

Gas Ionisation Detectors

position sensitive gas detectors

- *time projection chamber*
- *drift tubes*
- *sparc chamber*

Electron drift in E- and B-field

Magnetic field modifies electron drift velocity due to Lorentz force

equation of motion:
stochastic velocity
dependent force A

$$m\ddot{\vec{x}} = q\vec{E} + q\vec{v} \times \vec{B} + m\vec{A}(t)$$

$$m\vec{A}(t)$$

$$m\ddot{\vec{x}} = q\vec{E} + q\vec{v} \times \vec{B} - m \frac{\vec{v}(t)}{\tau}$$

drift velocity

$$\vec{v}_{drift}(t) = \frac{\mu}{1 + \omega^2 \tau^2} \left(\vec{E} + \frac{\vec{E} \times \vec{B}}{B} \omega \tau + \frac{(\vec{E} \cdot \vec{B}) \cdot \vec{B}}{B^2} \omega^2 \tau^2 \right)$$

mobility

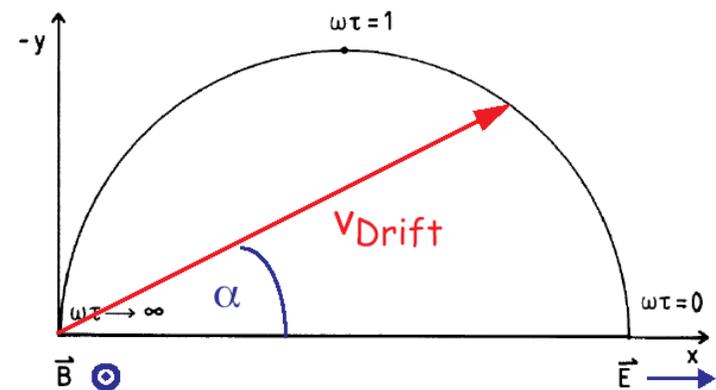
$$\mu = e \cdot \tau / m$$

cyclotron frequency

$$\omega = e \cdot B / m$$

absolute value
of drift velocity

$$|\vec{v}_{drift}(t)| = \frac{\mu E}{\sqrt{1 + \omega^2 \tau^2}}$$



Lorentz angle α between velocity and E field

$$\tan \alpha = \omega \tau = v_{Drift} \cdot \frac{B}{E}$$

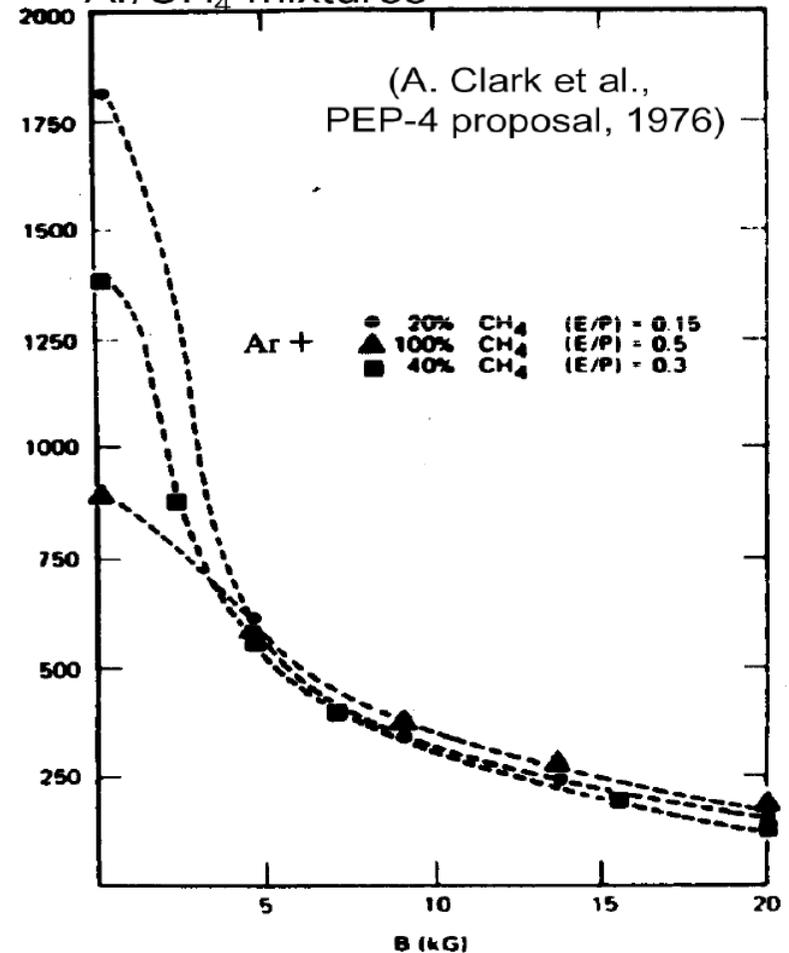
Diffusion in E- and B- fields

Magnetic field reduces also the diffusion coefficient of electrons in transversal Direction with respect to B-field.
For $B=(0,0,B_z)$ and E field parallel to B field the following relationship holds:

$$D_z = D \text{ und } D_x = D_y = \frac{D}{(1 + \omega^2 \tau^2)}$$

This effect is used in TPCs (next chapter)
To reduce the transversal diffusion.

Transverse diffusion σ (μm) for a drift of 15 cm in different Ar/CH₄ mixtures



Time projection chamber

Time projection chamber TPC consists of a gas filled volume.

After a particle has passed the volume the electron from the ionisation drift along meters of distance to the end plane where the electrons are detected with MWPCs.

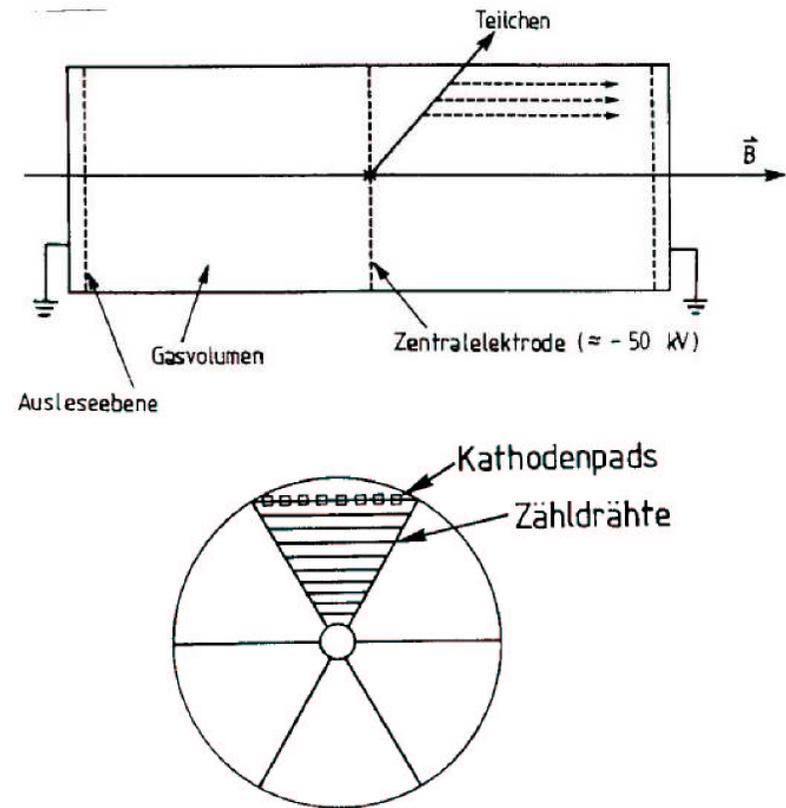
In addition to anode wire planes also cathode stripes or pads are used.

