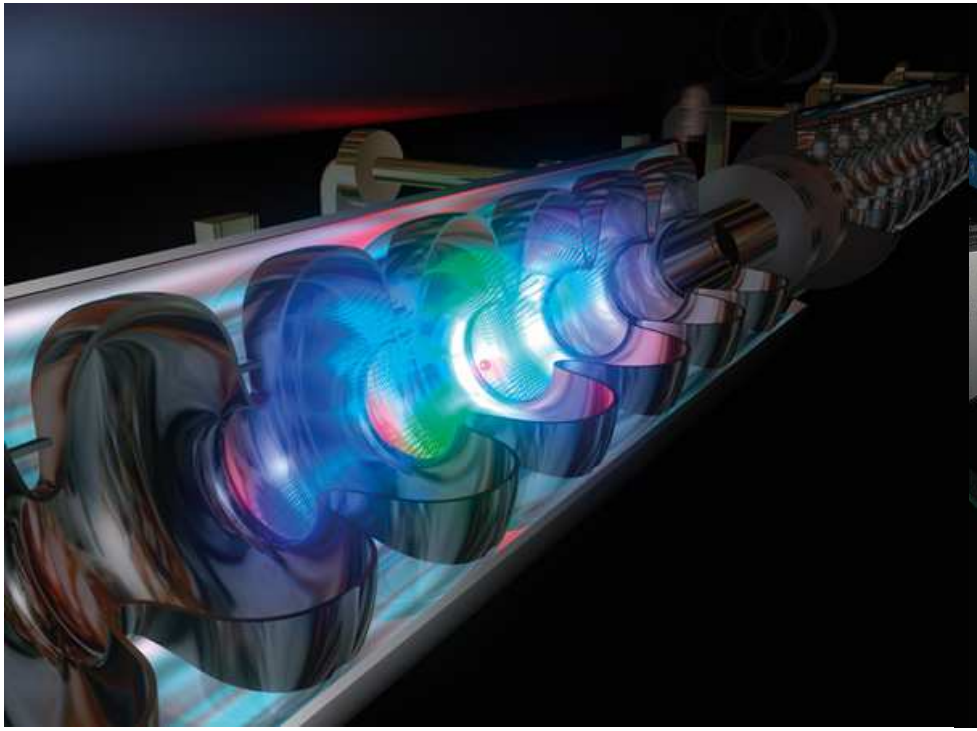
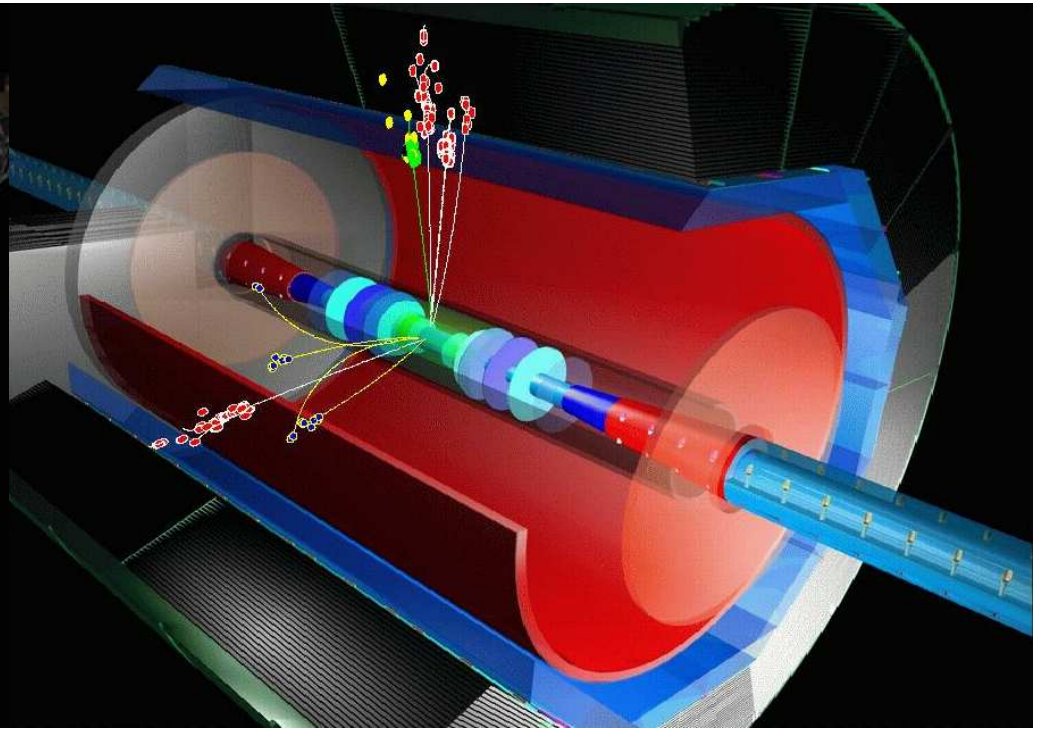
ILC International Linear Collider

