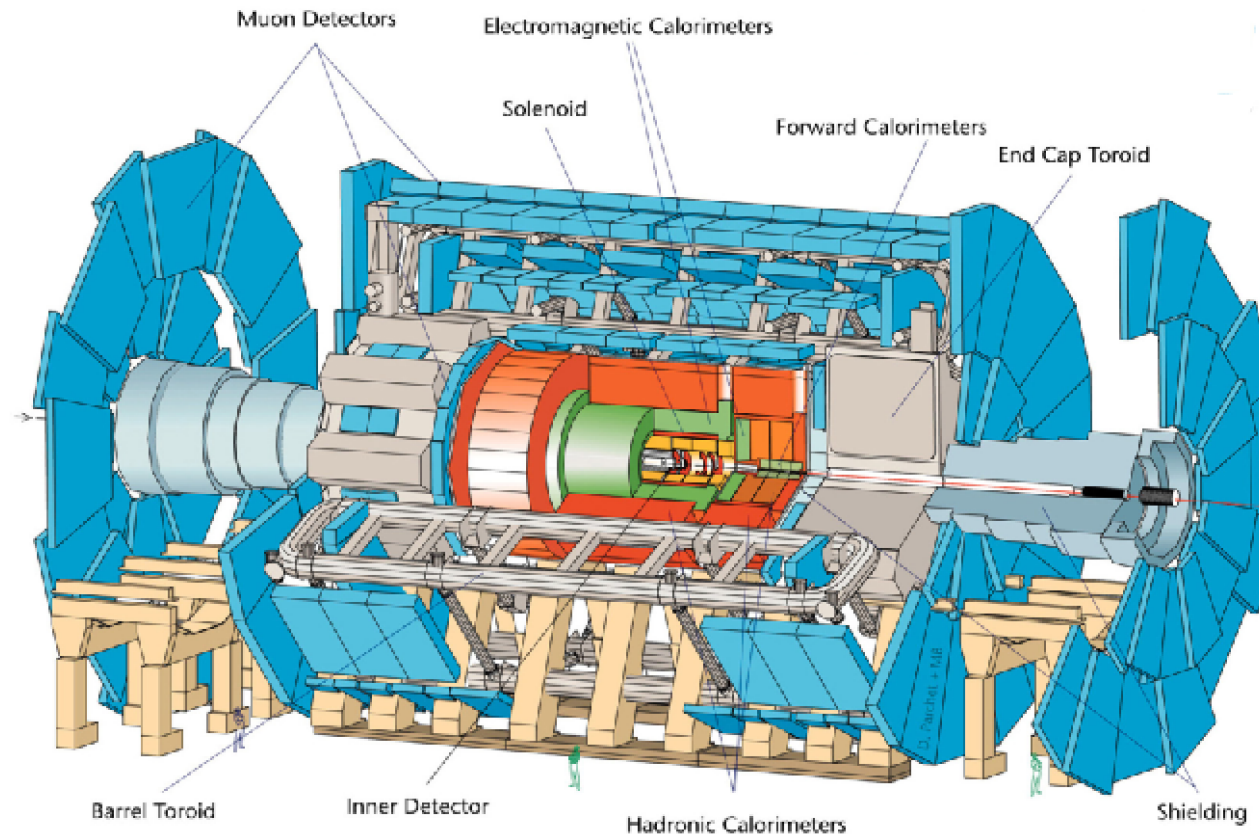


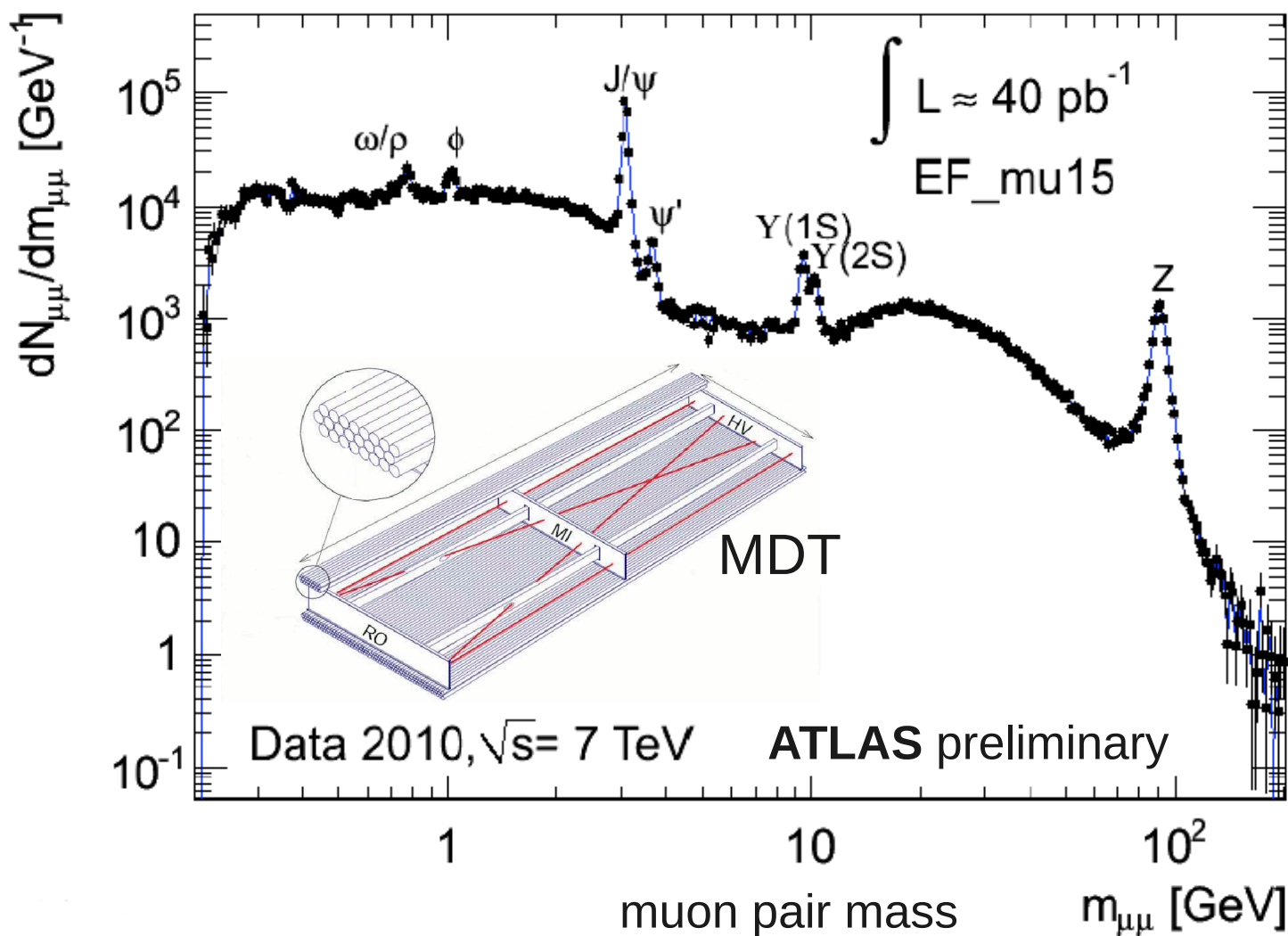
Precision Tracking at High Background Rates with the ATLAS Muon Spectrometer



Ralf Hertenberger, LS Schaile, LMU München
for the ATLAS Collaboration CERN

Rediscovery of the Standard Model

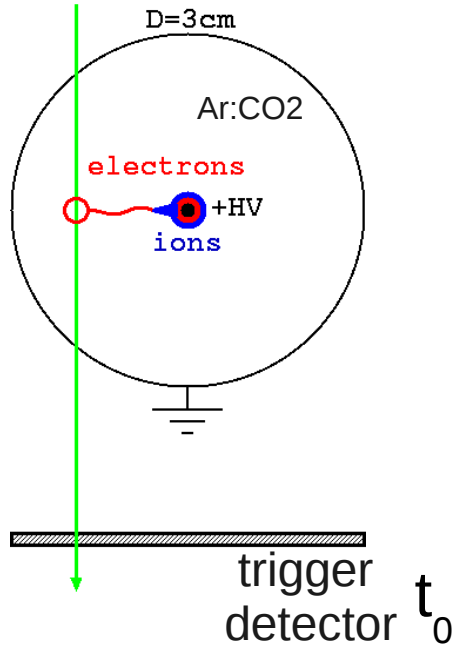
the ATLAS muon spectrometer works according to specs