2d position information and drift time allow
3d reconstruction of tracks

Diffusion strongly reduces by $E \parallel B$, causes spirals around B field lines with Larmor radius $< 1 \mu\text{m}$

Very high position resolution and dE/dx info

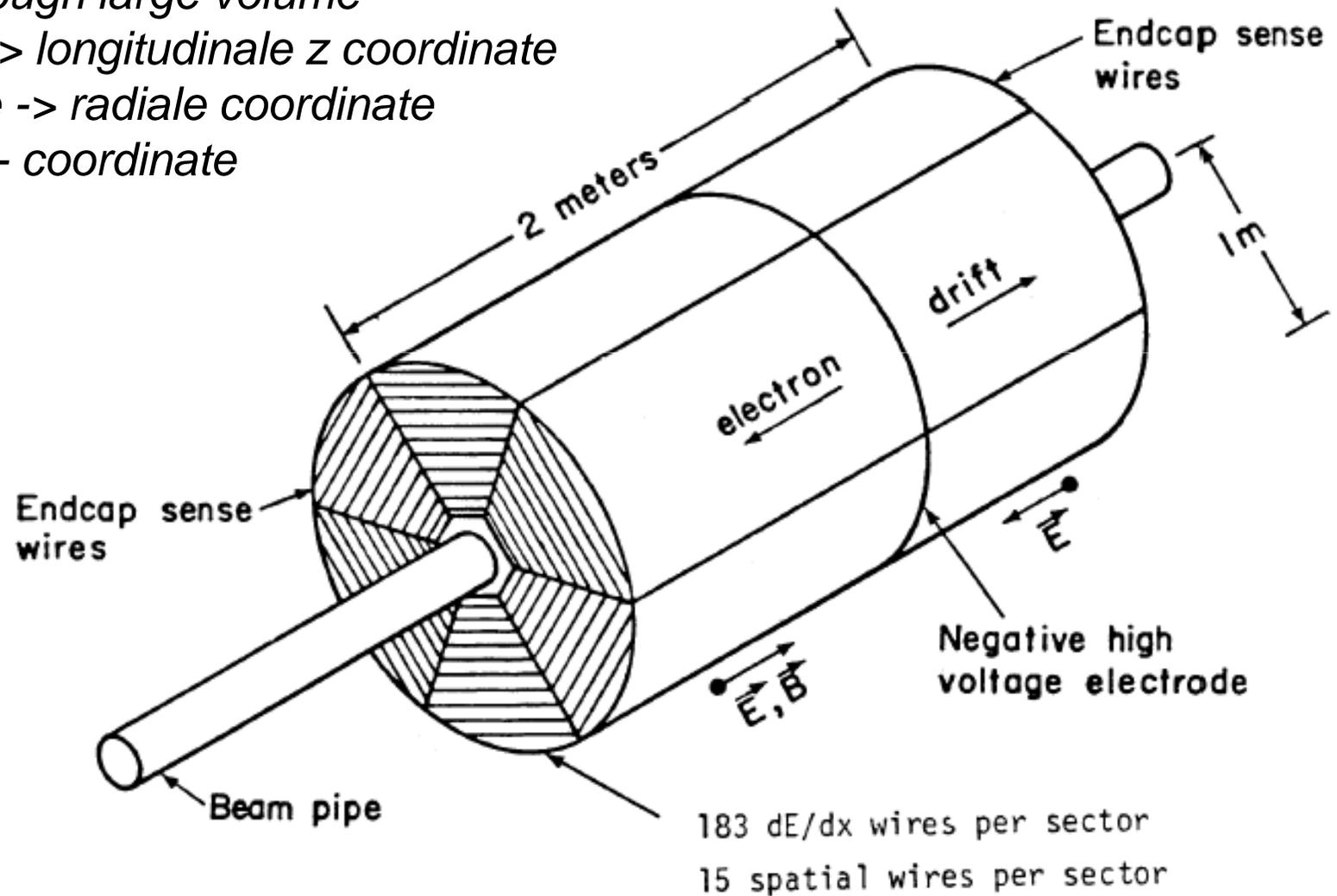
Challenges: count rate capability, high counting gas requirements



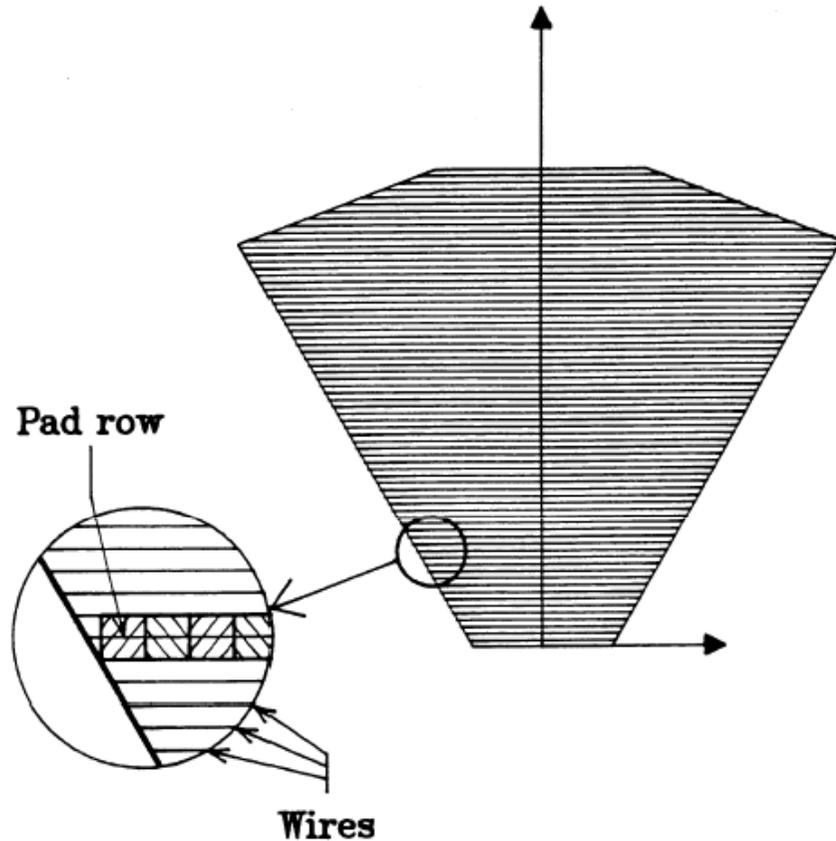
TPC

Time Projection Chamber TPC

- e^- drift through large volume
- drift time \rightarrow longitudinale z coordinate
- wire plane \rightarrow radiale coordinate
- pads \rightarrow ϕ - coordinate