CERN, 20th January 2006

The GEM-TPC for the ILC

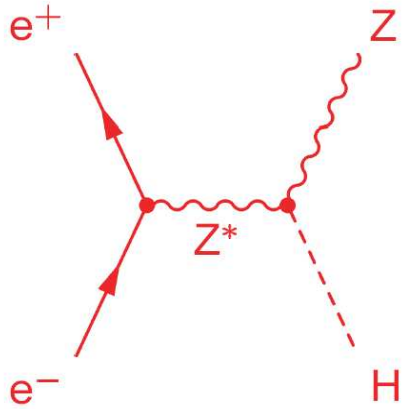
Stefan Roth, RWTH Aachen



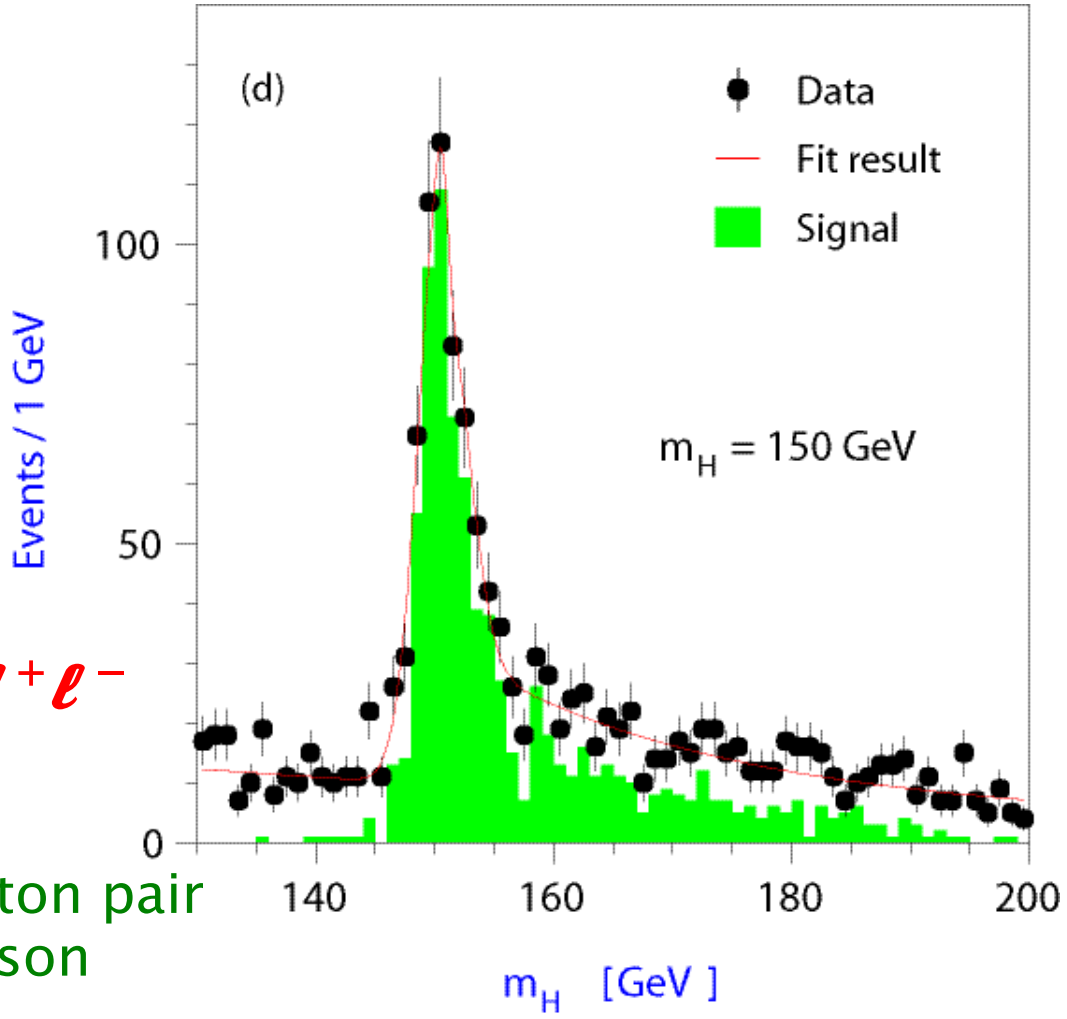


Precision Measurement of Higgs

Measure Higgs production independent of decay



Reaction $e^+e^- \rightarrow H Z \rightarrow X \ell^+\ell^-$



Resolution of recoil mass of lepton pair limited by natural width of Z boson

required momentum resolution: $\Delta(1/p_t) < 5 \cdot 10^{-5}$ GeV^{-1}

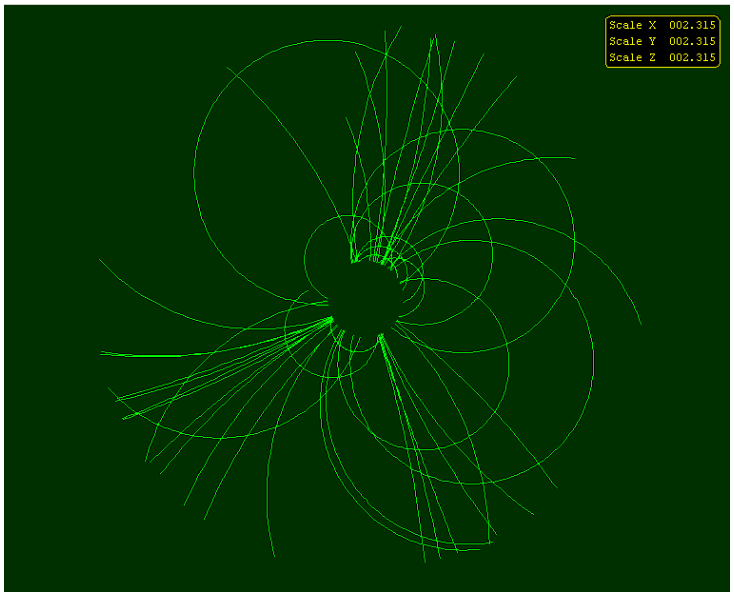
(CMS-Tracker: $\Delta(1/p_t) \approx 1.5 \cdot 10^{-4}$ GeV^{-1})

Why using a Drift Chamber?

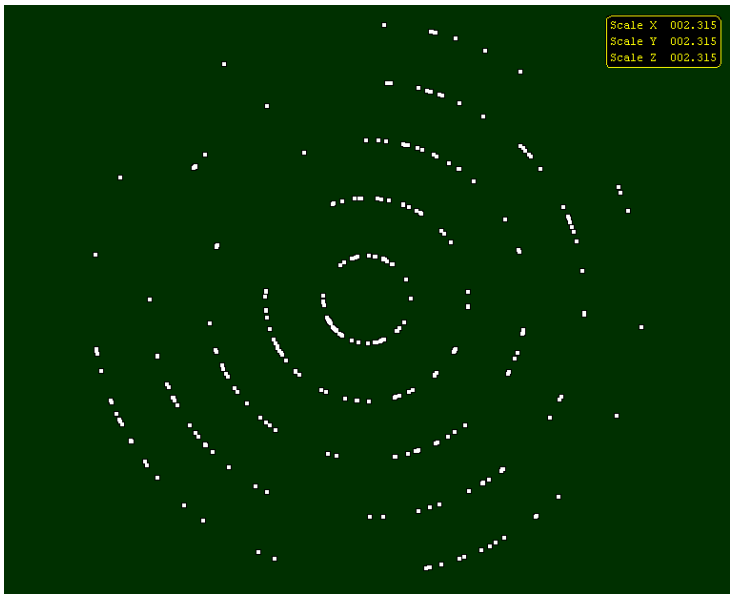
Advantage of TPC versus full-silicon tracker à la CMS :

- small material budget in front of precision calorimeter
- little multiple scattering improves momentum resolution
- measurement of dE/dx
- efficient pattern recongnition

drift chamber (TPC)



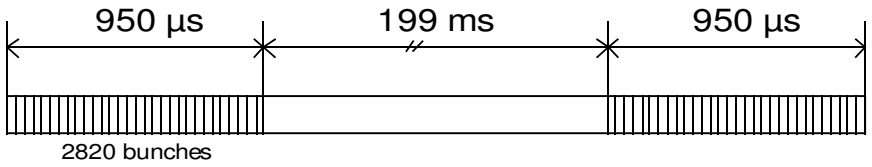
silicon detector

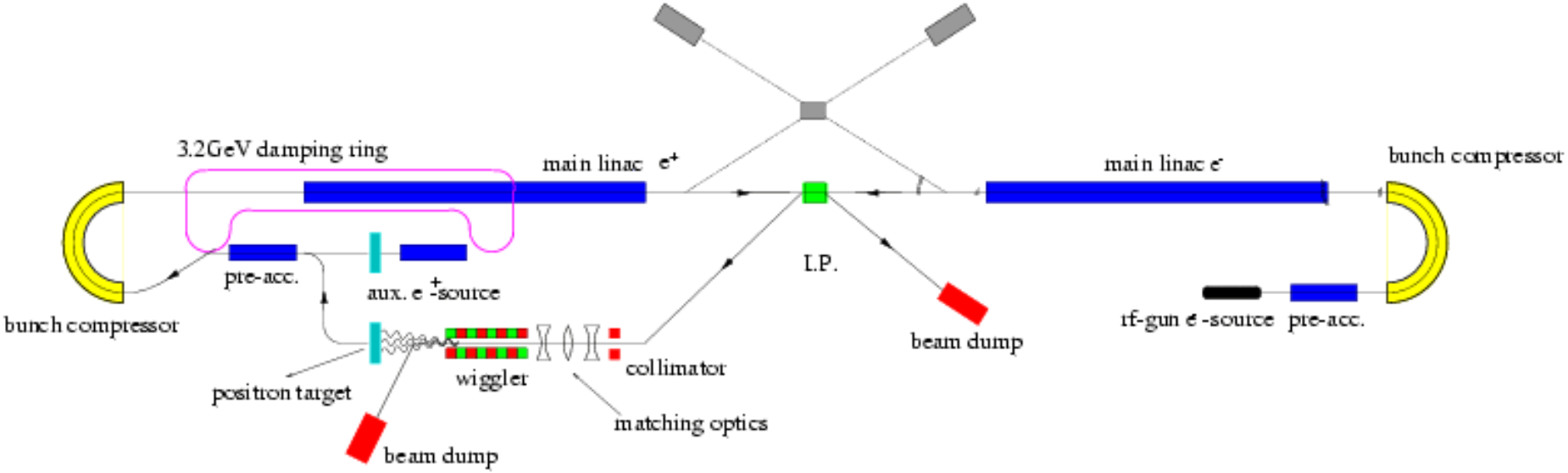


much smaller particle rates than at the LHC !

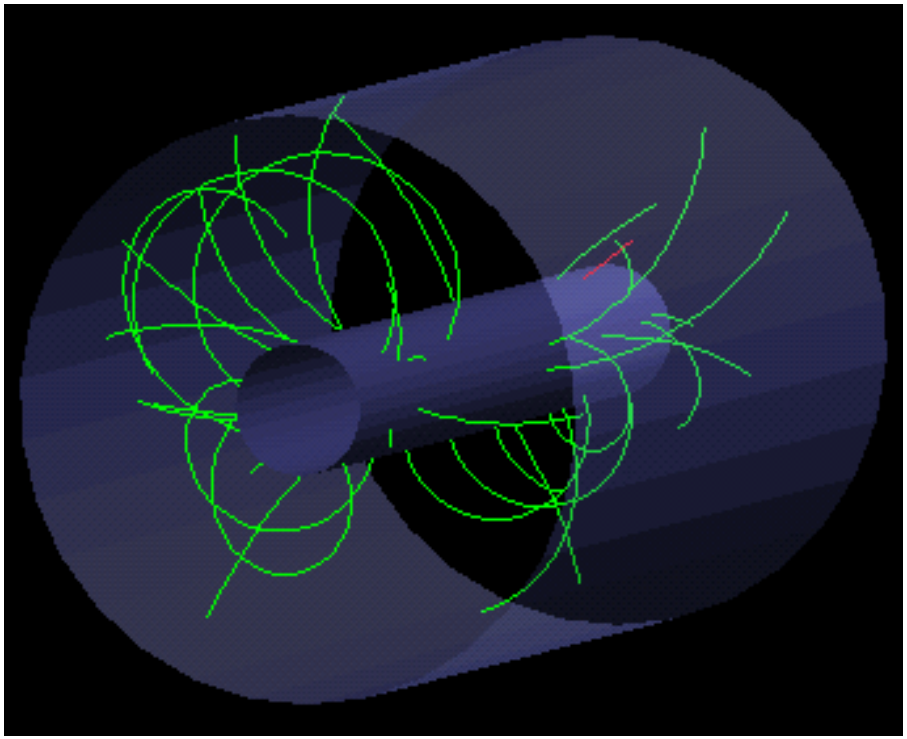
ILC – International Linear Collider

- Design based on “cold technology”
  TESLA – TeV Energy Superconducting Linear Accelerator
- CM energy: 90 – 1000 GeV
- Luminosity: $3 \times 10^{34}\ cm^{-2}\ s^{-1}$ (ca. 5000 x LEP)
- Time structure: 1 ms long bunch trains with 5 Hz
- Bunch separation: 337 ns