Design: $\Delta p/p = 10 \%$ @ $1 \text{ TeV } \mu \rightarrow \Delta x < 100 \mu\text{m}$

Cylindrical Drift-Tube Detector: principle

charged
particle

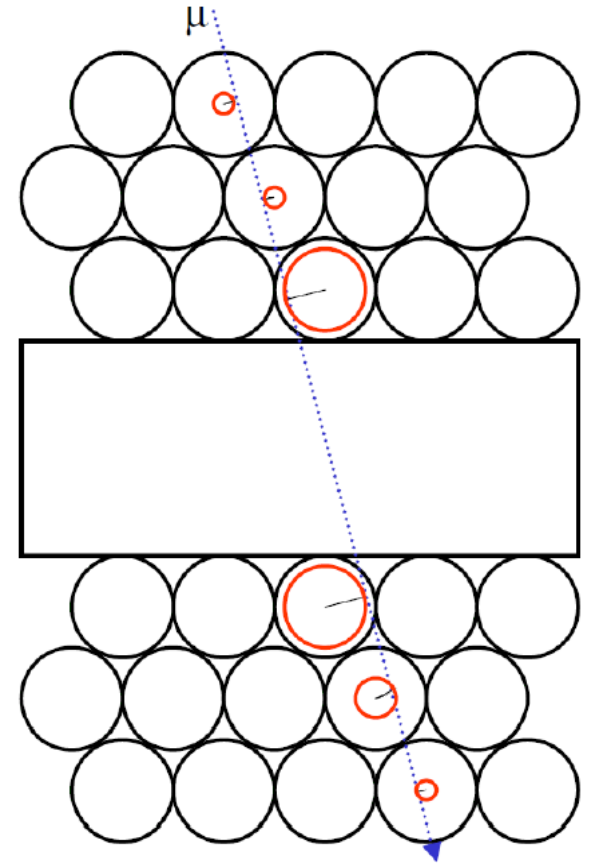
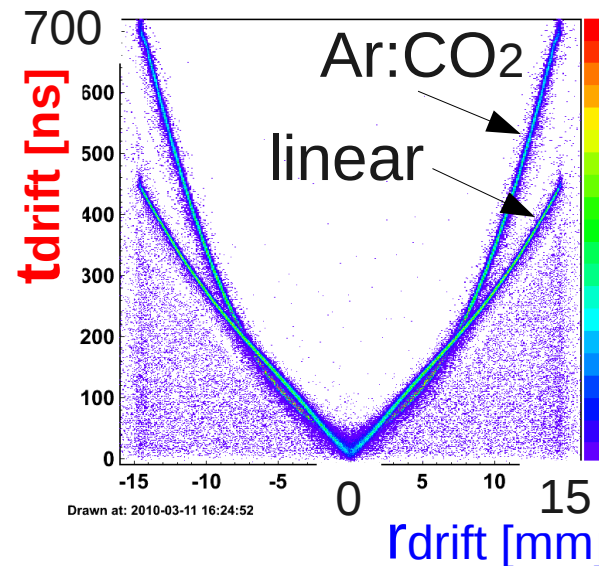


Ar:CO₂ 93:7%
3 bar
3080 V
 $\varnothing = 3$ cm
gain=20000
 $\Delta r = 80 \mu\text{m}$

