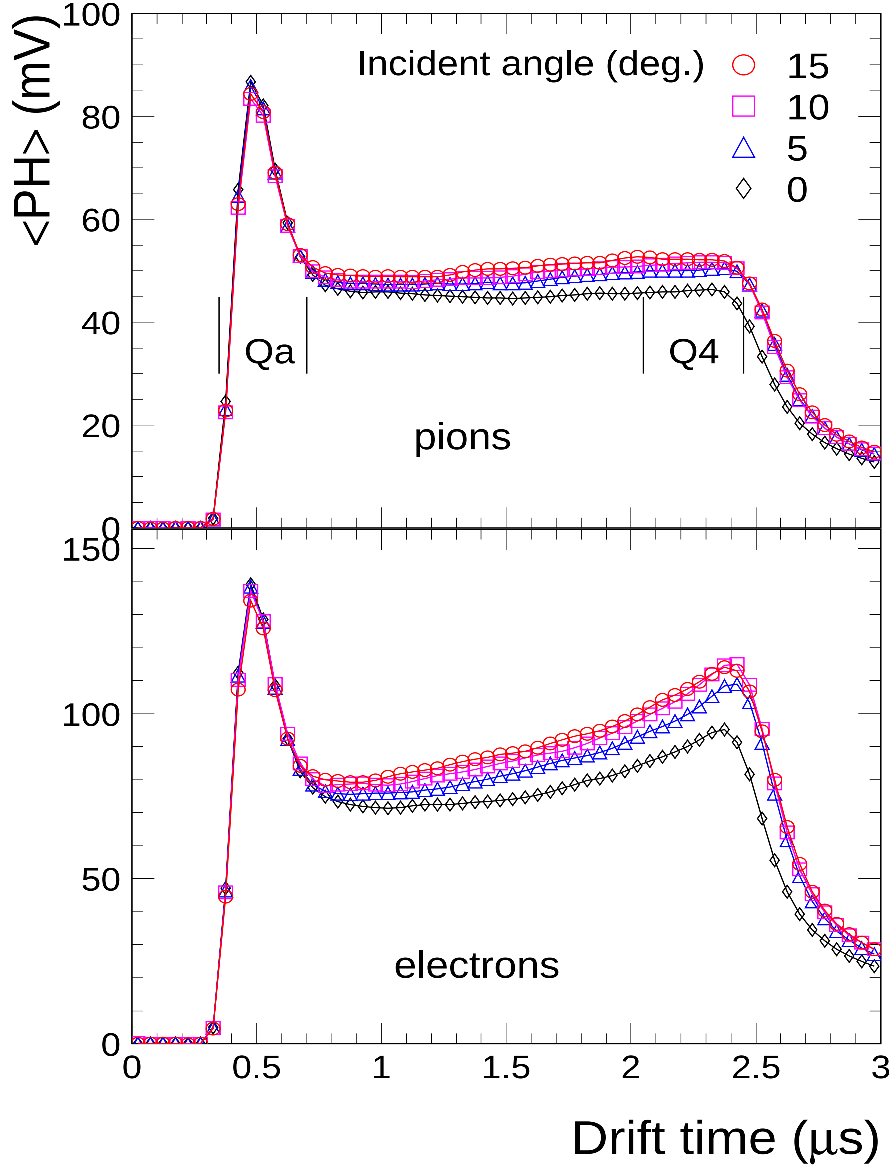
Gas gain (amplification)



NIM A523 (2004) 302 [physics/0402044]

- measured using ^{55}Fe:
  5.96 keV / $W \simeq$ 260 electrons
  measure rate (Bq) and current on the anode (nA)
- measurements (symbols) and calculations (Imonte, lines) agree well
- ...only if Penning effect taken into account
  $CO_2^* + Xe \rightarrow CO_2 + Xe^+ + e^-$

Space charge

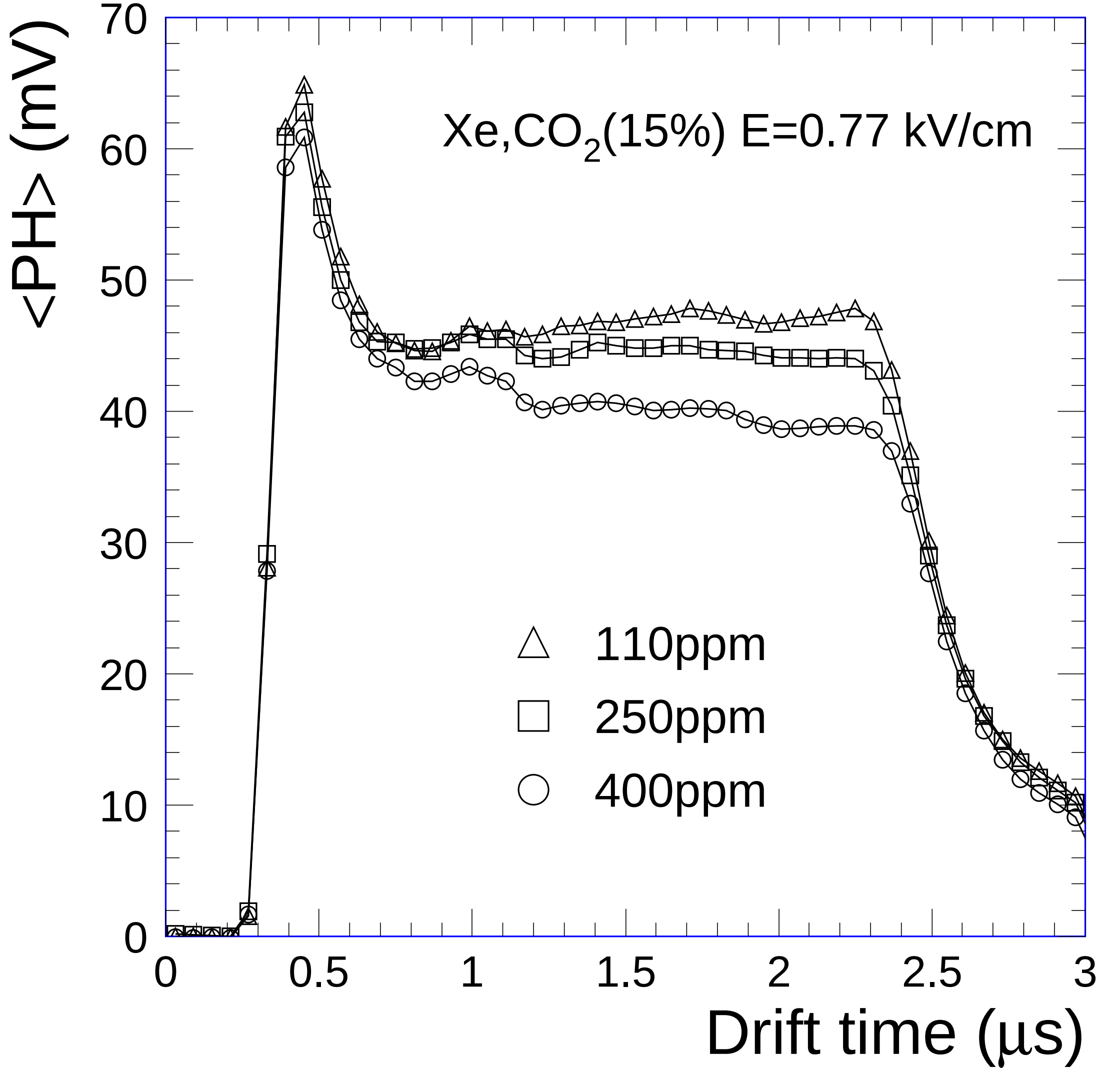


... around the anode wires

- reduction of late signal due to reduced effective gas gain (screening from earlier avalanches, slow moving ions) - *quantitatively understood*
- pronounced at normal incidence (0 deg.), a local effect ($\sim 100\mu$m)
- larger for higher gains
- leads to a slight degradation of e/π identification perf.