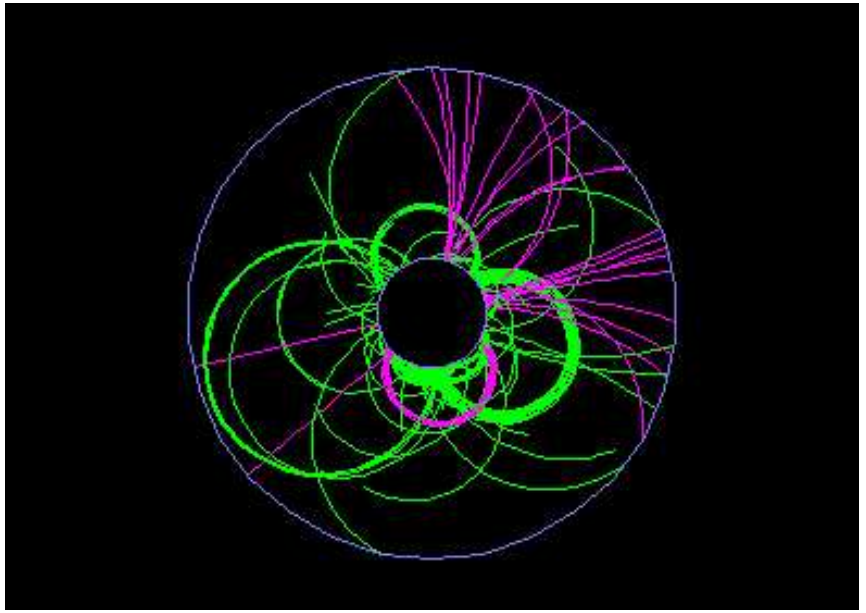




Timing



- continuous TPC read-out during bunch train (2820 BX)
- no hardware trigger
- 1 ms of raw data in front end