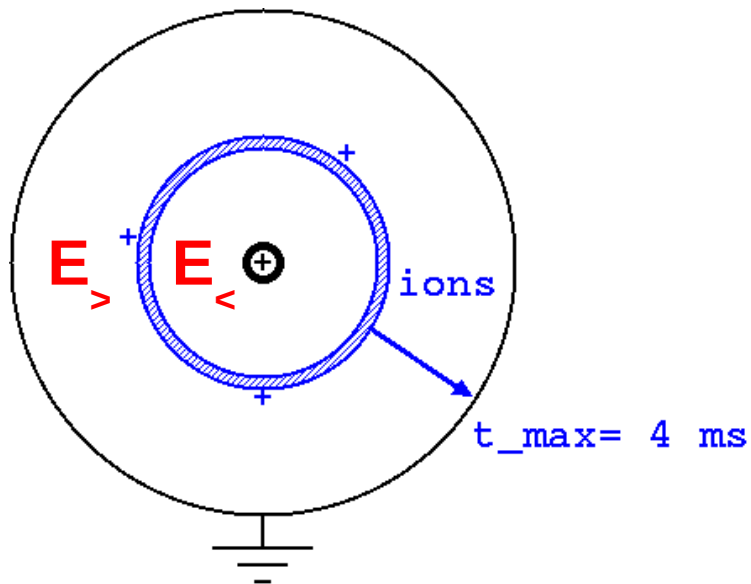
t_{drift} :
measurement

r_{drift} :
 $f(t_{\text{drift}}, E\text{-field, hit rate, ...})$

autocalibration



Space Charge Fluctuations:

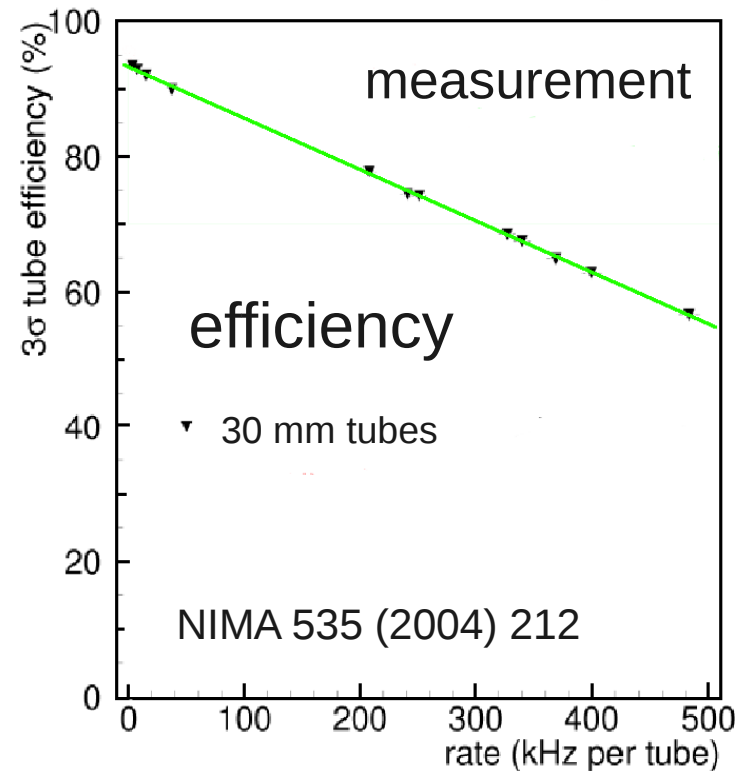
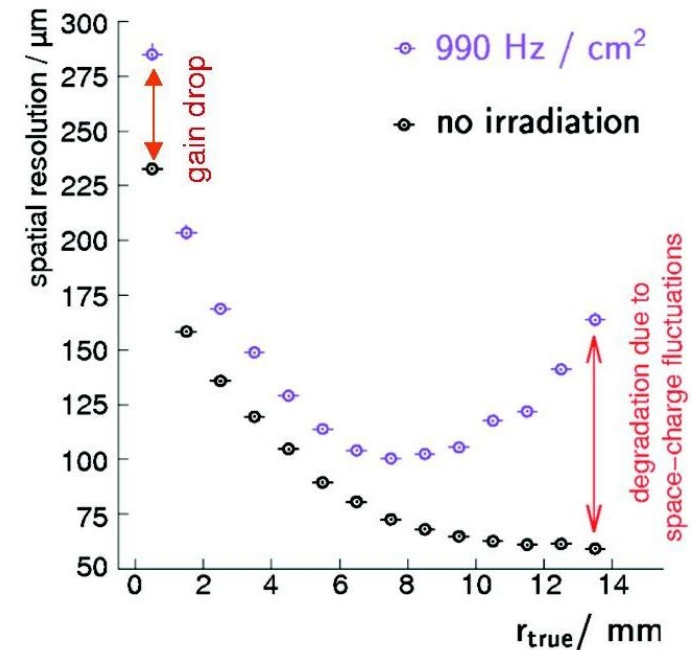