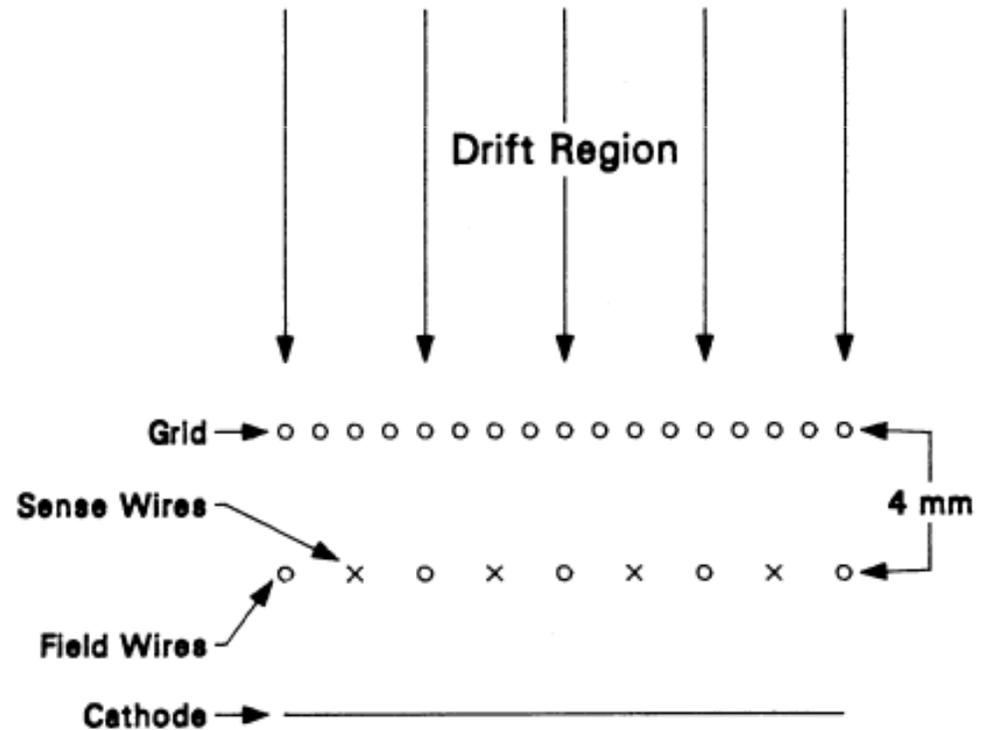


Time projection chamber

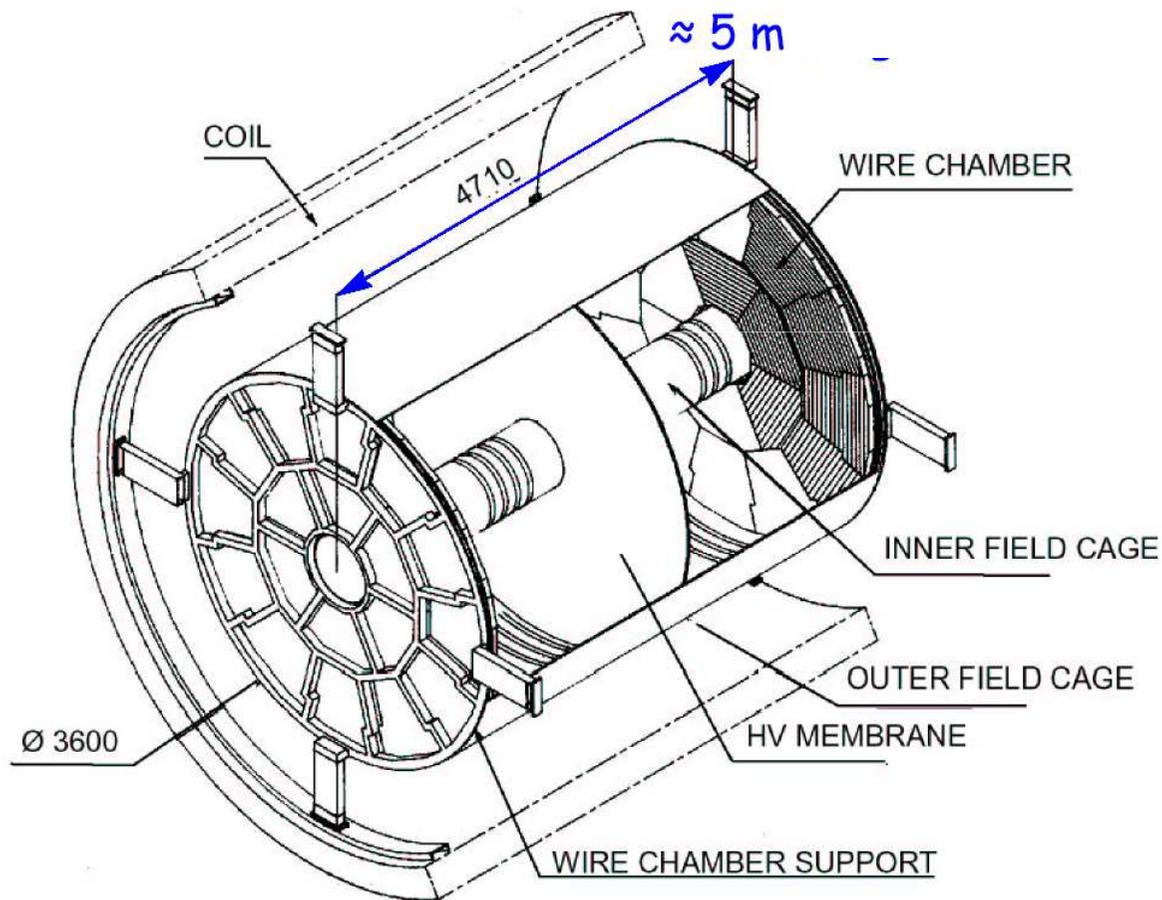


x, y – coordinate
position sensitive detection
- wire planes
- segmented cathode - pads