NIM A525 (2004) 447 [physics/0402043]

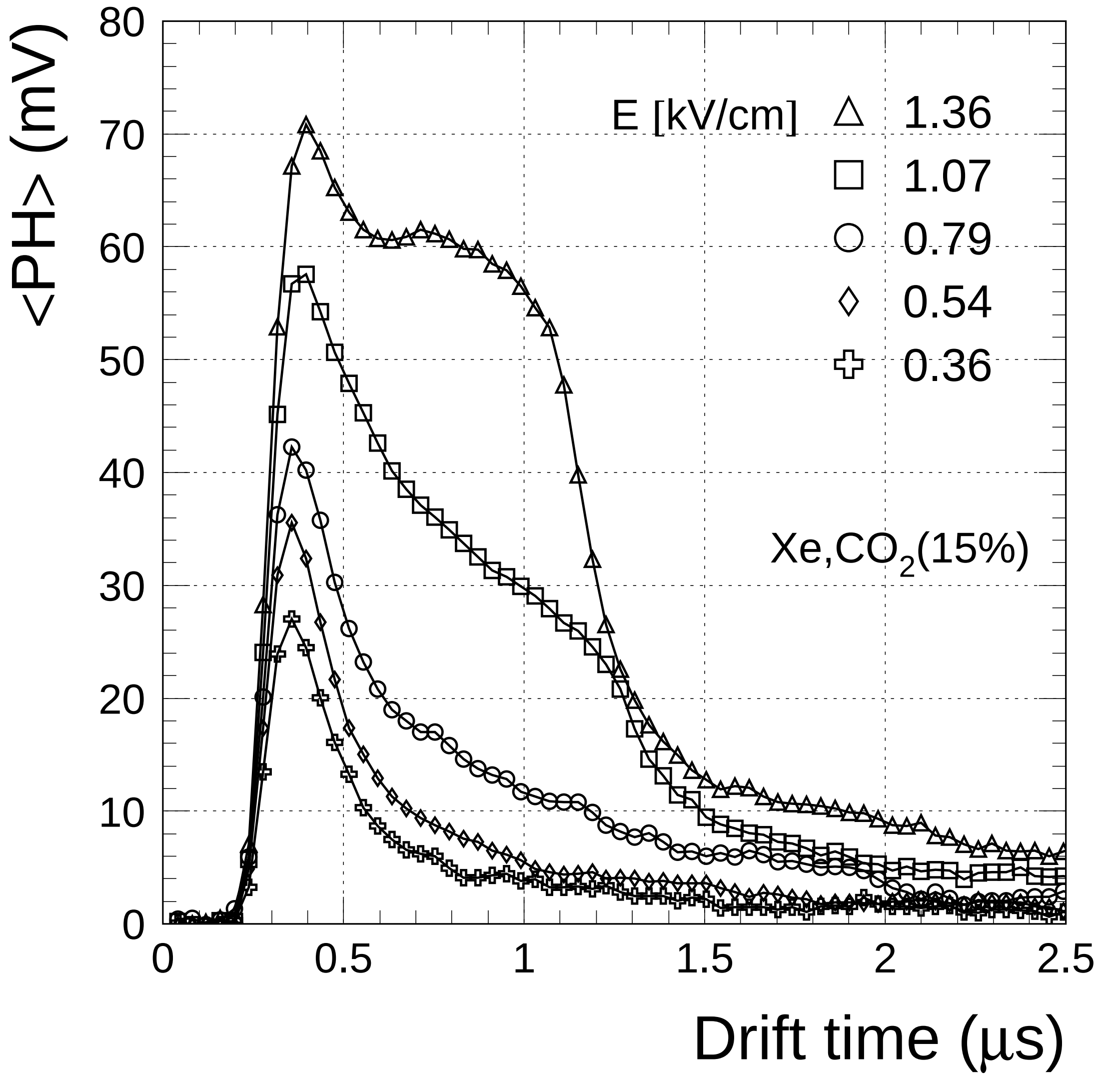
Electron attachment: on oxygen



NIM A498 (2003) 143 [physics/0303059]

- three-body resonant capture:
  $I + e^- \longrightarrow I^{-*}$
  $I^{-*} + S \longrightarrow I^- + S^*$
  I=O_2, H_2O; S=quencher
- attachment on O_2 is moderate, can be serious for long drifts (TPCs)
- conditions in drift chambers: O_2 ~10 ppm, H_2O~100 ppm

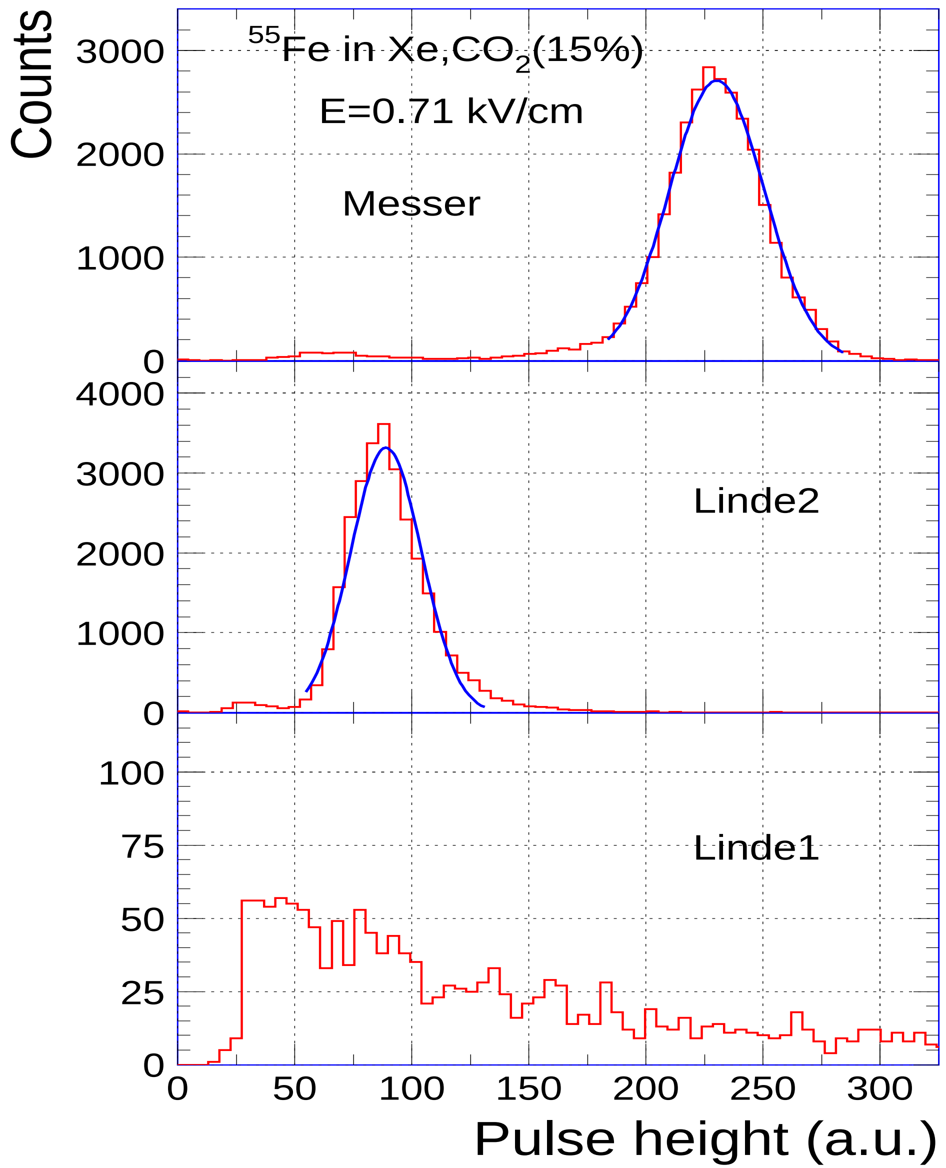
Electron attachment: on SF_6



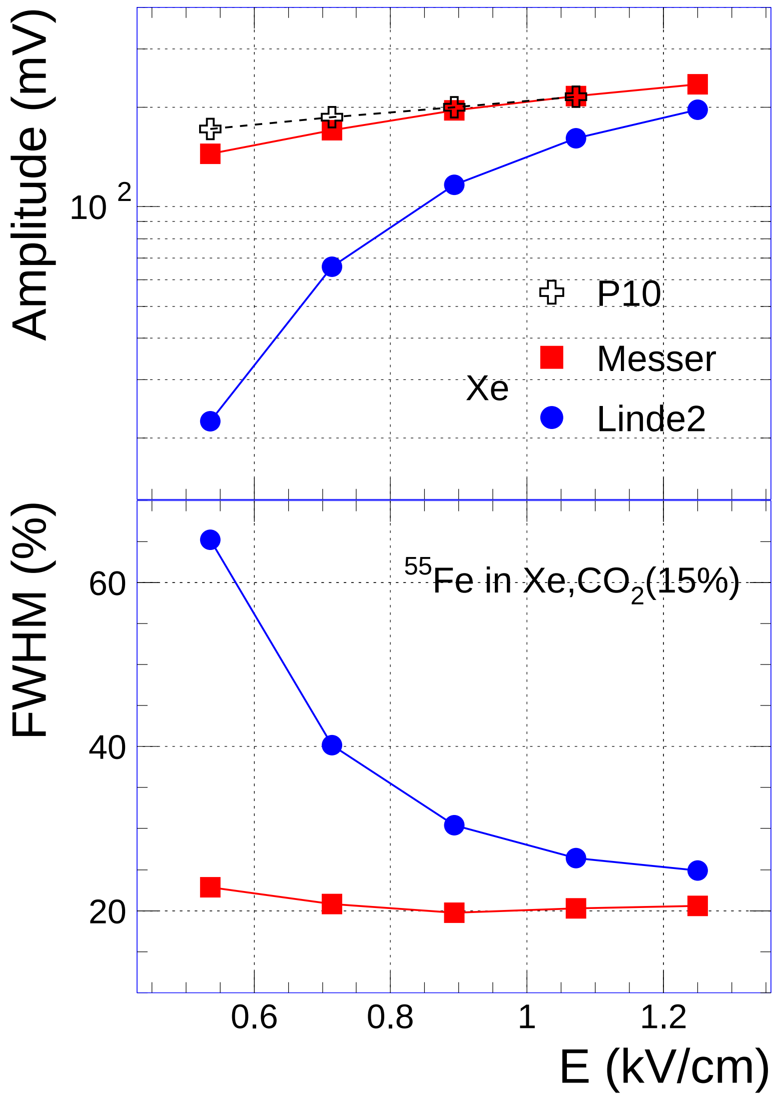
NIM A498 (2003) 143 [physics/0303059]