positive ions $\Rightarrow$ space charge 4 ms

E -field $<$ near anode
 E -field $>$ near tube wall

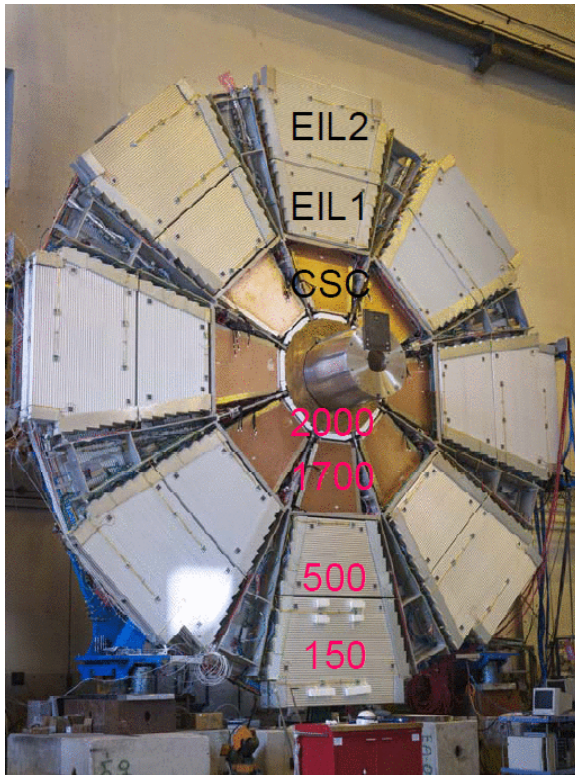
reduced gas-amplification
 fluctuating max. drift-time
 $\Rightarrow$ reduced efficiency
 reduced spatial resolution
 $\Rightarrow$ rate limited

spatial resolution GIF/CERN 2004



Expected Background at HL-LHC: $L = 5 \cdot 10^{34} / \text{cm}^2 \text{ s}$

ATLAS Small Wheel



replacement: 2018

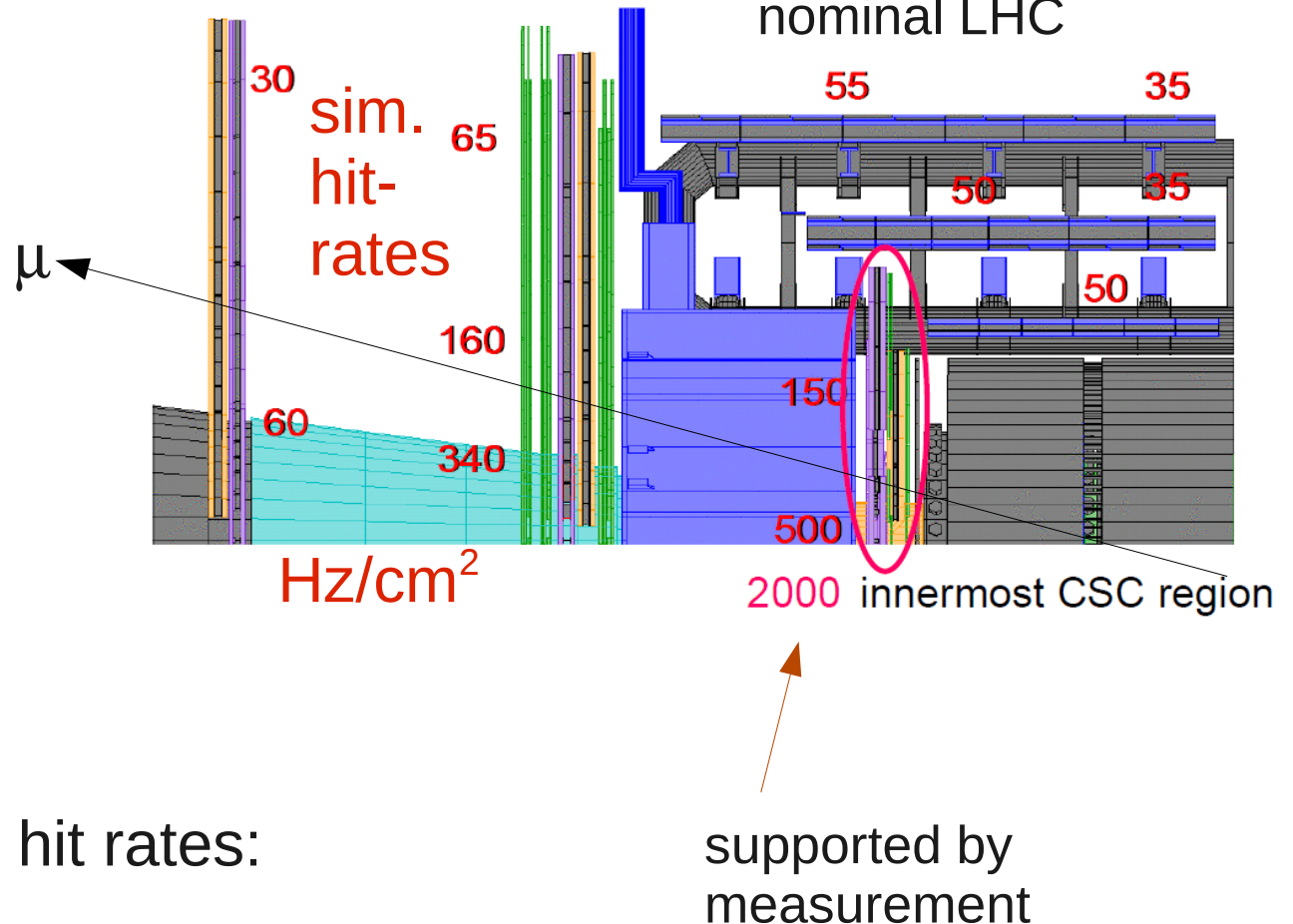
max. background hit rates:

10 kHz / cm² @ $L = 5 \cdot 10^{34} / \text{cm}^2 \text{ s}$

high-rate capable detectors necessary
no ageing !

1/4 ATLAS Detector

$L = 10^{34} / \text{cm}^2 \text{ s}$
nominal LHC



LMU Detector-Development Studies for different regions of the μ -spectrometer

option for region of moderate background at HL-LHC:

linear and fast drift-gas (using unmodified 3cm drift-tubes)
gas with electron drift independent on electric field
reduced space charge fluctuations
less occupancy

regions of highest background for LHC and HL-LHC:

sMDT: drift-tubes with reduced radius (15mm) (H. Kroha 12:30)
reduced occupancy (factor 7)
linear region of rt -relation $\Rightarrow$ small space charge fluctuations
high rate capability

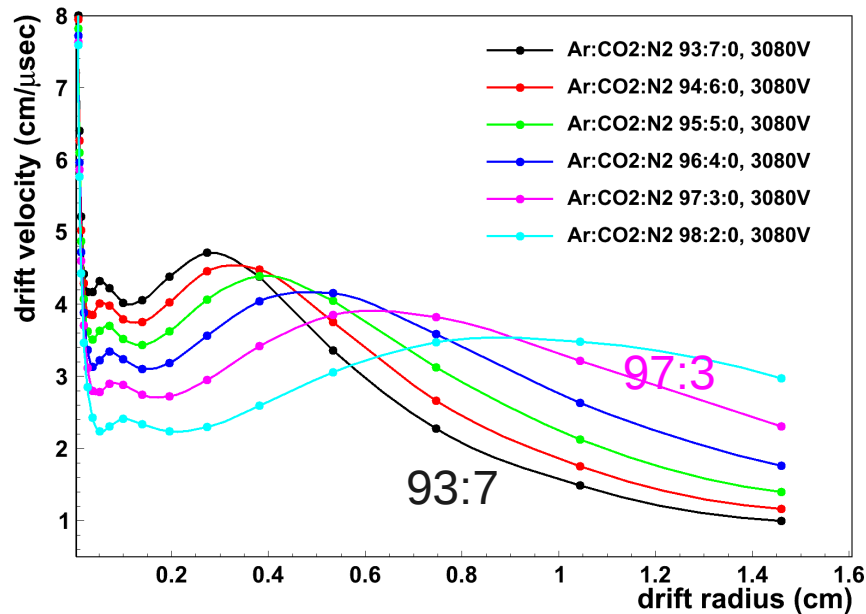
micromegas (micromesh gaseous detector)

planar structure with geometrically optimized ion path length
direct position measurement
multi-track resolution