z - coordinate
drift time of e^- - cluster from trajectory to wire plane



Time projection chamber

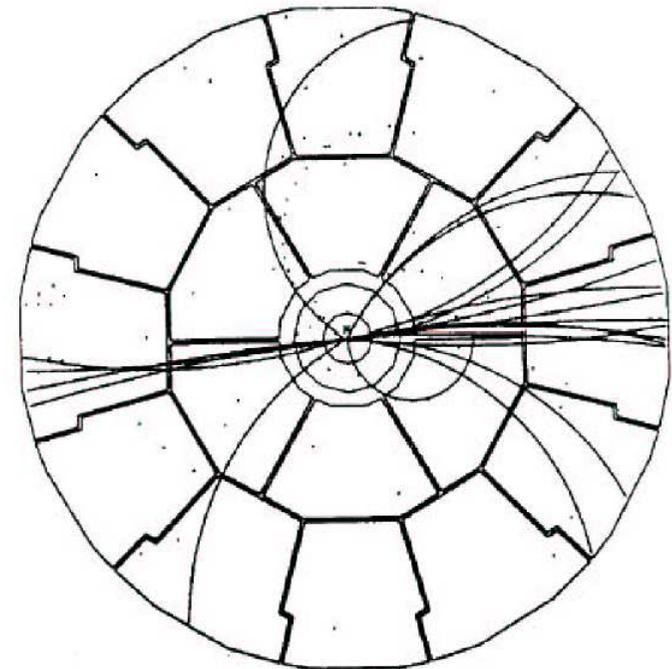


Resolution values

$$\sigma_{r\phi} = 173 \mu\text{m}$$

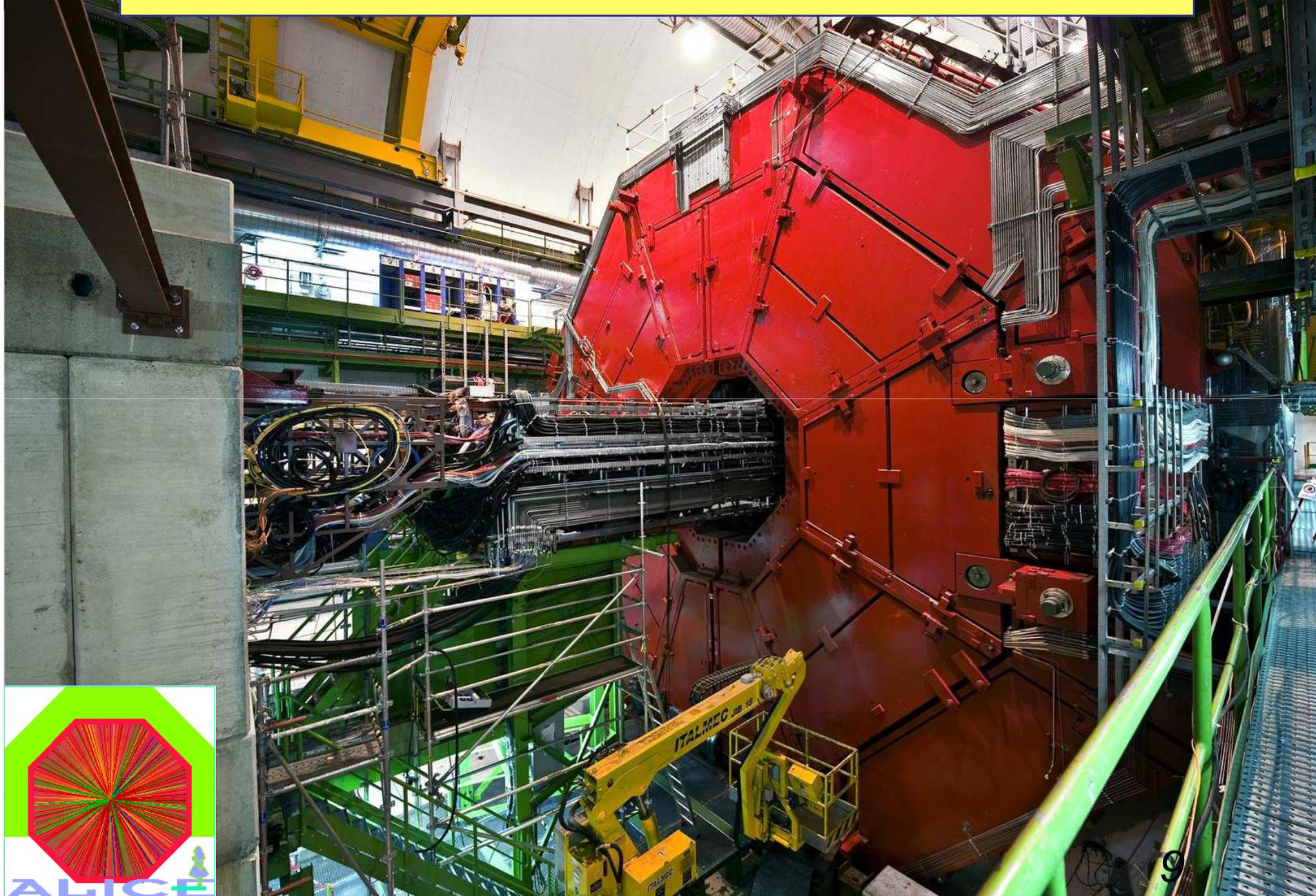
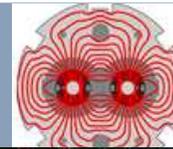
$$\sigma_z = 740 \mu\text{m}$$