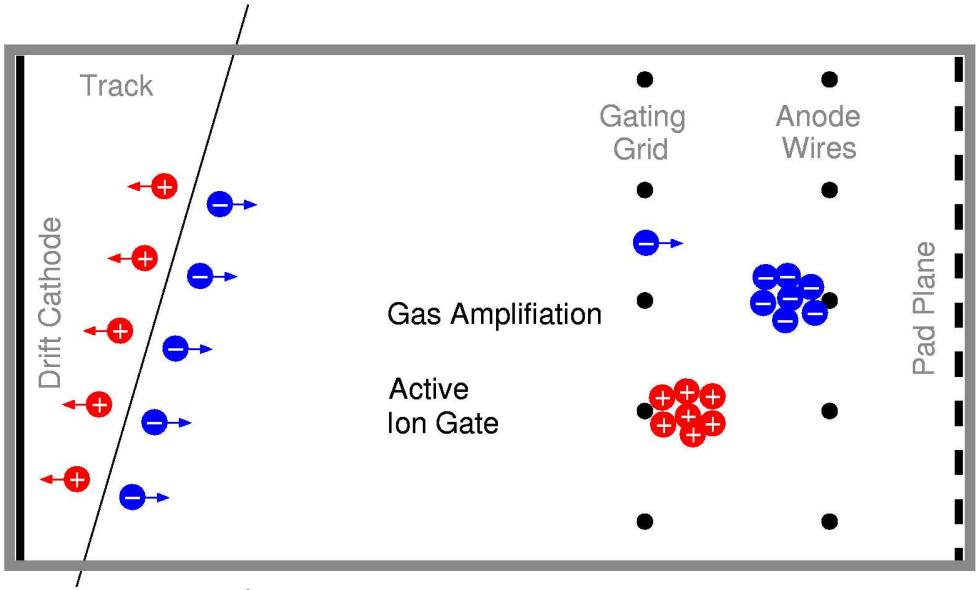


Time measurement in TPC

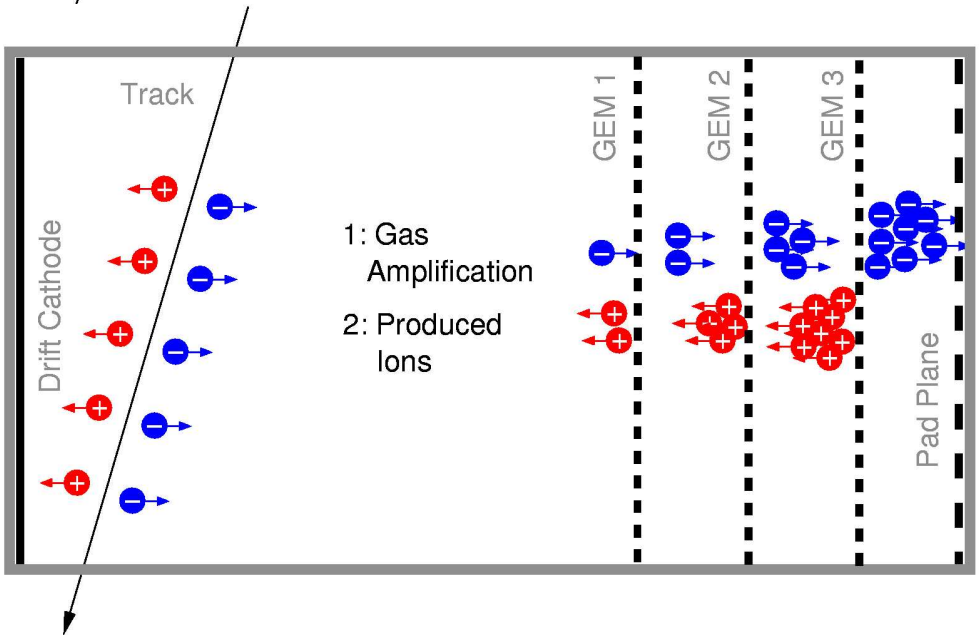
- z coordinate
- event tag

Ion Back-Drift

LEP: Gating between bunches
$\Delta t = 22\ \mu s$



ILC: Length of bunch train
2820 x 337 ns = 950 µs



Drift time is about 50 µs,
no Gating between
individual events possible

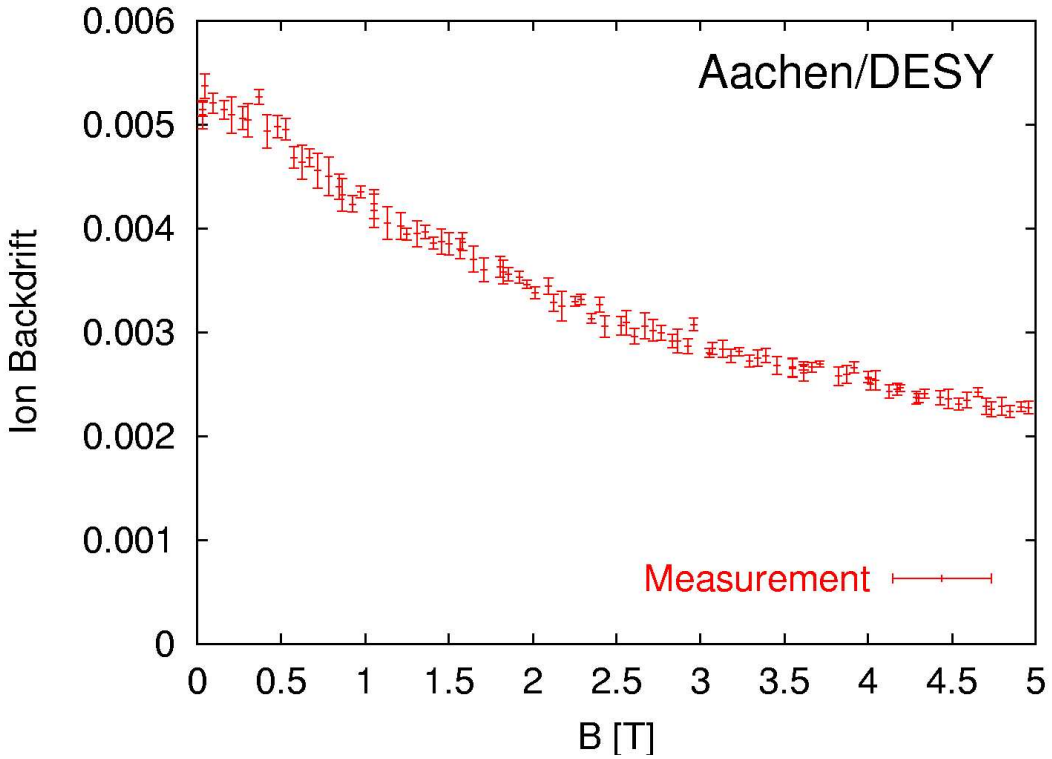
Ion Back-Drift in Magnetic Field

Measurements in 5 T magnet

Anode current increases with magnetic field

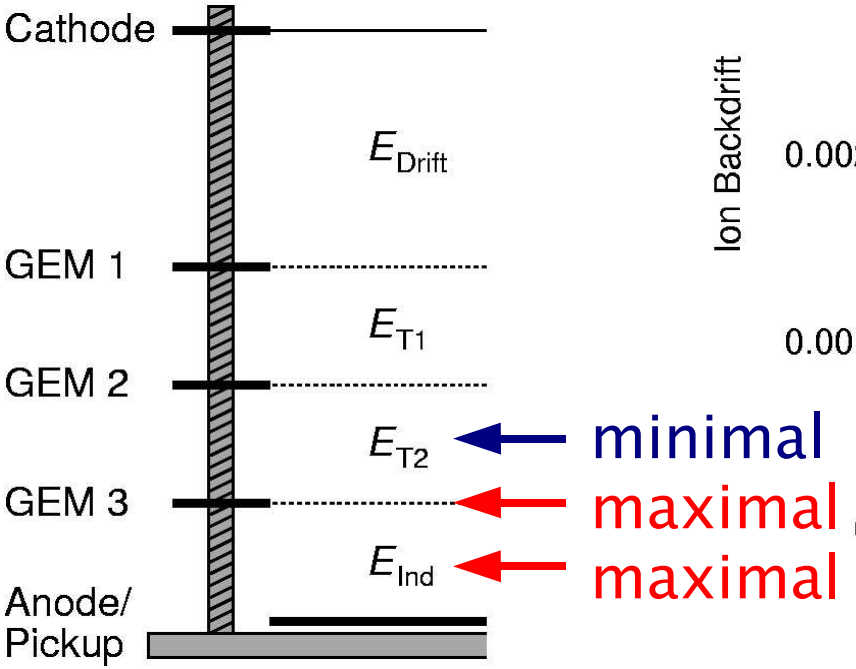
Explained by increased extraction efficiency

Ion back-drift = $I_{Cathode}$ / I_{Anode}



Minimisation of Ion Back-Drift

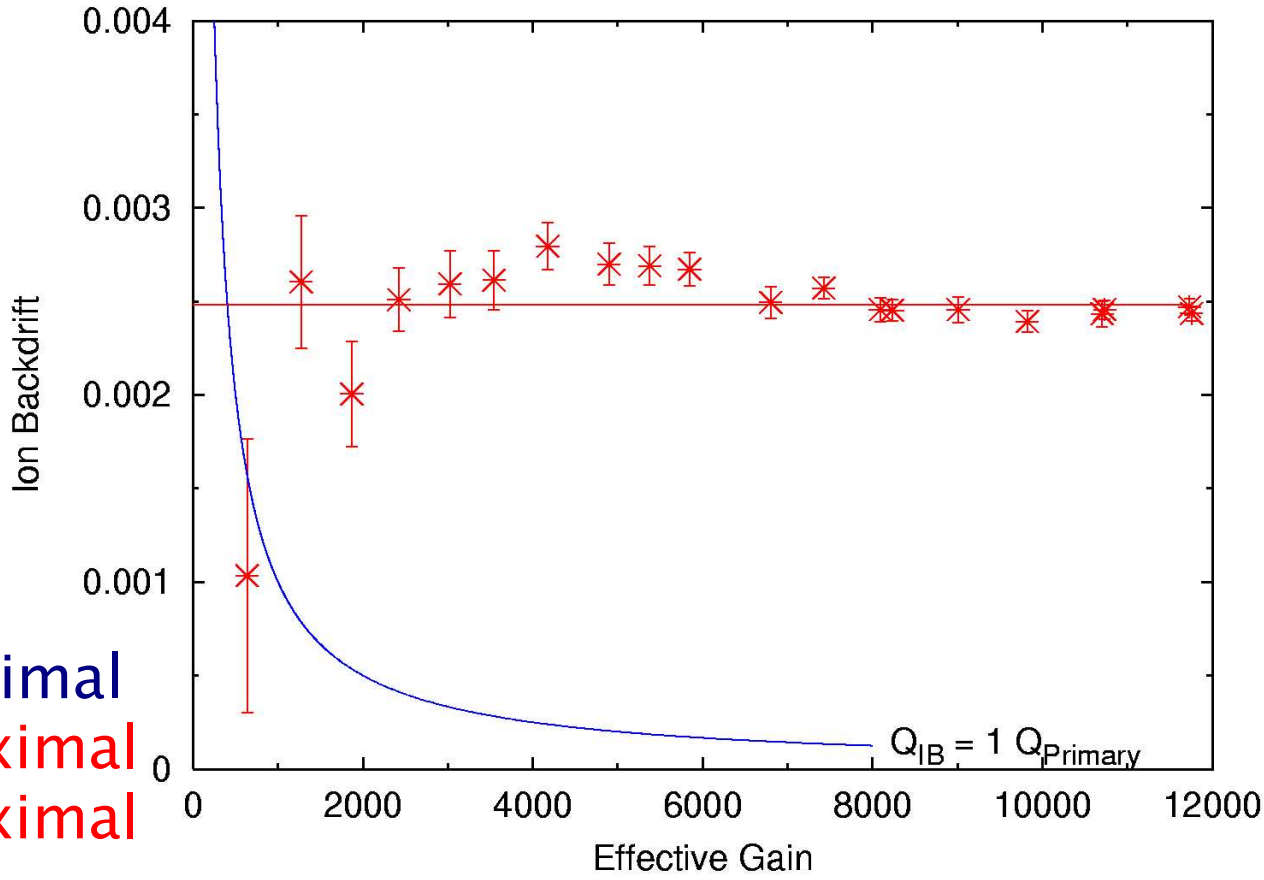
- Search for GEM setting with minimum Ion back-drift
- Important: Remove ions at place of origin !
- Ideal case: back-drifting ioncharge ≤ primary ionisation
  relative ion back-drift ≤ 1 / gas-gain