- huge! ...but can be quantitatively understood
- strong dependence on E (electron characteristic energy)
- enhanced by CO_2 presence present, but reduced, with CH_4
- why SF_6? present (0.9 ppm) in the Xe bottle (we found it by chance - during beam tests...)

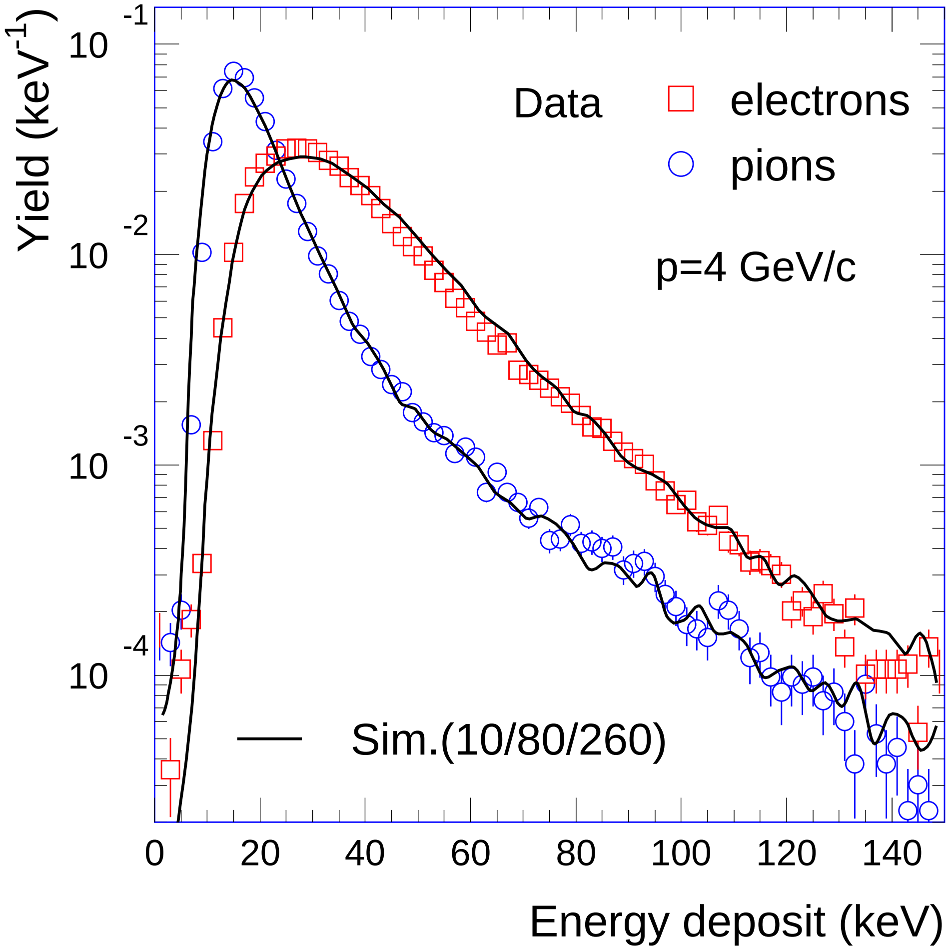
Electron attachment: early diagnosis

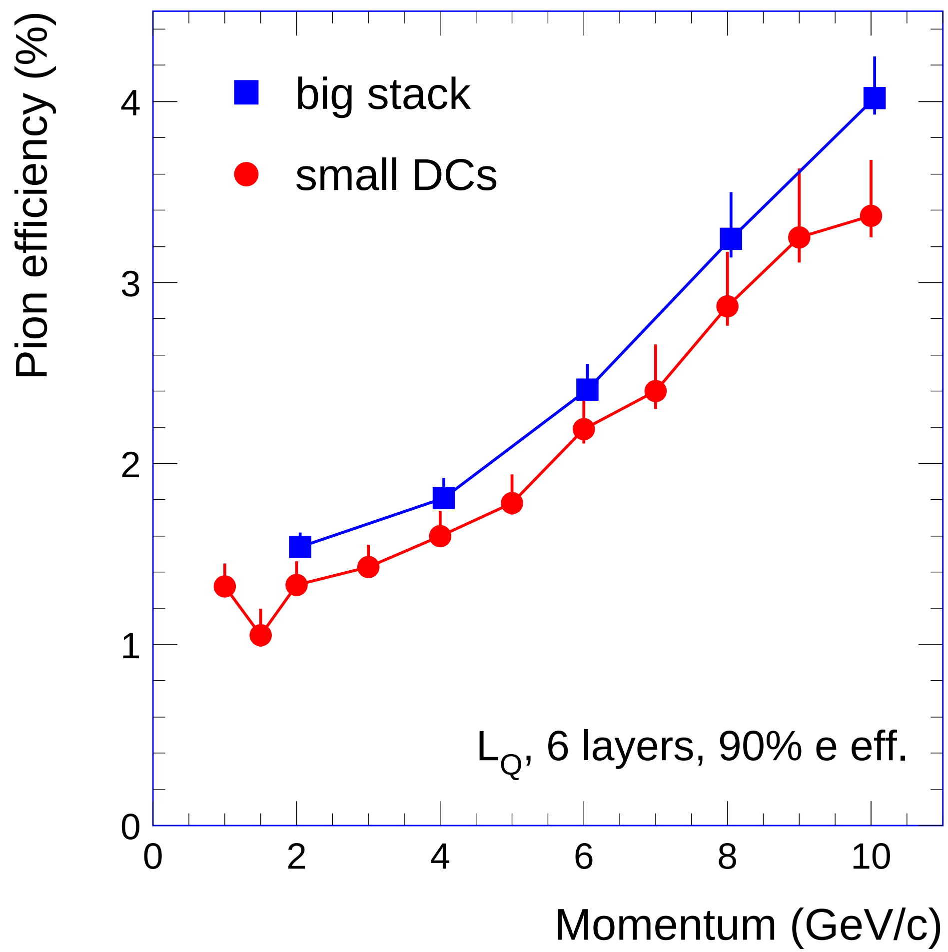


...using a prototype DC



Electron/pion identification

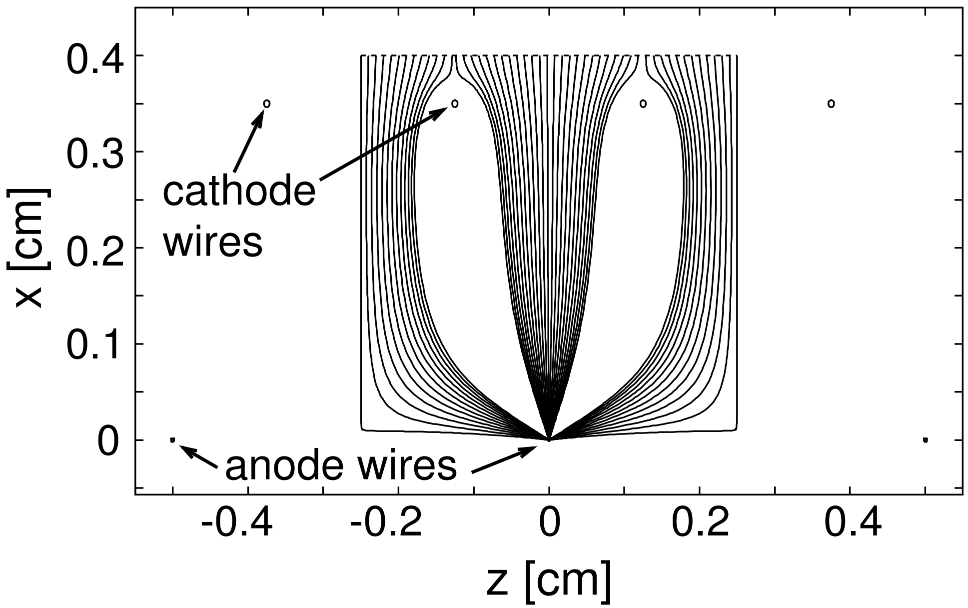




- Likelihood on total charge, including TR (well described by simulations)
- Pion rejection of 100 achieved, further improvements possible