$r-\phi$ Projektion





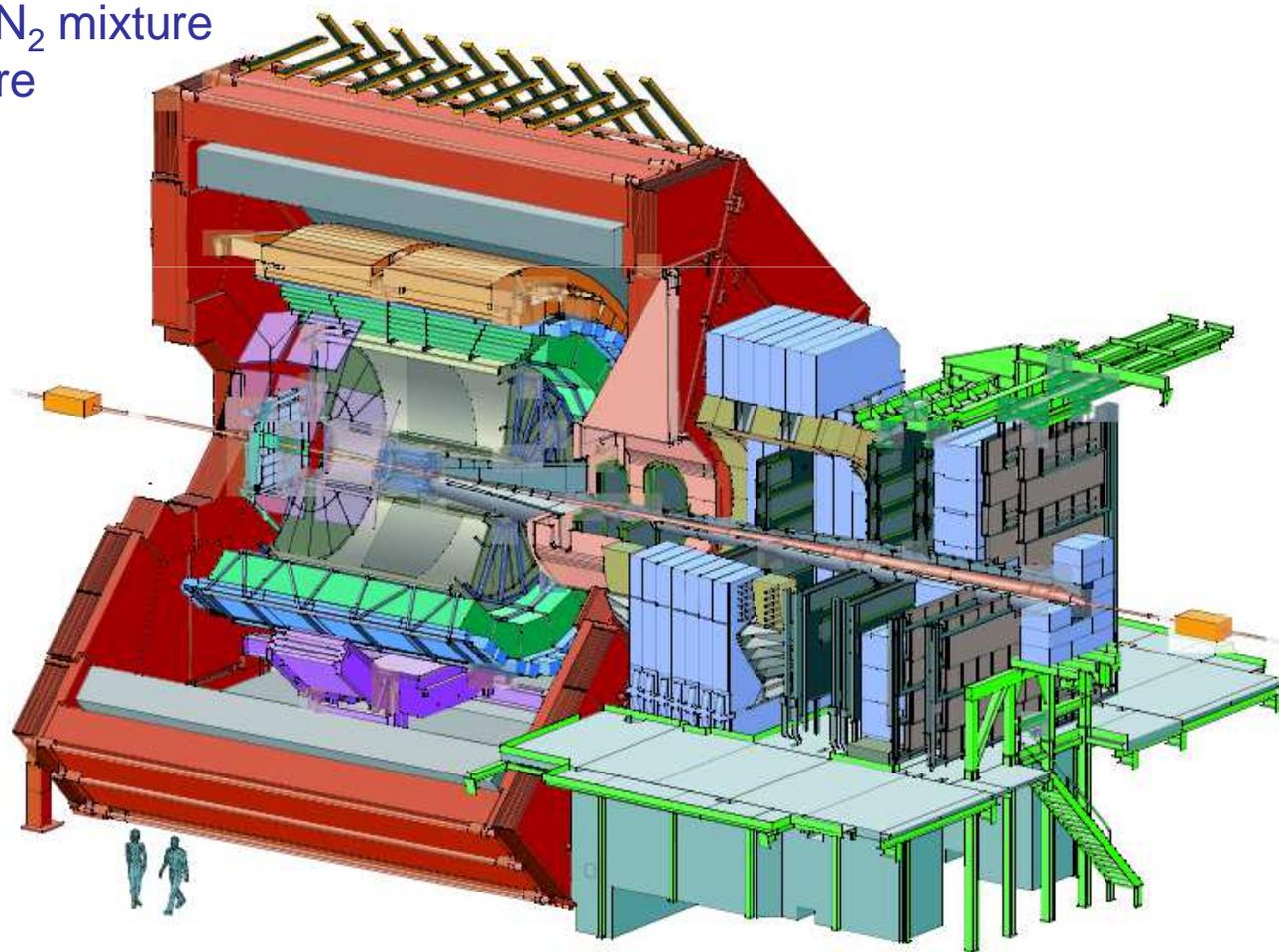
ALICE detector at LHC



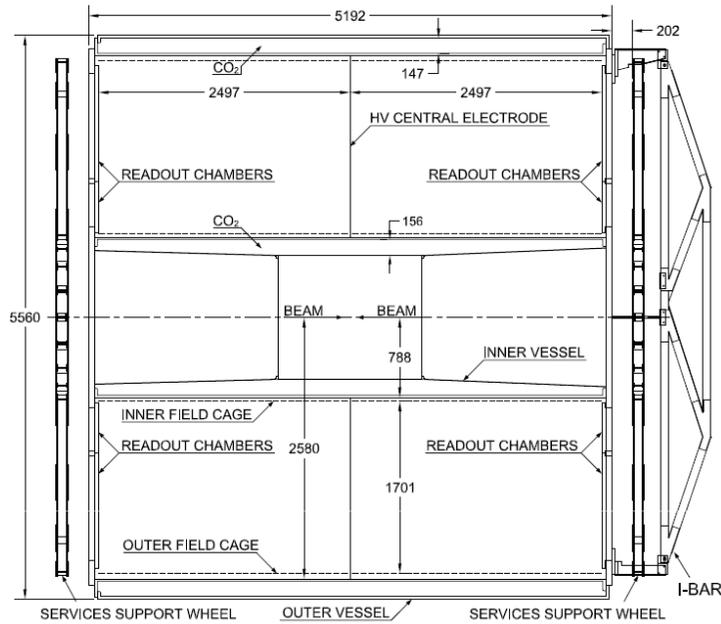
ALICE Time projection chamber

Large Hadron Collider (LHC), ALICE Time Projection Chamber (TPC)

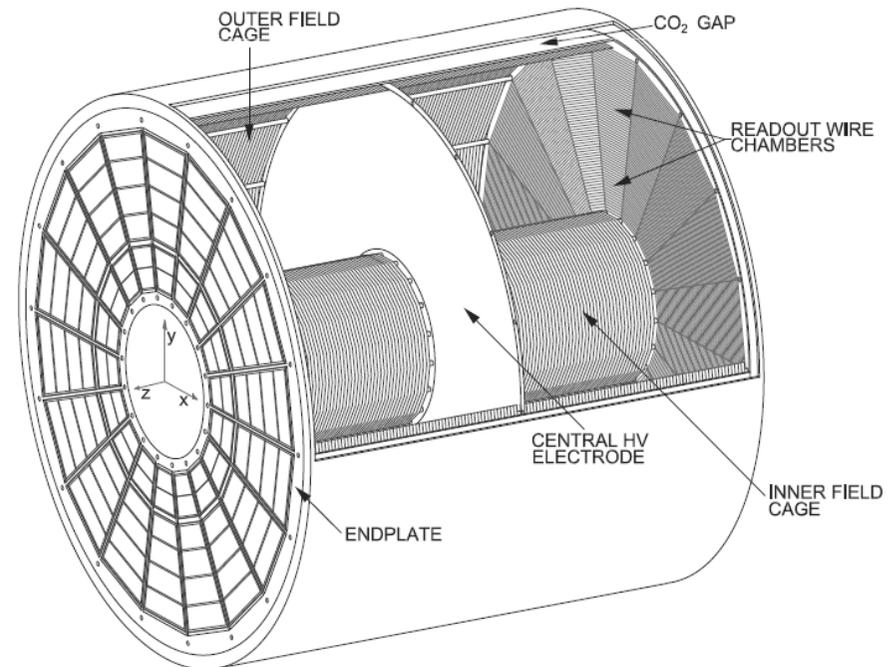
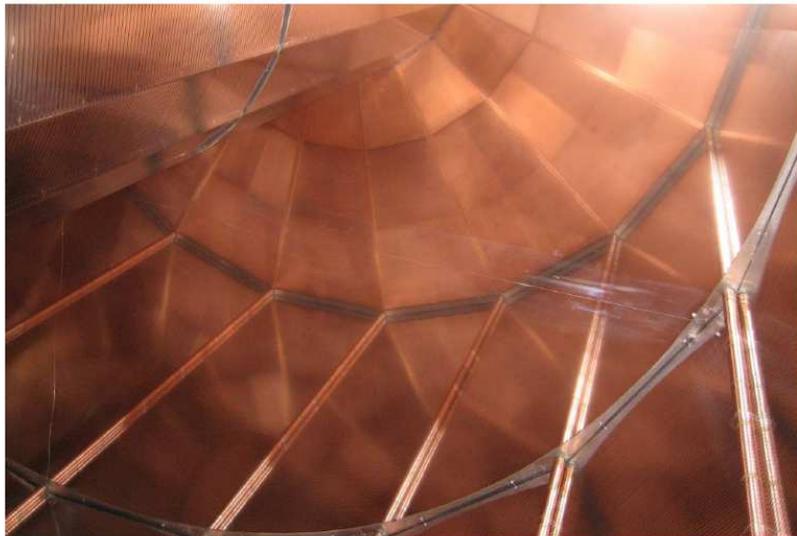
- active volume 100m^3 , inner radius 85 cm, outer radius 250 cm, length 500 cm
- solenoid magnet, field: 0.5 T, parallel to LHC beam
- electrode at center of the cylinder, HV=100 kV, axial electric field: 400 V/cm.
- counting gas Ne-CO₂-N₂ mixture at atmospheric pressure