minimal

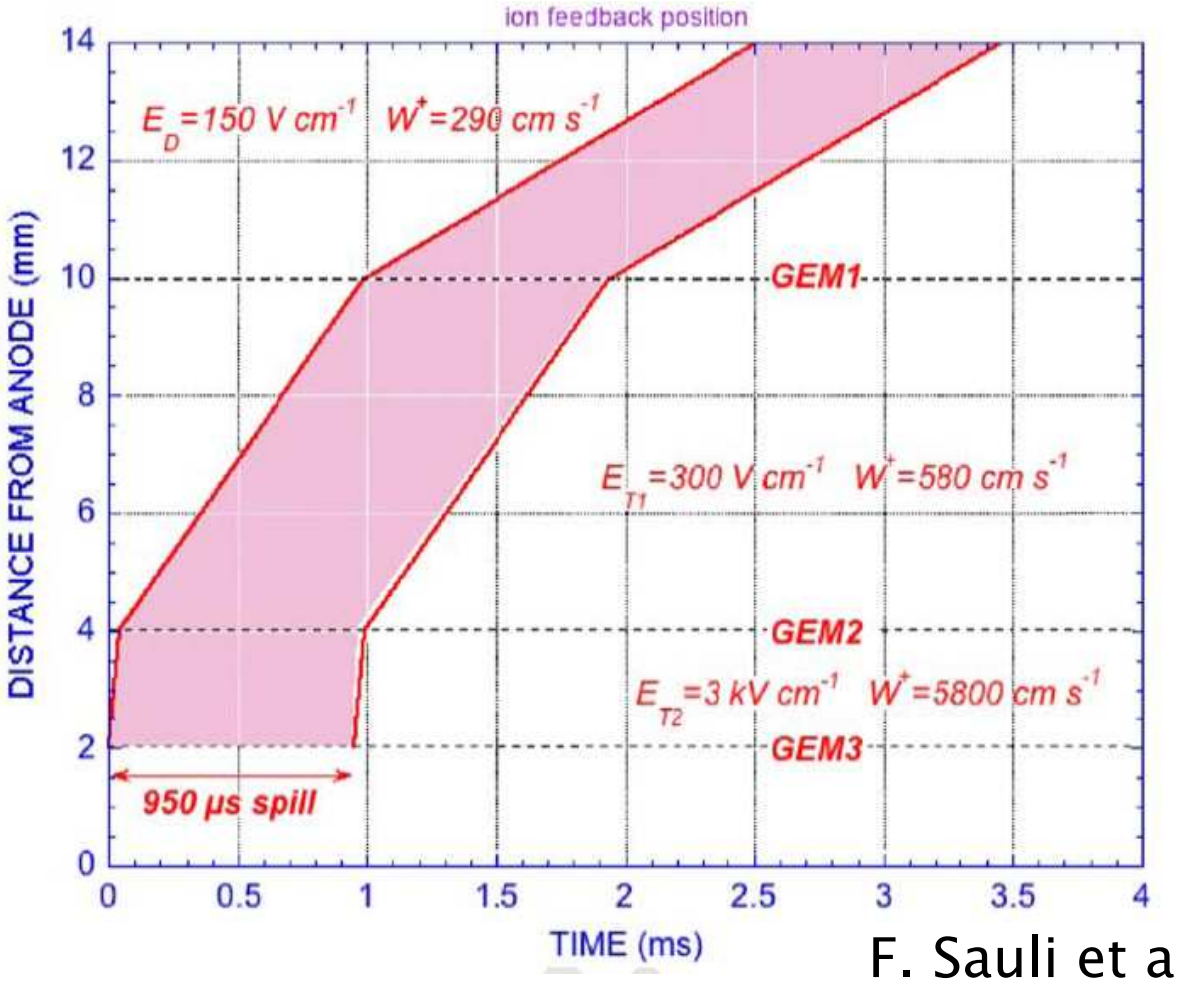
maximal

maximal



Gating after Spills

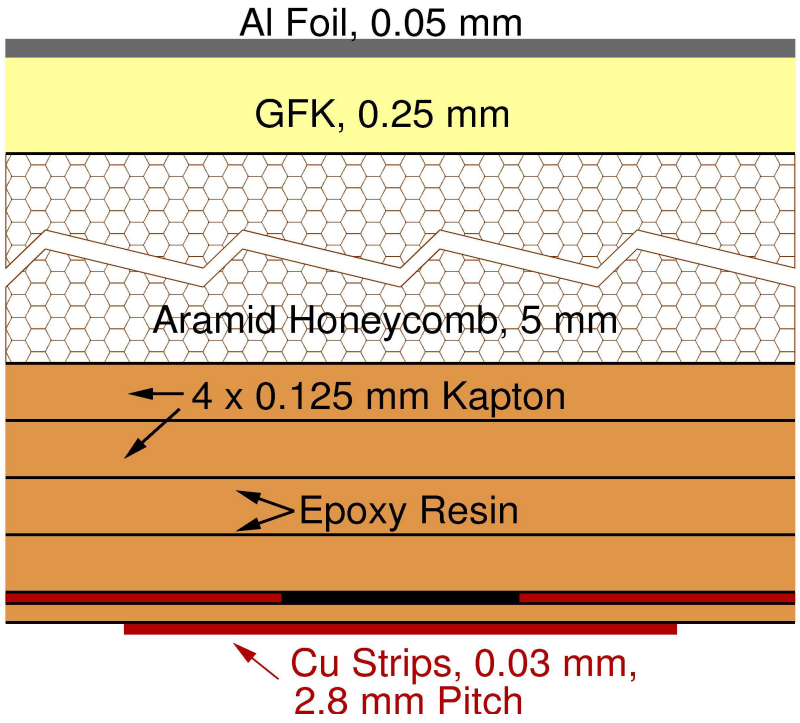
- Slow Ion mobility: Place additional GEM above Readout system
- Important: Distance large enough to cover ions of 1 ms bunch trains
- End of train: Reverse voltage at GEM to hold off ions from drift region

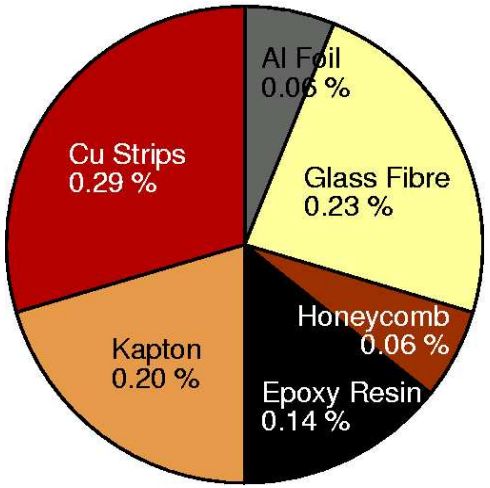


F. Sauli et al, subm. to NIM

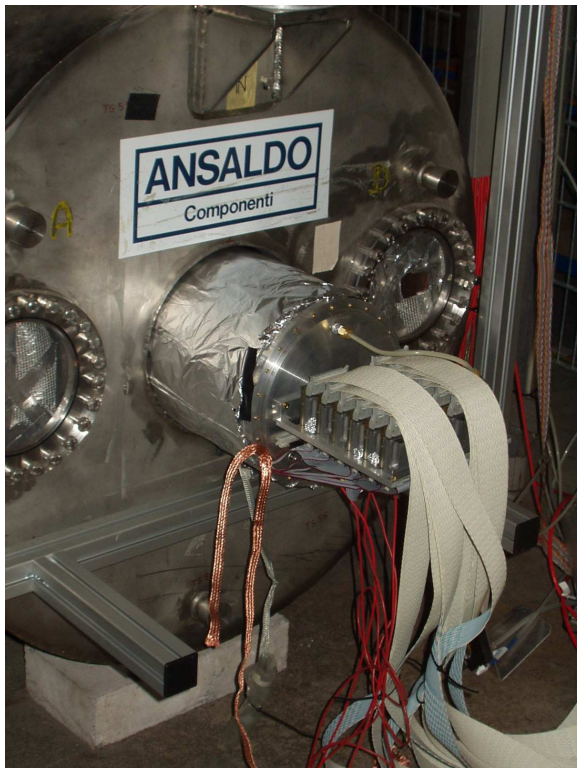
Construction of Prototypes

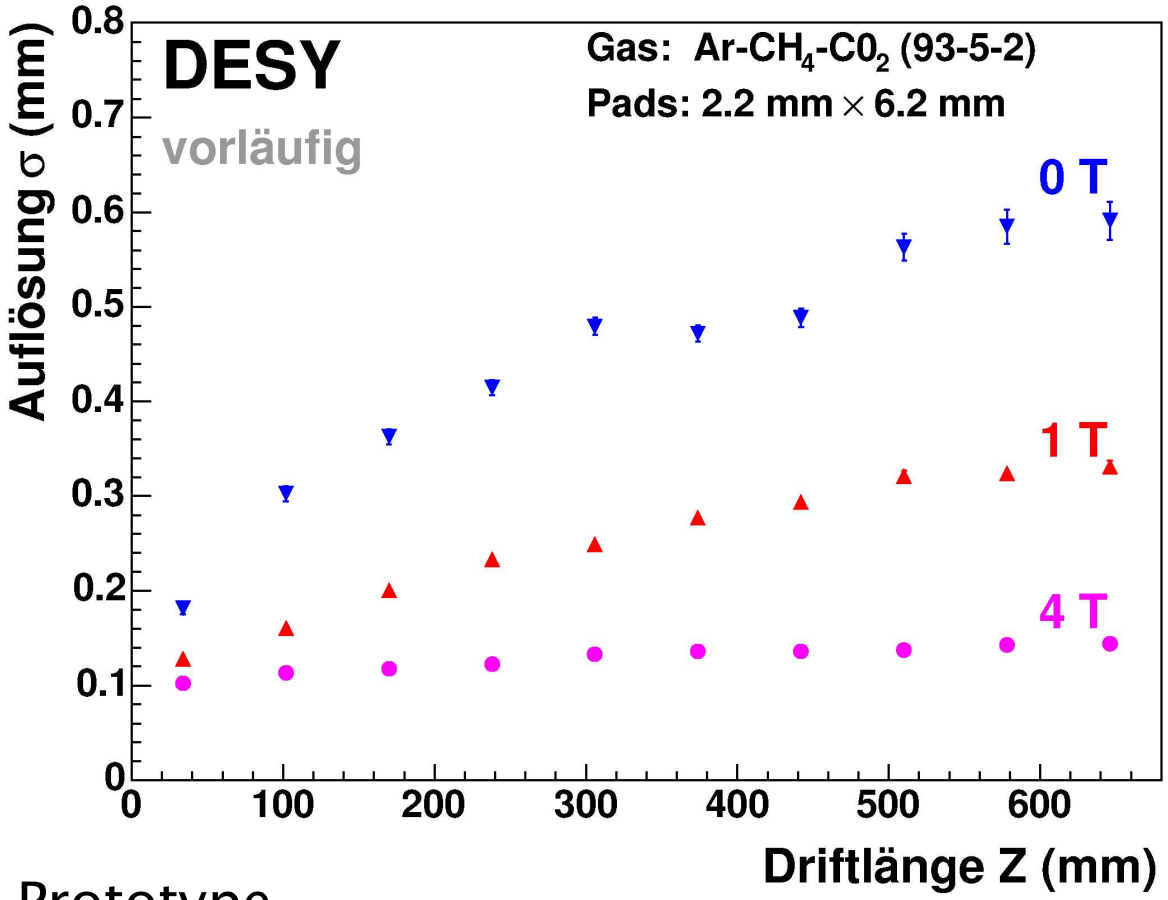
- Compact design to fit into test magnet
- Material budget only 1% X_0