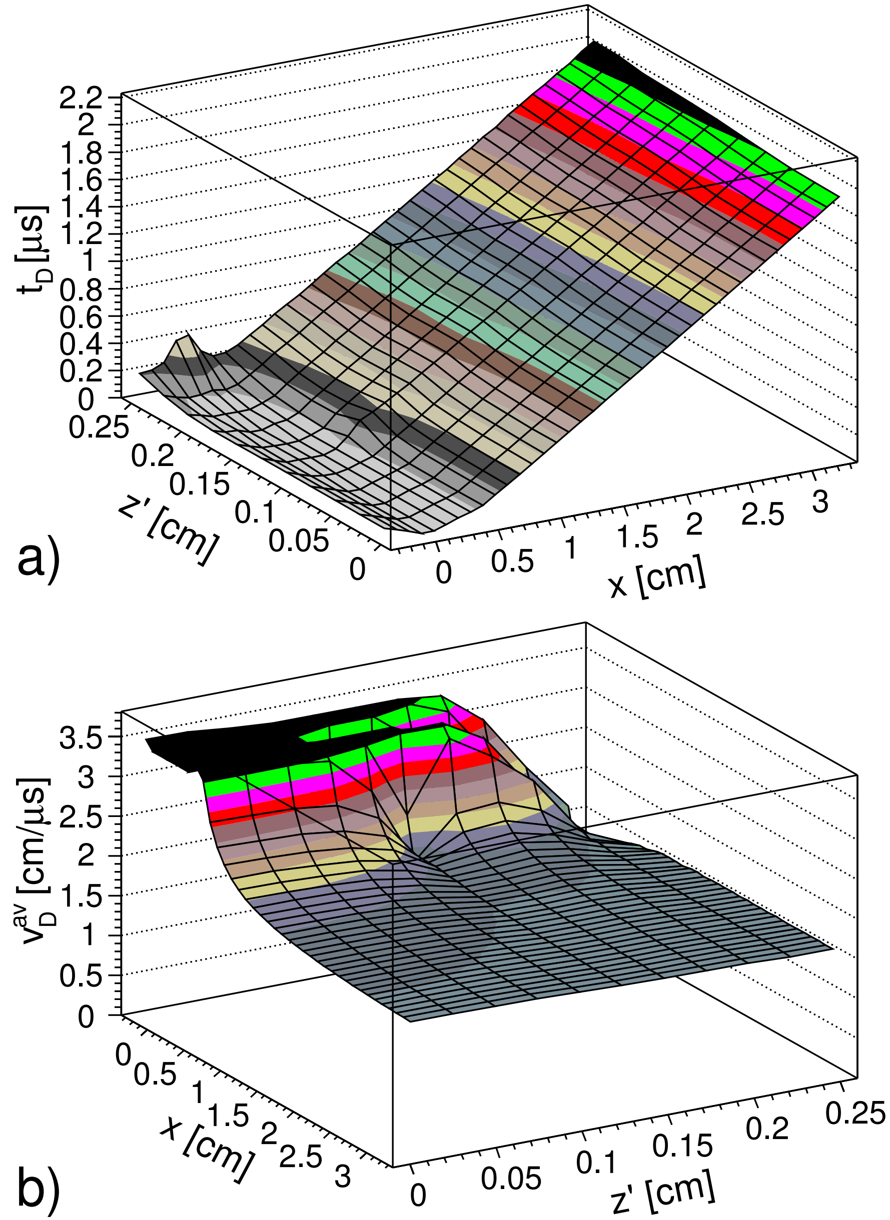
Position resolution: detector geometry

drift cell

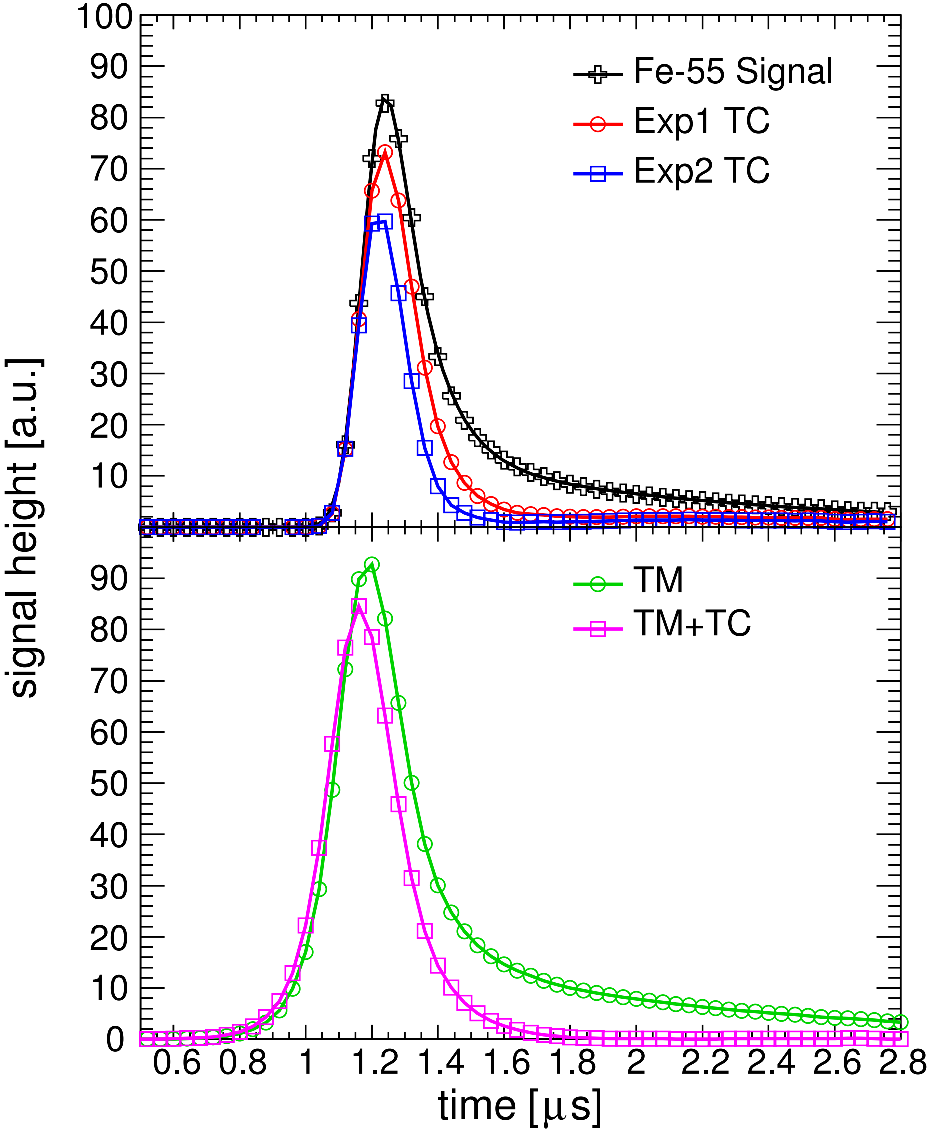


→ non-isochrony

NIM A535 (2004) 457

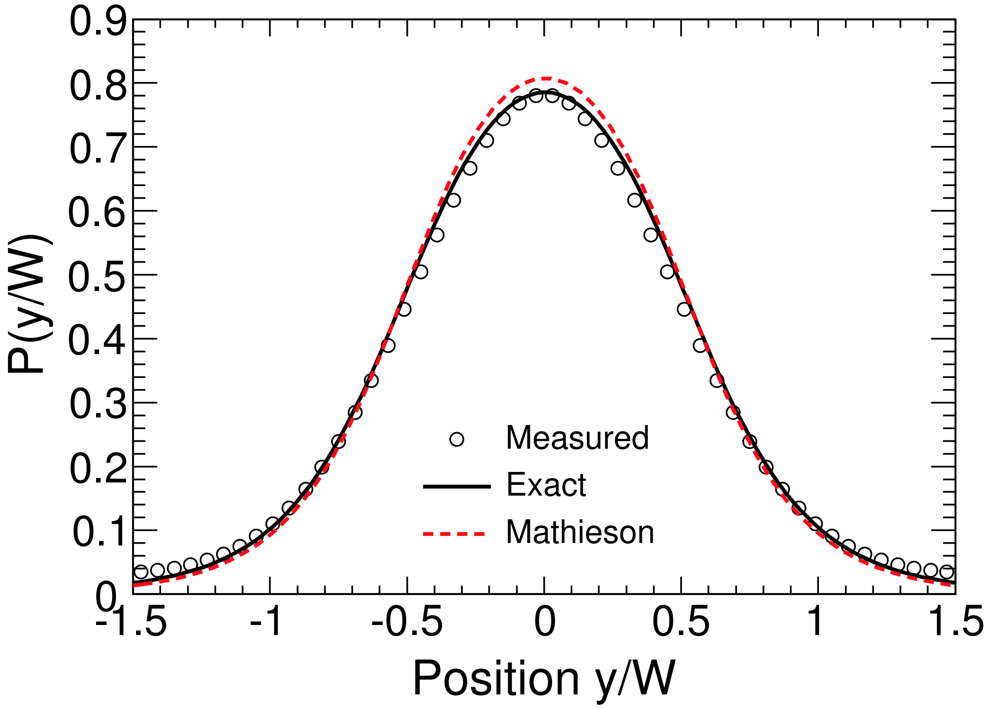


Position resolution: detector signal and PRF



← asymmetry due to slow ions (ion tail) leads to angle distorsions
we do "tail cancellation" (on-line)