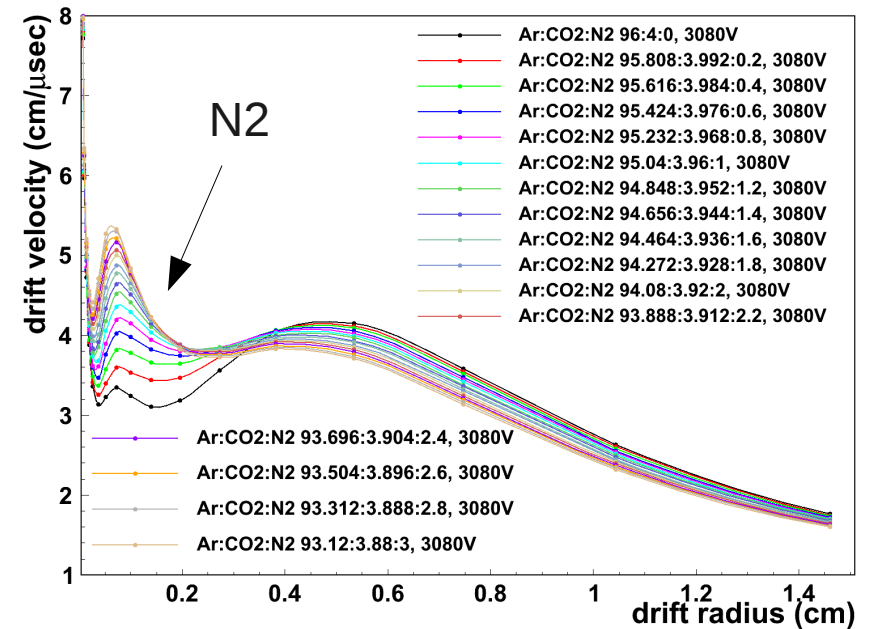
Linear, Fast Drift Gas Ar:CO₂:N₂ option for 3cm drift-tubes at HL-LHC

Garfield / Magboltz simulation

Ar:CO₂



addition of N₂



less CO₂ => faster gas

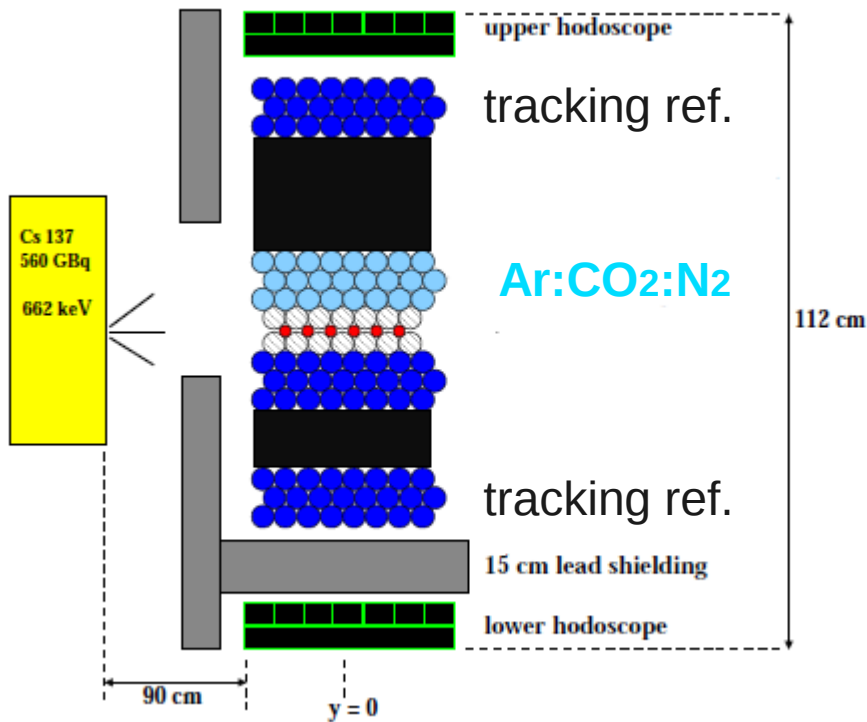
N₂: modifies only the region $r < 0.4$ cm => more linear

=> Ar:CO₂:N₂ 96:3:1 % Vol.