Cosmics in Magnetic Field



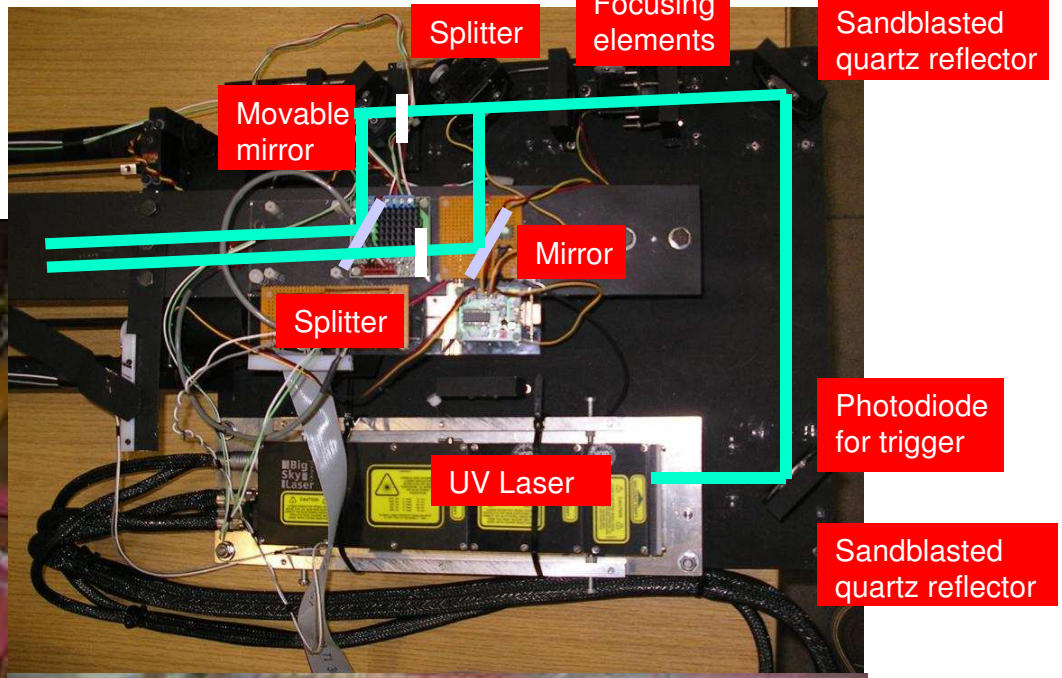


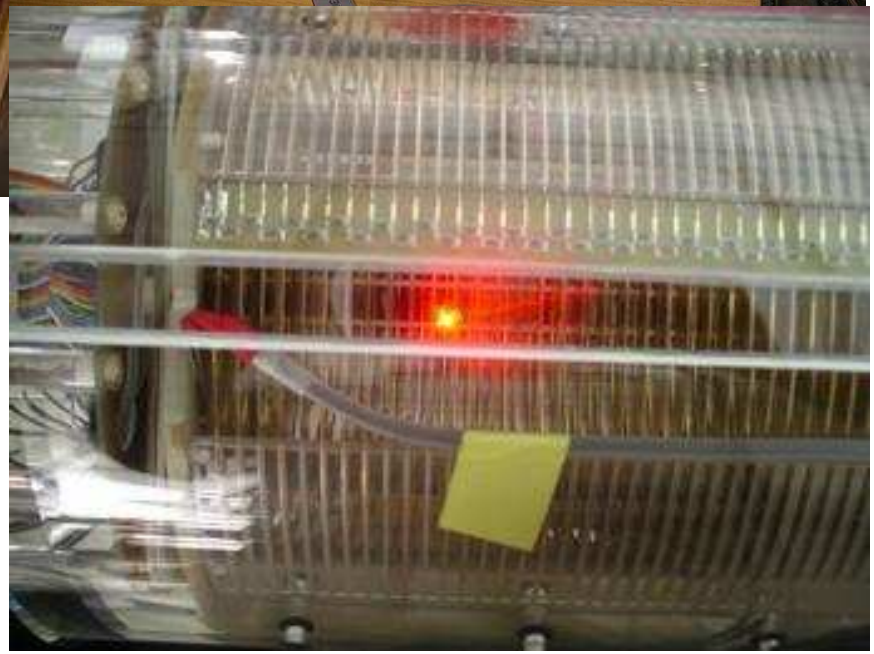
Measurements with DESY-Prototype

- Improvement of spatial resolution for high magnetic fields
  Reduction of transversal diffusion
- At 4 T magnetic field the spatial resolution is dominated by read-out structure

Measurements with UV-Laser

Victoria University / DESY



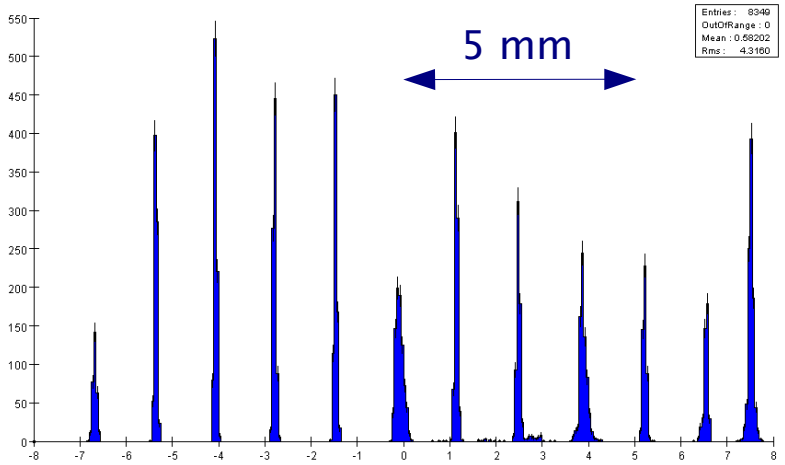


Laser beam integrated into TPC

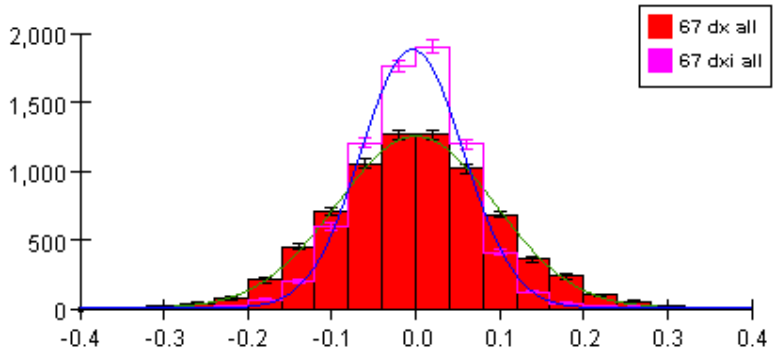
Measurements in 4 T magnetic field

Tracks from UV Laser

Scan of laser beam:

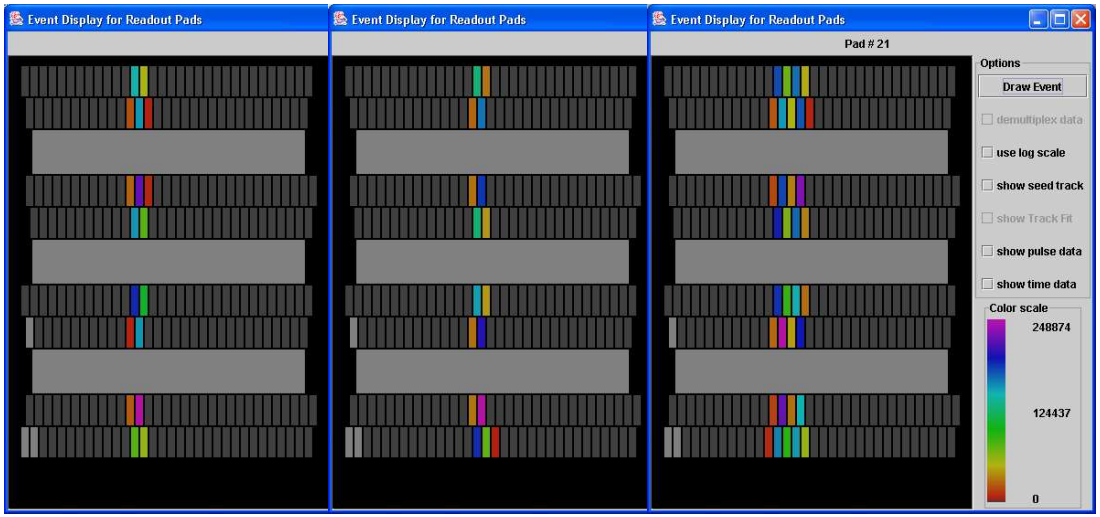


- very stable beam position
  RMS < 4 µm over 20 min
- Spatial resolution ca. 75 µm



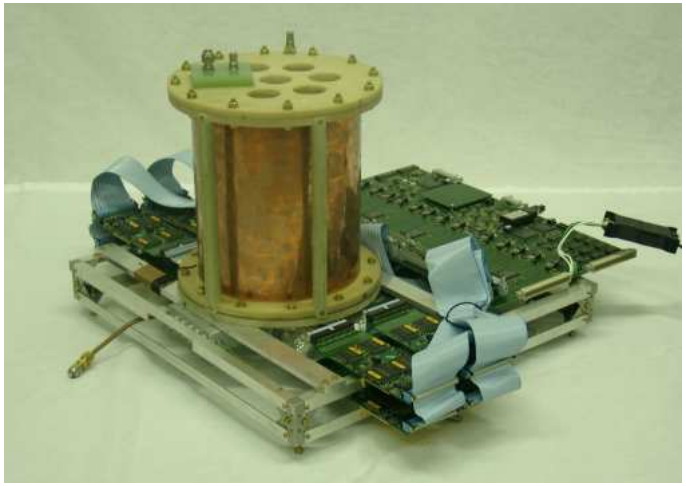
Split of laser beam:

only beam 1 only beam 2 both beams



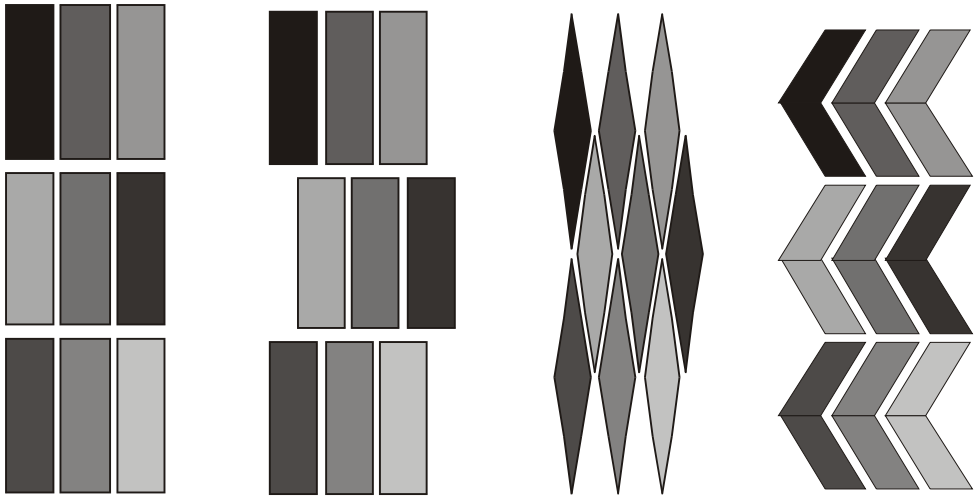
Double track resolution:
ca. 3 mm for 2 mm pads

Study of Pad Geometries



Uni Karlsruhe / DESY

TPC prototype with
different pad geometries
(typical size 2x6 mm)



5.6 GeV e^+ test beam at DESY
Prototype TPC in 1 T magnet

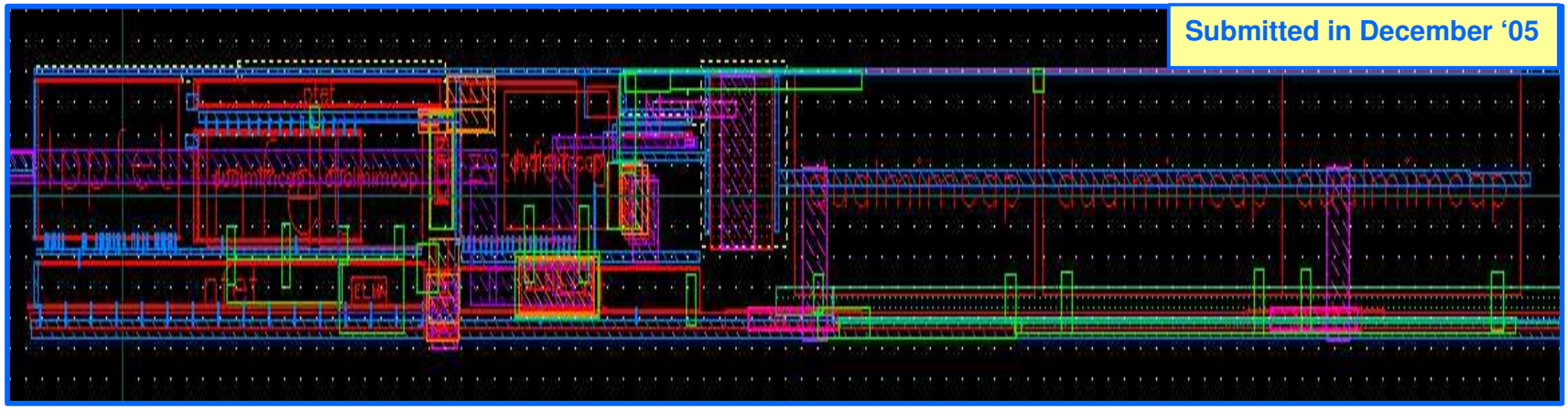
General Purpose TPC Readout Chip

CERN (L. Musa et al.):

- Number of readout channels: 32 or 64
- Programmable charge amplifier:
  charge in the range: ~10^2 – ~10^7 electrons
- high-speed high-resolution A/D converter

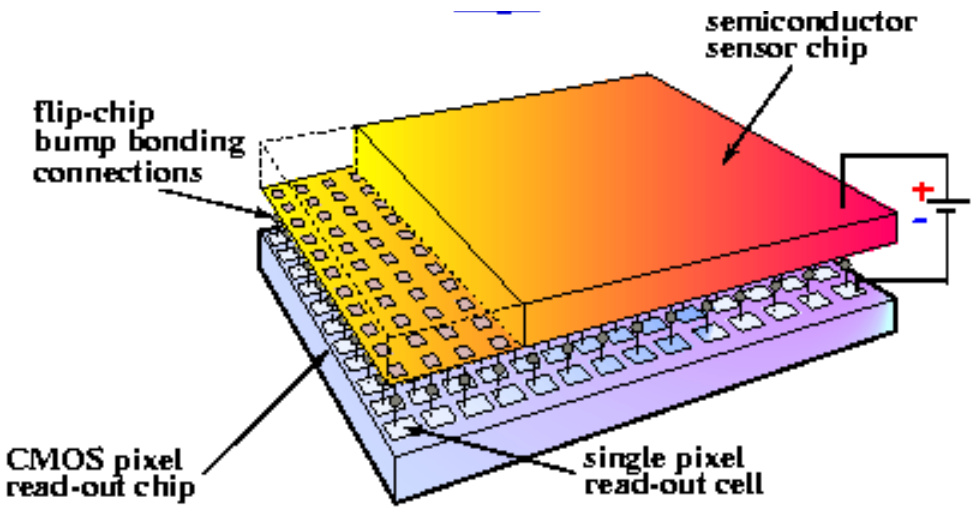
➔ Upgrade of ALTRO chip used for ALICE TPC