PRF (signal sharing on adjacent pads)



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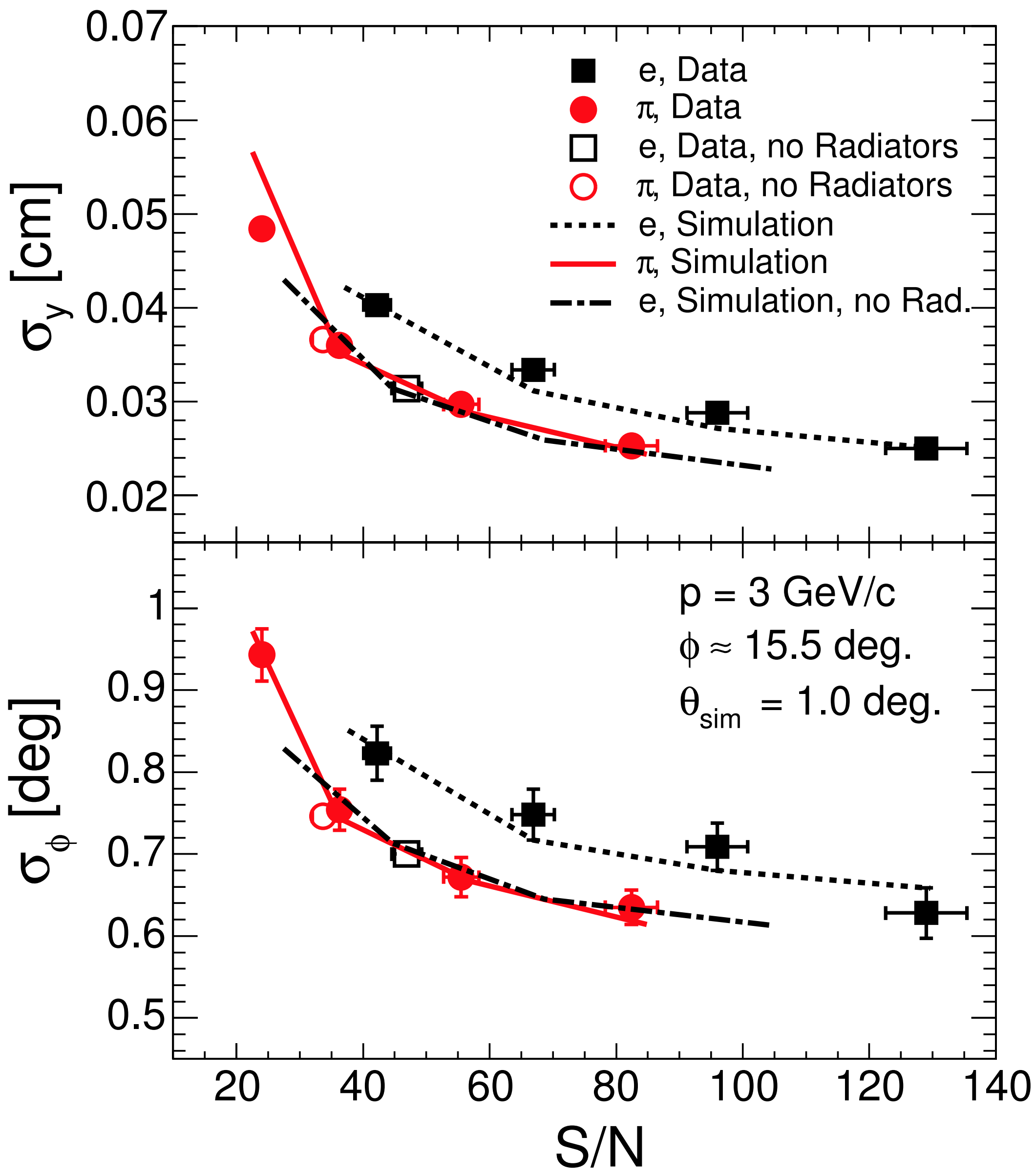
Position resolution: S/N dependence



- Expected improving of resolution with signal-to-noise ratio
- Electrons: worse than pions (due to TR, angular dep. of absorption)
- Good agreement with simulations
- Same resolutions with or without B-field