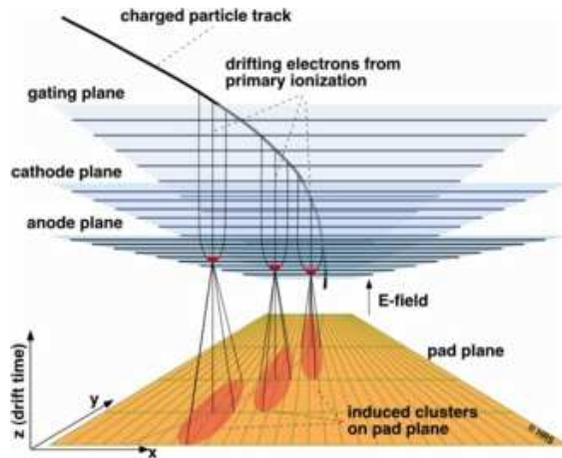
Time projection chamber



- central electrode
 - stretched 23 μm thick mylar foil
 - aluminised on both sides,
 - 6x6m² foil stretched
 - high voltage 100 kV



Time projection chamber



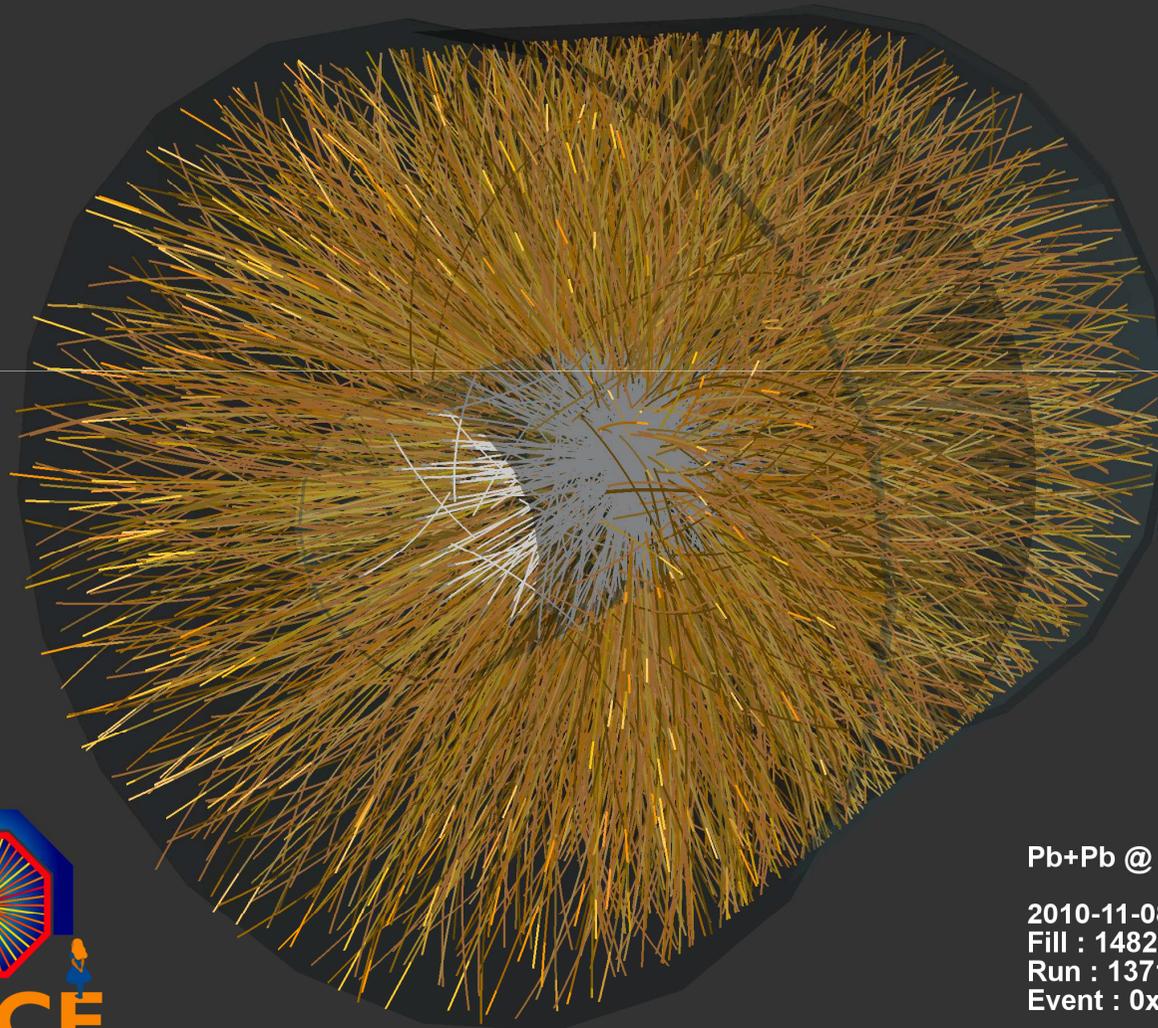
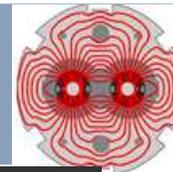
- *electrons and positive ions from avalanche, move towards the anode wire and electrodes,*
- *induce a positive current signal on the pad plane.*
- *current signal has fast rise time (less than 1 ns) long tail, charge a few fC.*



- readout of signals from 557568 pads
- signals are passed to 4356 Front-End Cards
- 10 cm away from the pad plane
- FECs is charge-sensitive shaping amplifier
- transforms the charge induced in the pads into differential semi-gaussian signal
- fed to input of ALICE TPC Read Out chip
- digitize and process the input signals
- readout takes place at any time
- speed 200 MByte/s