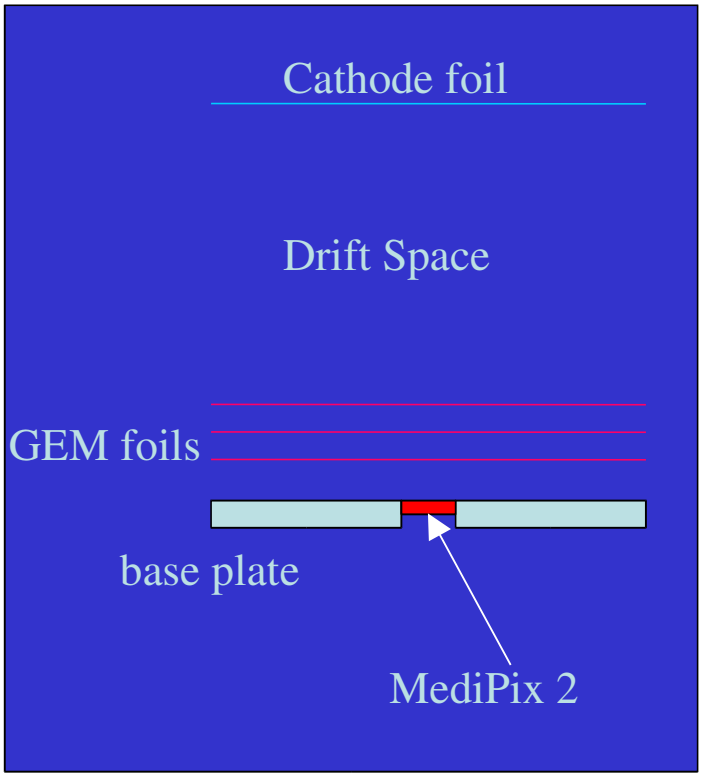
Low-noise Amplifier (CMOS 0.13 μm) already designed



Silicon Read-Out

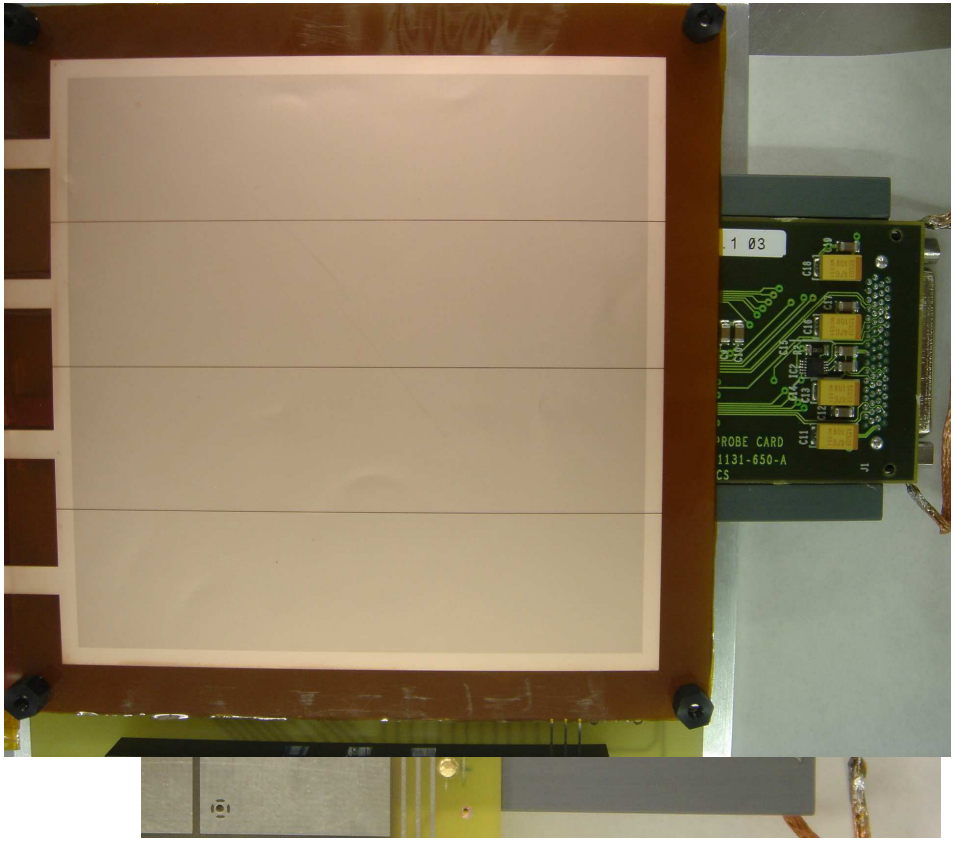
- MediPix 2 pixel detector (CERN development)
- Remove silicon sensor
- Use read-out electronics to detect GEM signal

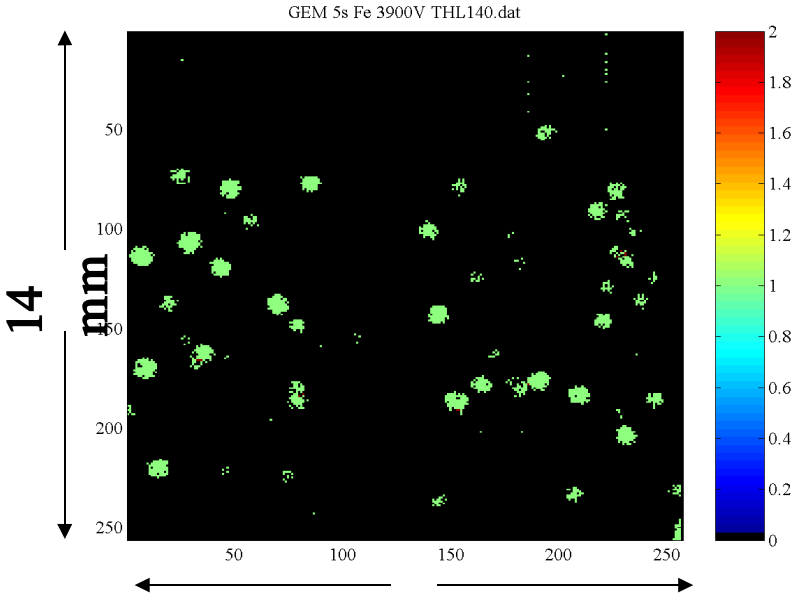


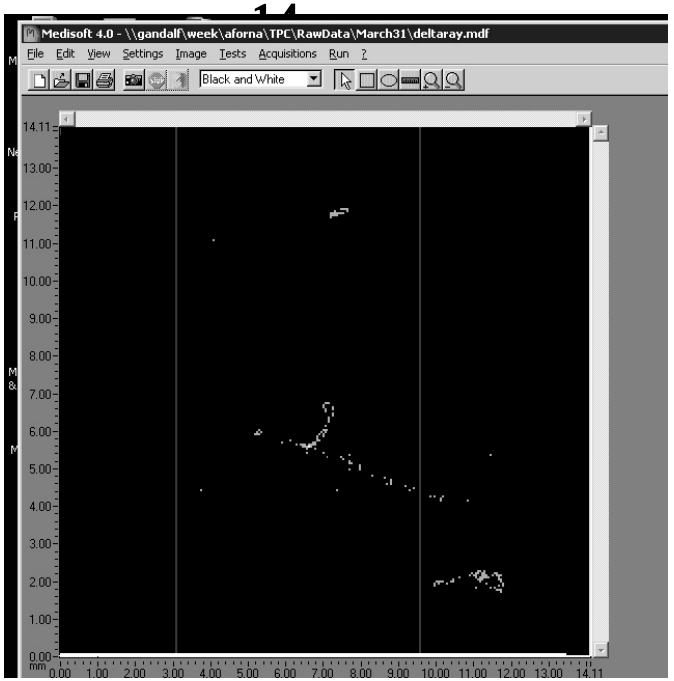


GEM Read-Out with Medipix-Chip

Uni Freiburg / NIKHEF:







From MediPix to TimePix

CERN (M. Campbell et al.), NIKHEF, Napoli, Prague:

- Include timing information: Develop TimePix readout chip with only small modifications to MediPix to avoid failures in chip design
- Brainstorming meetings at CERN
- Use “pixel arrival time” and “time over threshold”
- Two possible timestamp methods under study:
  - local oscillator per pixel
  - clock sent to all pixels

Summary and Outlook

- Relative ion back-drift at the level of 2 permille reached
- Additional options for ion suppression under study
- Field cage prototypes constructed
- First measurements of spatial resolution are promising

- Design and construction of a large prototype (EUDET)
- Measurements in electron and hadron test beams
- Study of various read-out planes (GEM, Micromegas, Si-GEM)
- Decision on the final TPC design