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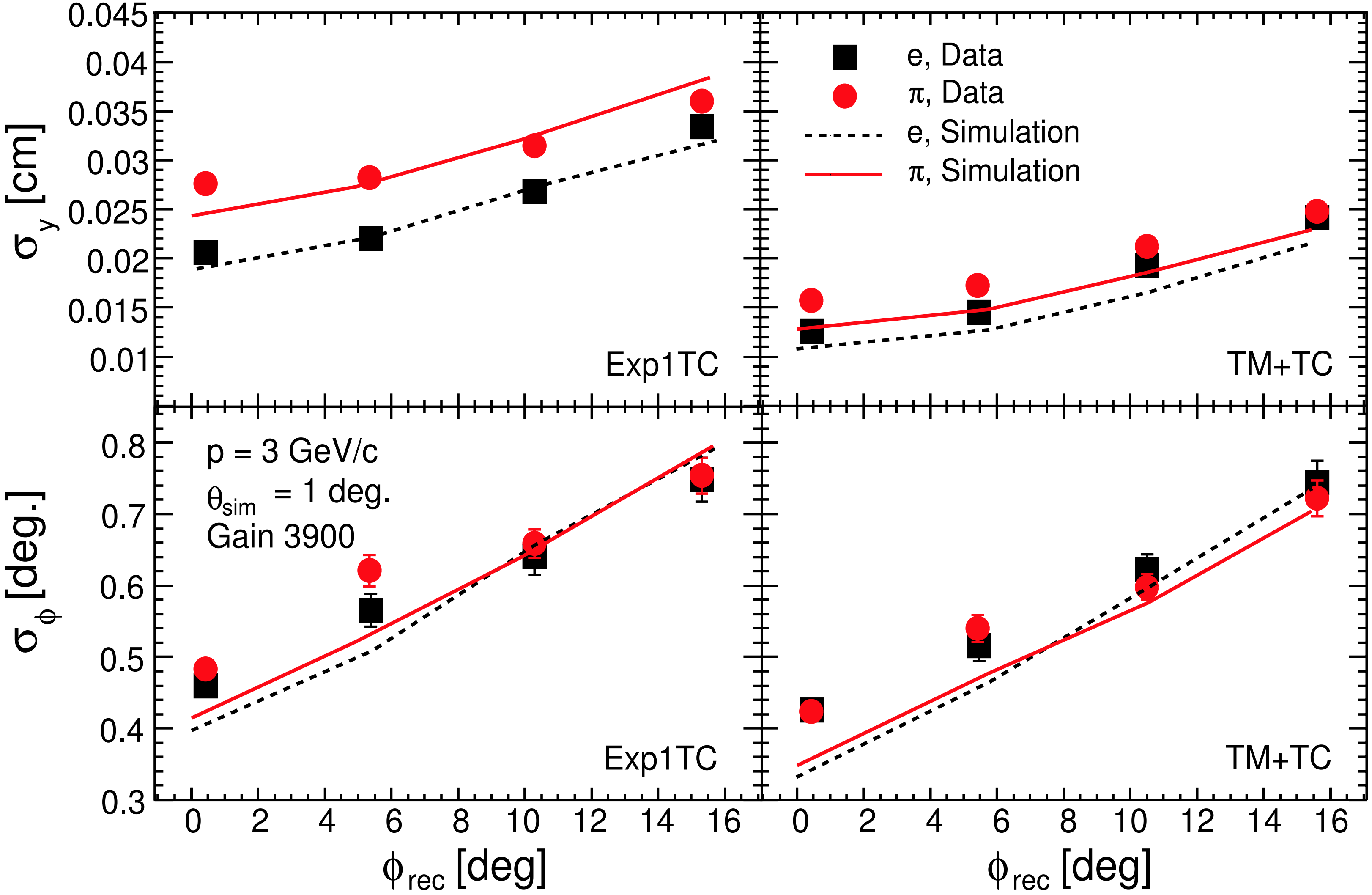
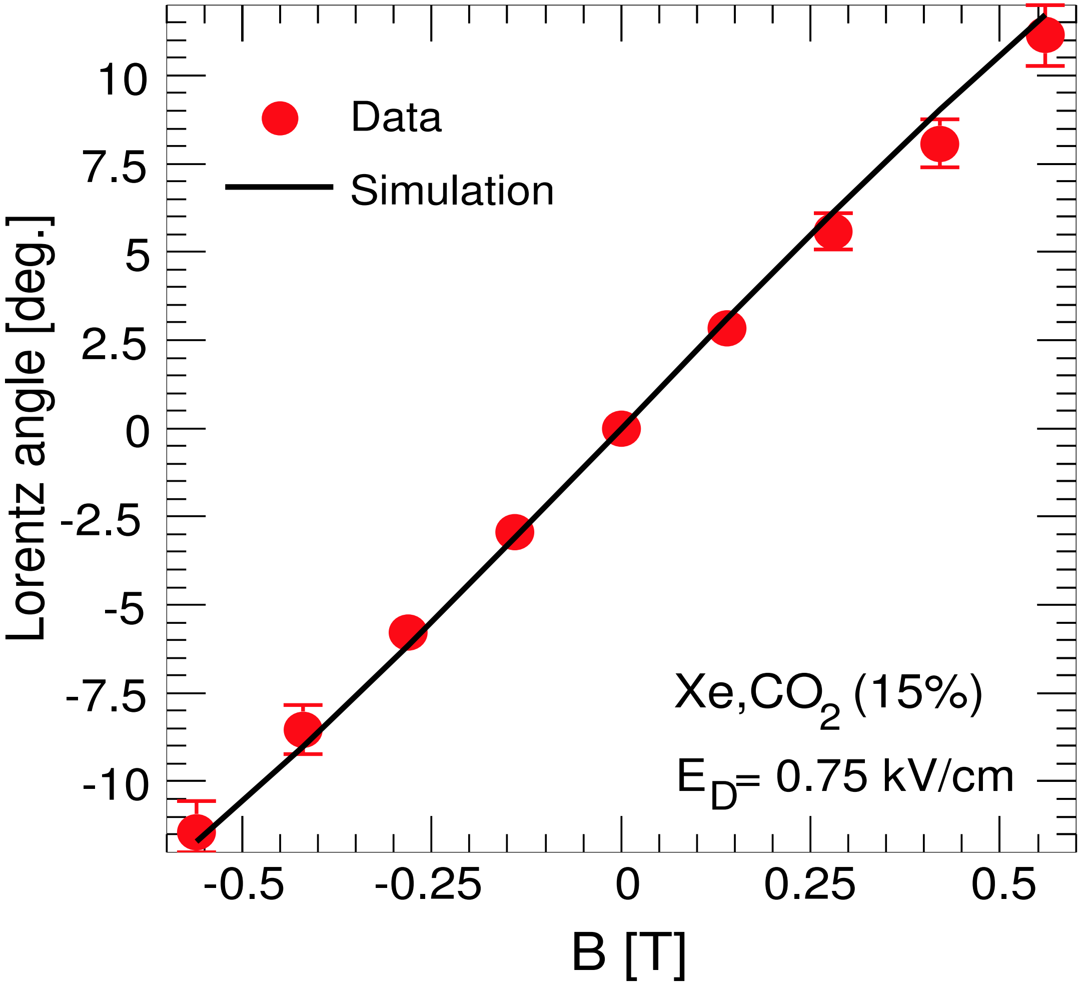
Position resolution: angle dependence



due to remanent signal asymmetry; point resolution: 130 μm

Lorentz angles



- angle measurement in magnetic field with our prototype chambers
- need good alignment of detectors
- good agreement with simulations (Magboltz)

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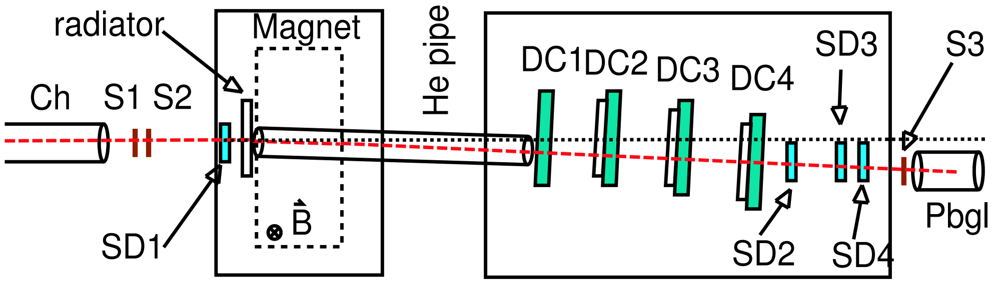
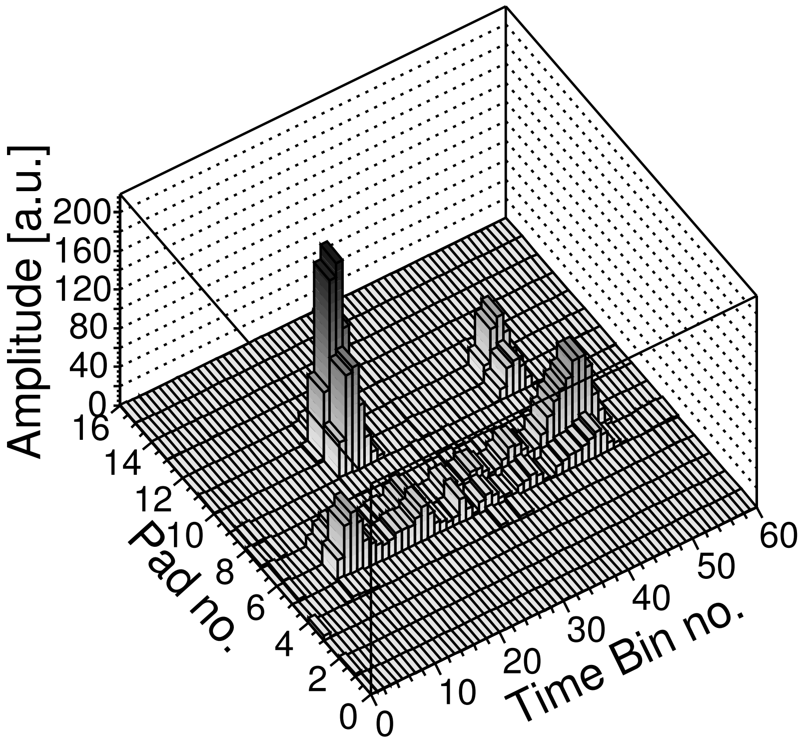
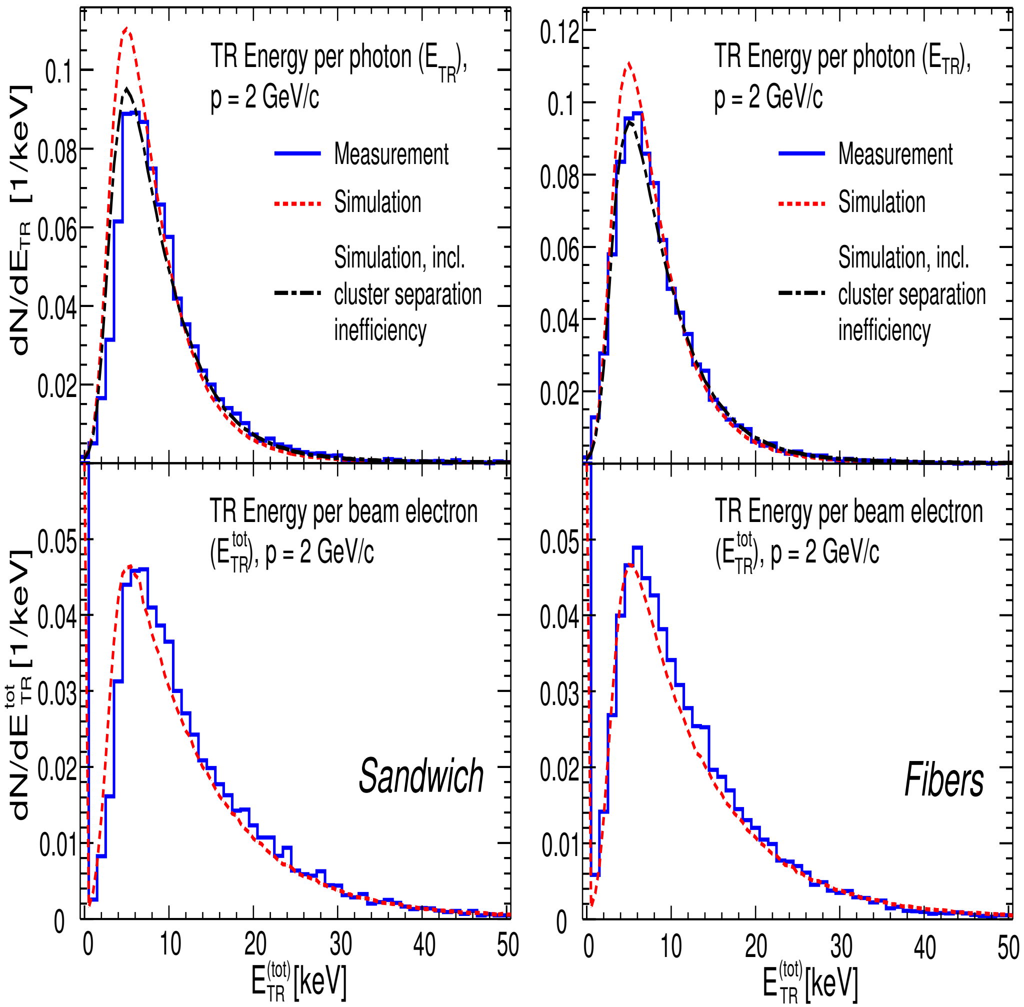
Transition radiation spectrum