ALICE



Pb+Pb @ $\sqrt{s} = 2.76$ ATeV

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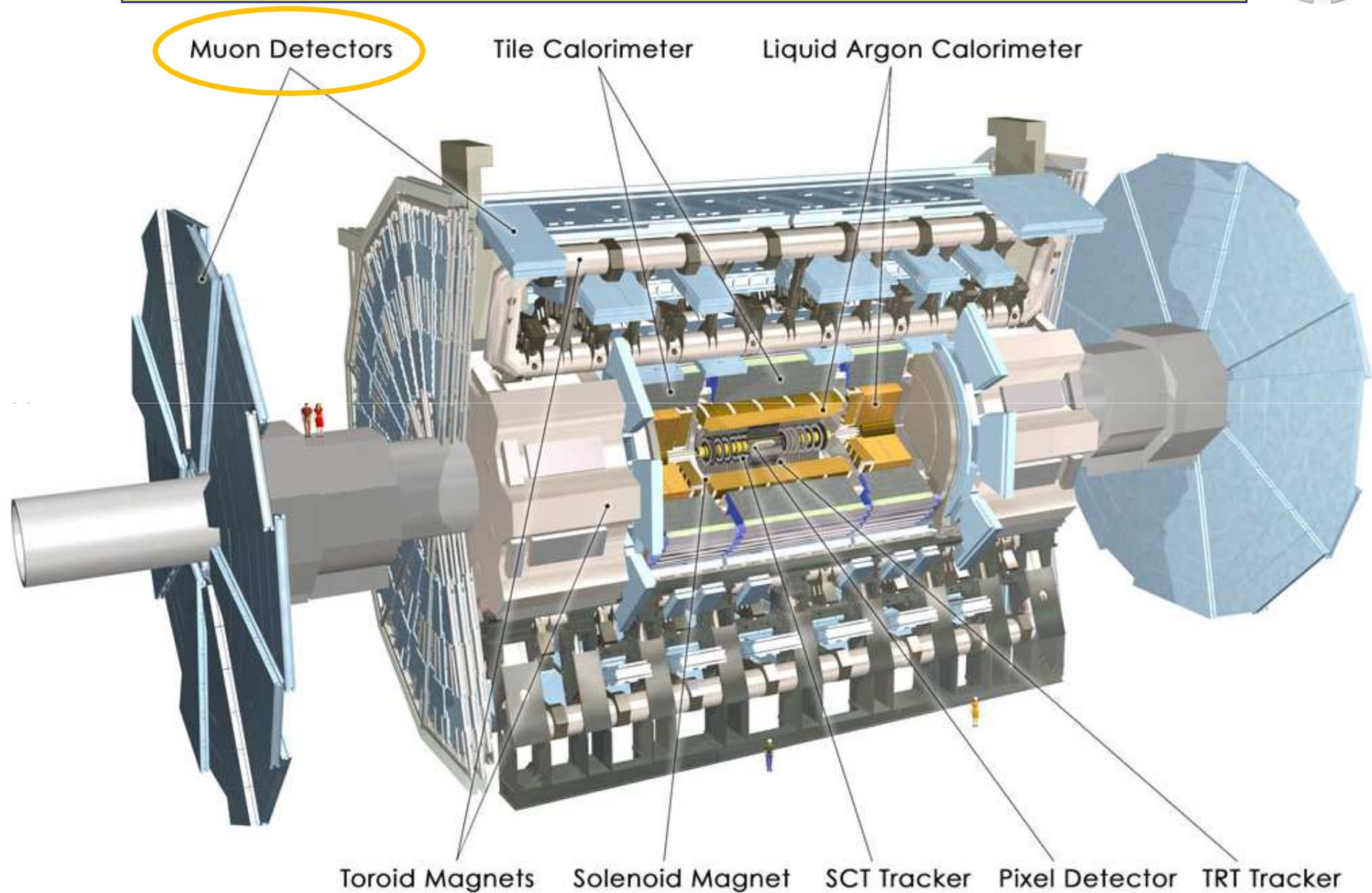
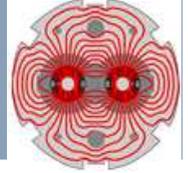
Fill : 1482

Run : 137124

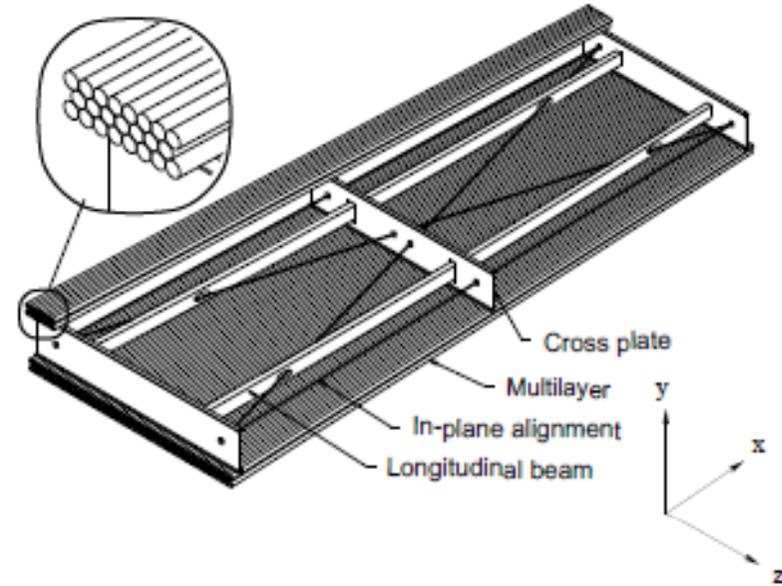
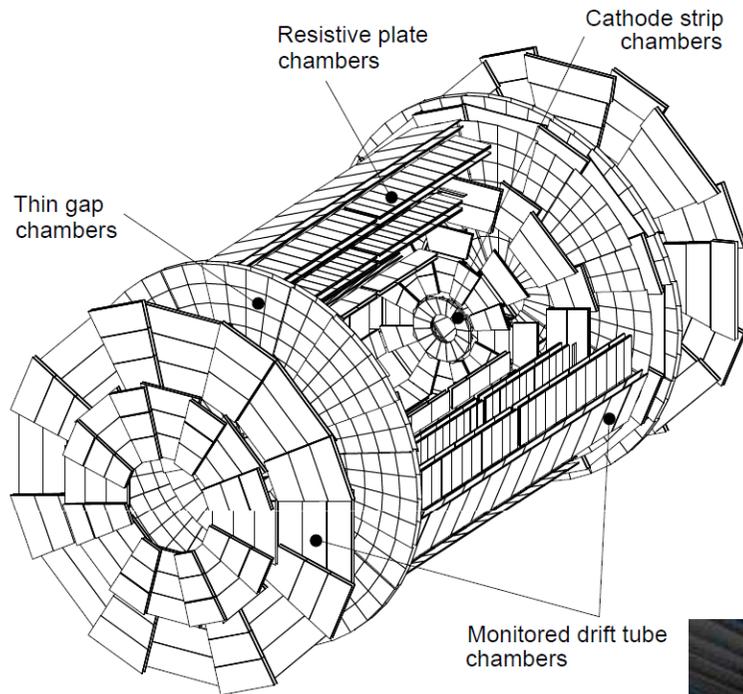
Event : 0x0000000042B1B693