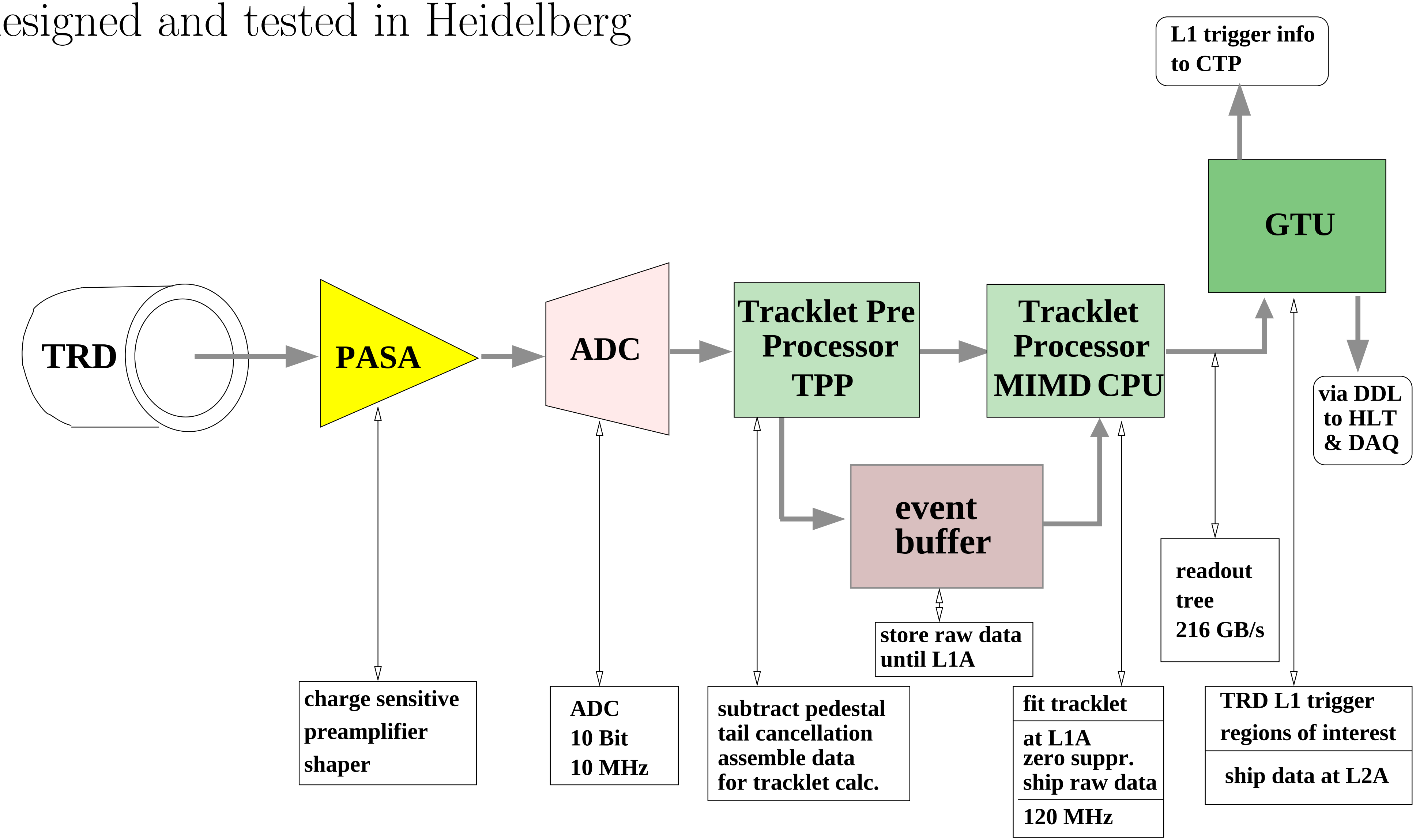




nicely reproduced by simulations (important for physics perf. simulations)

Front-end electronics

designed and tested in Heidelberg



DCS and "services"

Detector control system

- on-detector: network of custom computers (Linux) and interfaces (internet)
- clock distribution to MCMs, possibility of (slow) detector data readout
- off-det.: setting and monitoring voltages, monitoring currents, temperature

Gas system

- cooking the right mixture, circulate it, filter O_2 and H_2O
- regulates on-detector pressure ($\simeq$ 0.5 mbar) - compensates hydrostatics
- monitoring gas quality and environment (pressure) via drift velocity meas.

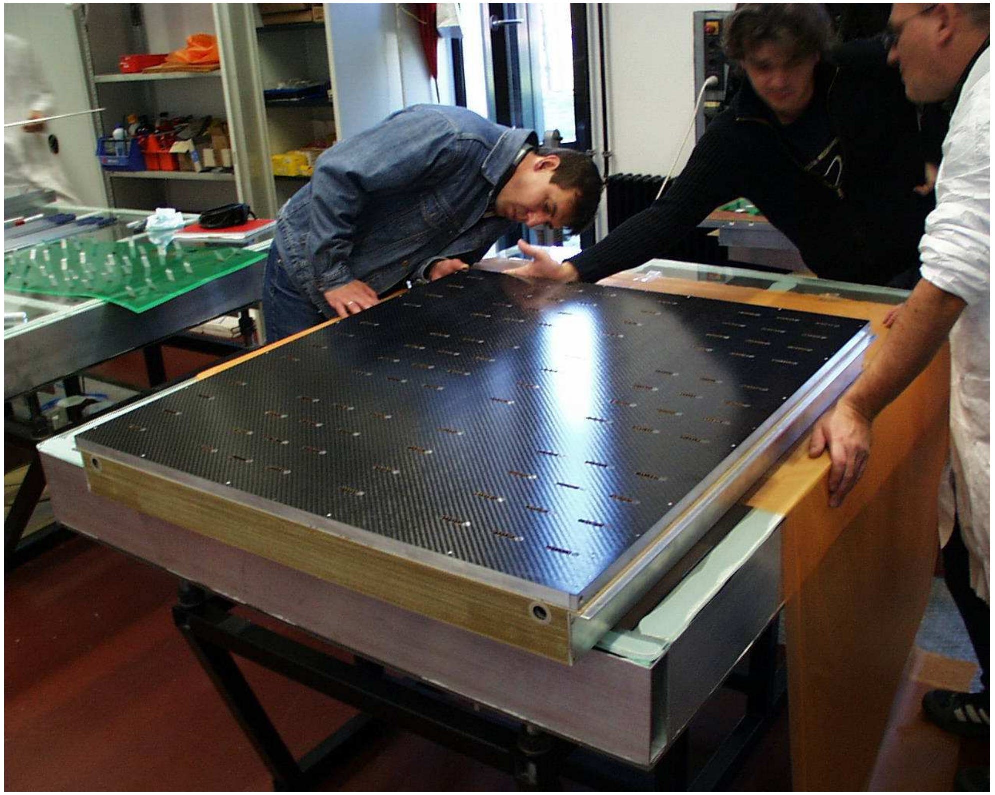
Cooling system

- water-based, transporting away the power (70 kW) dissipated on-detector

Chamber construction

Ongoing, 60% accomplished

Bucharest, Darmstadt, Dubna, Frankfurt, Heidelberg (radiators: Münster)



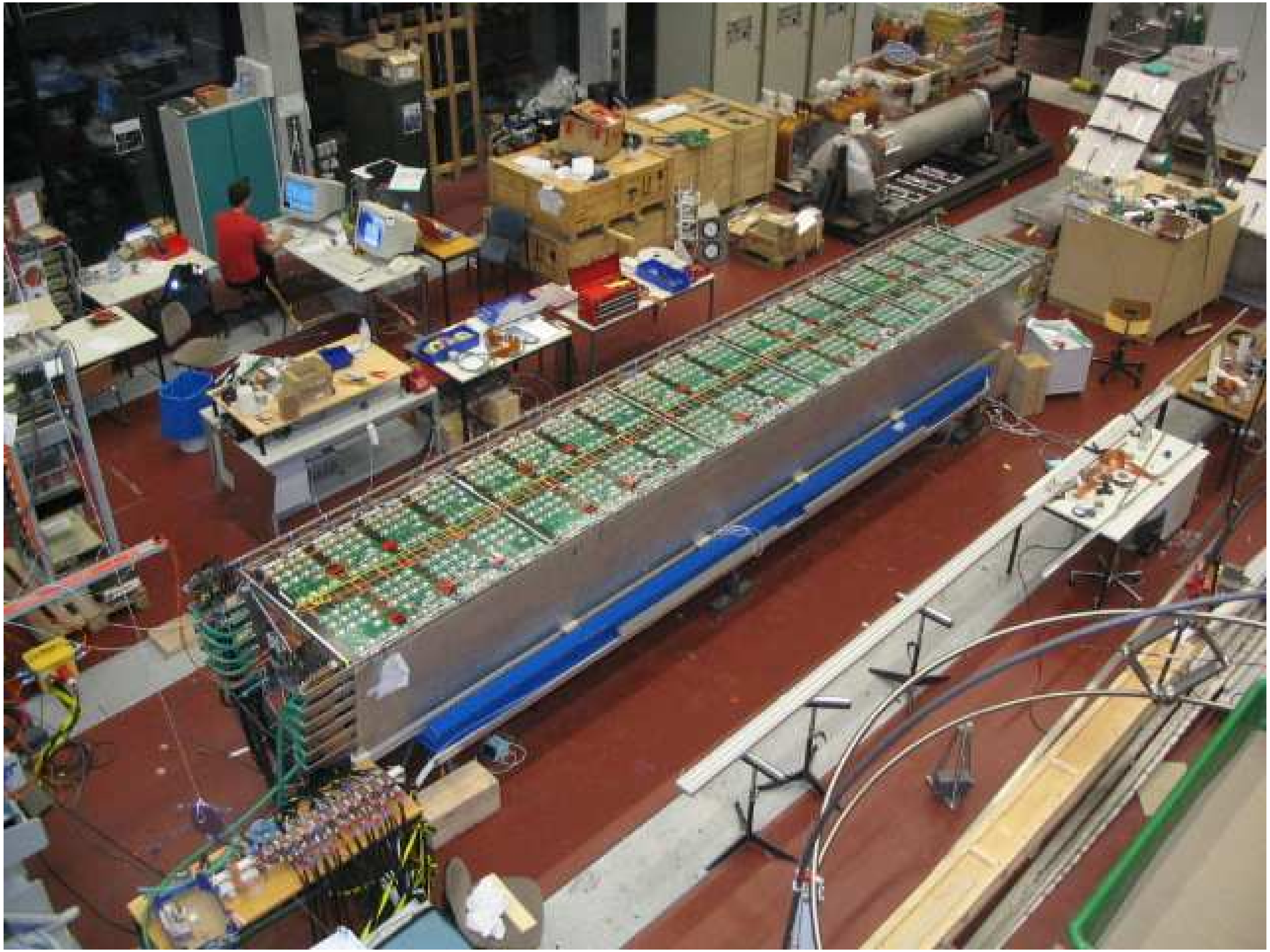
(radiator laminate panels, backpanels: Fischer AG)

The supermodule (30 chambers)

1st one finished in Heidelberg (all others: Münster)

1/18 of ALICE TRD (or ≃0.5 mil. euros)

...just ready in Heidelberg, awaiting shipping to CERN

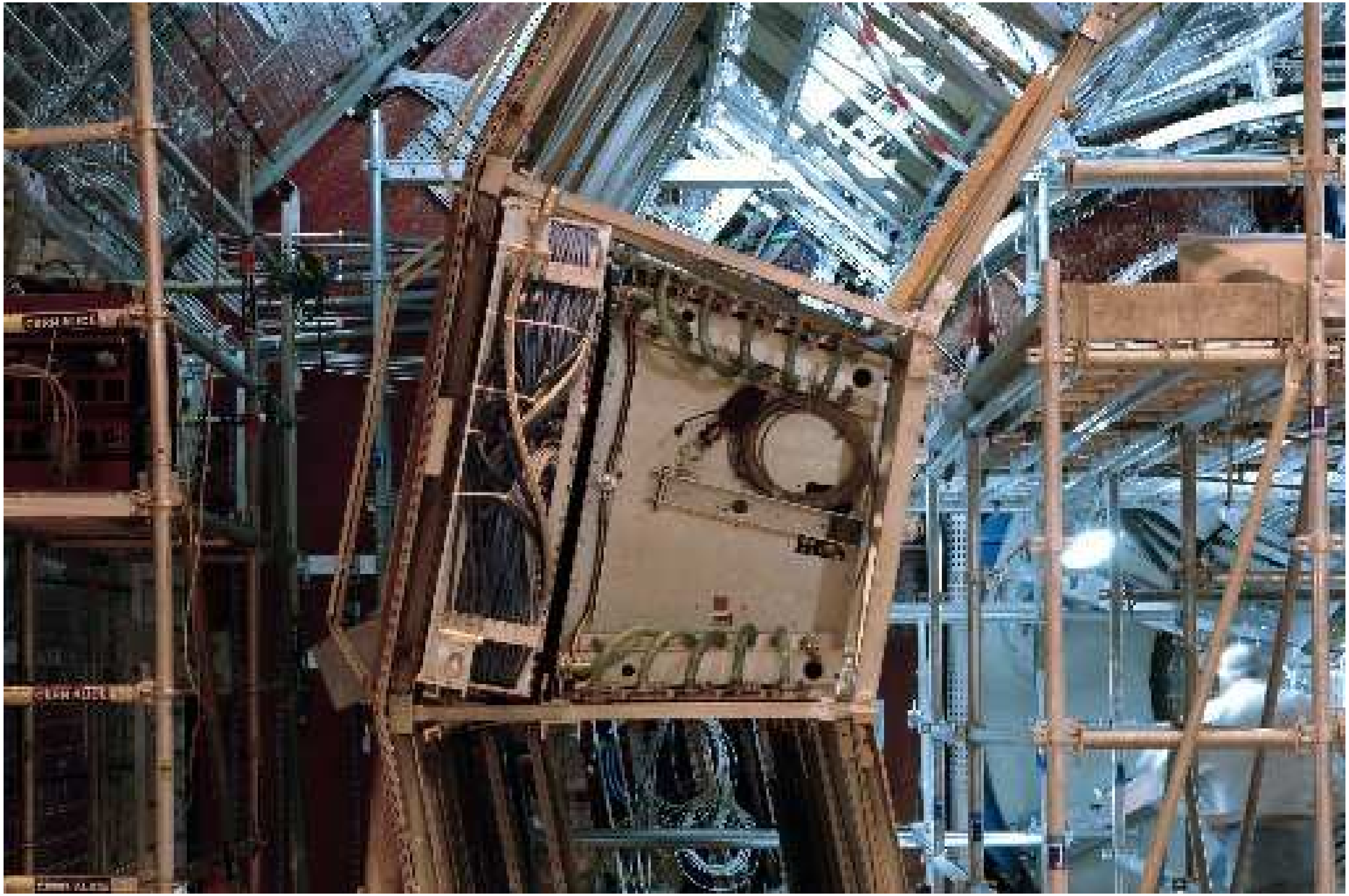


1/18 of ALICE TRD (or ≃0.5 mil. euros)

...being tested with cosmic rays at CERN

1/18 of ALICE TRD (or ≃0.5 mil. euros)

...in its final position



Ongoing activities

Construction

- FEE: companies (chips, MCMs, readout boards), testing in Heidelberg
- chambers: built in 5 inst. (60% done), equip. with FEE and tests: Frankfurt
- supermodules (17/18 to go): Münster (another 2 to be ready end of April)
- DCS: Heidelberg, Worms; cooling: GSI, Heidelberg, Münster; HV: Athens

Preparing for data (with simulations)

- calibration (gas gain, drift vel., time ref., PRF) and alignment (GSI)
- position reconstruction and tracking (GSI, Heidelberg)
- e/π identification (new methods, bidimensional distributions: GSI)

...and of course physics performance studies

...and the people behind them

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