ATLAS detector at LHC



ATLAS Drift tubes



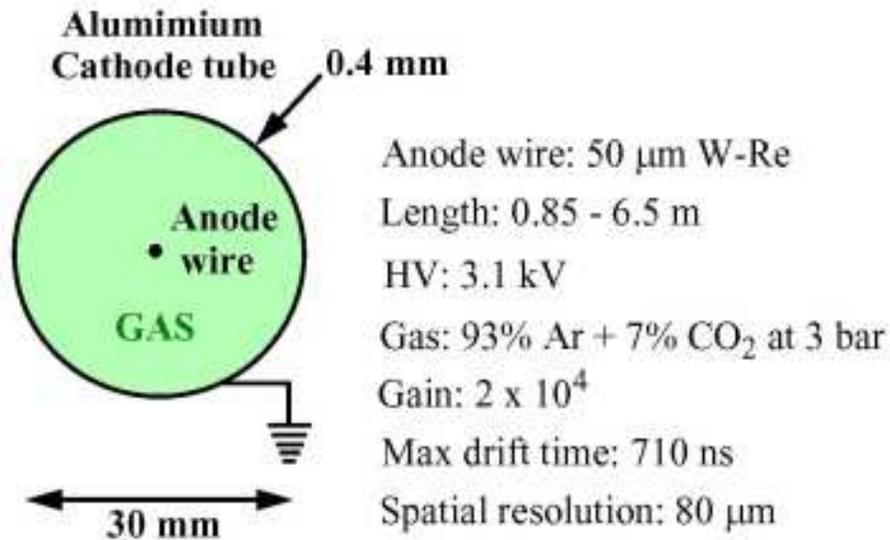
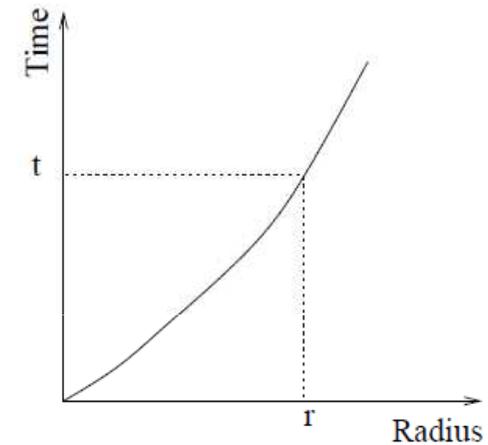
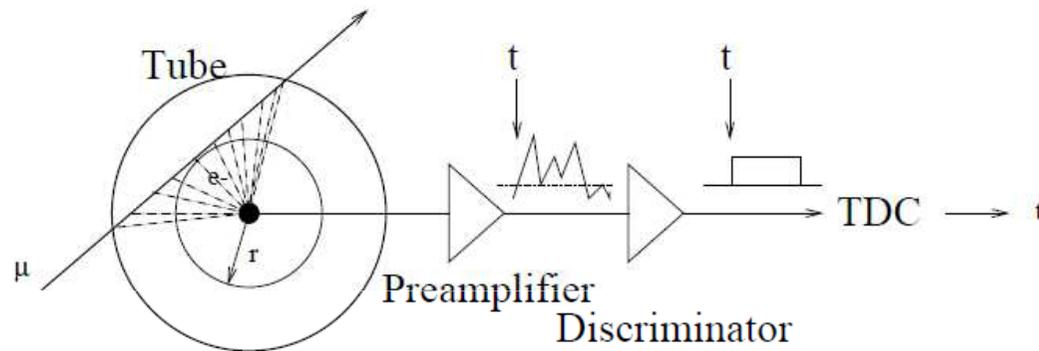
*monitored drift tube chambers
for muon identification*



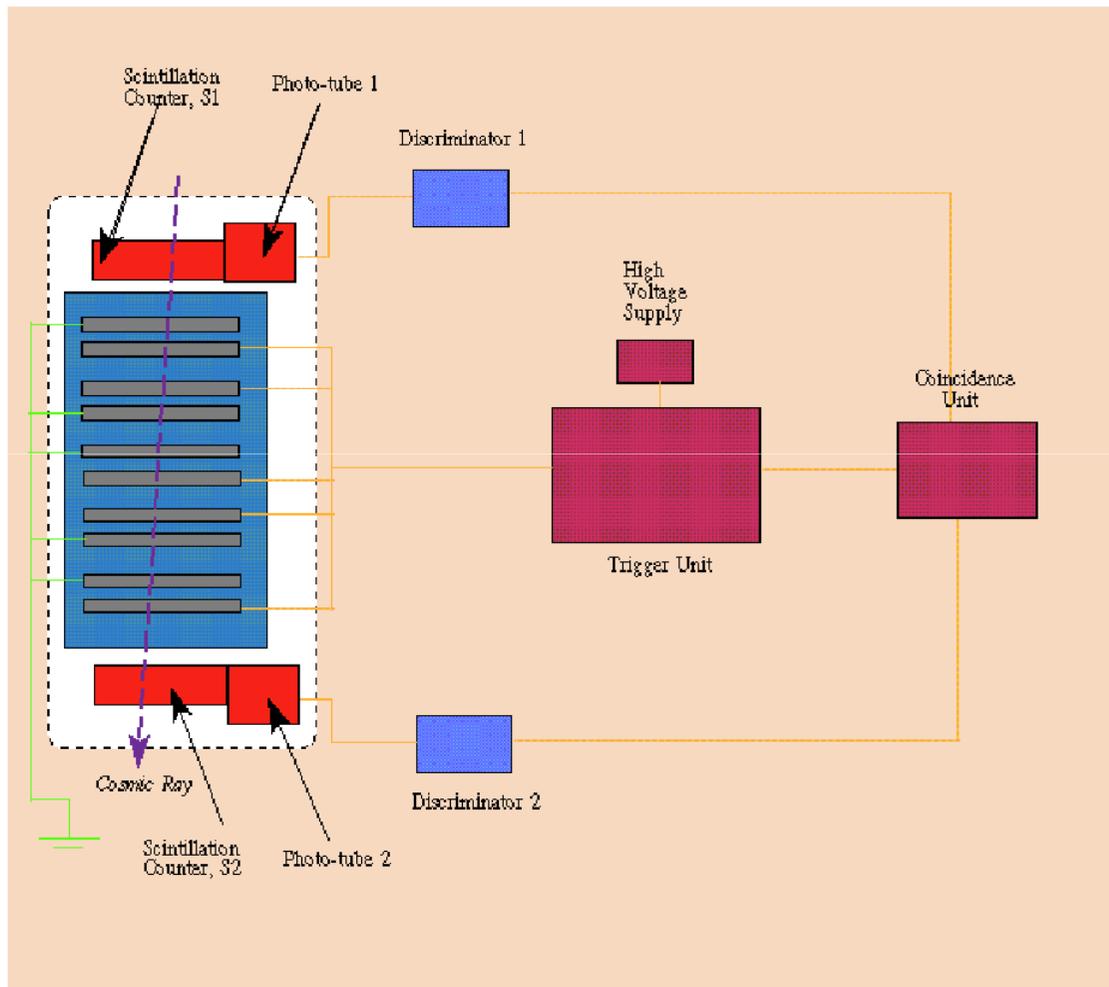
ATLAS Drift tubes

Drift tubes

Time difference between primary ionisation and gas amplification
with fast external time reference



Sparc chamber



*Photo pictures
triggered by external
trigger*

Low rate < 100Hz

Sparc chamber