Reduced Background Sensitivity Ar:CO₂:N₂

3 cm drift-tubes

gamma irradiation facility CERN



Ar:CO₂: $t_{\max} = 680$ ns

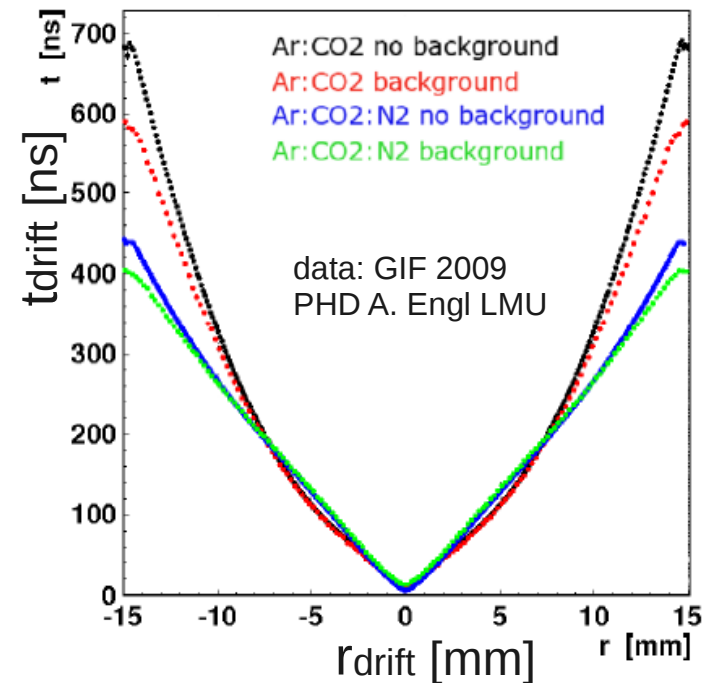
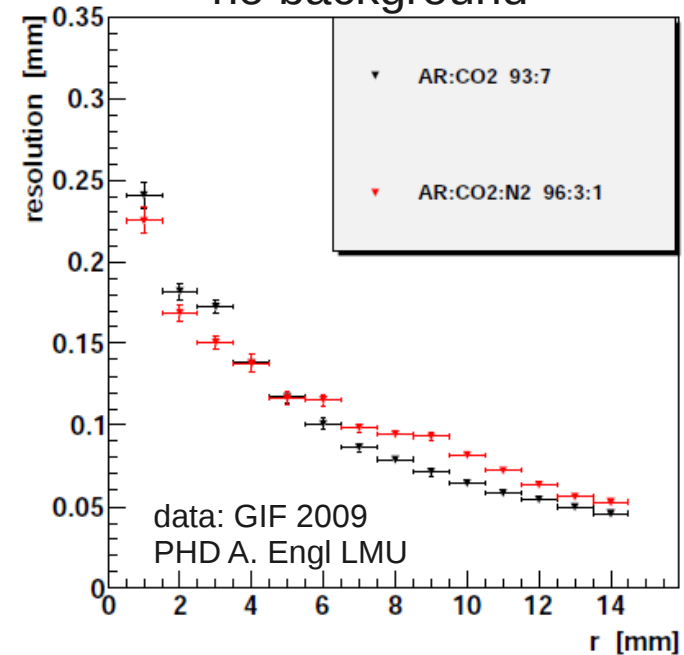
Ar:CO₂:N₂: $t_{\max} = 440$ ns

1900 Hz/cm²:

Ar:CO₂ $\Delta r = 234$ μ m

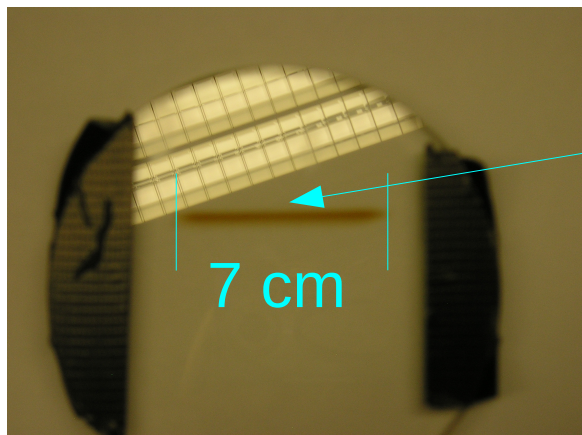
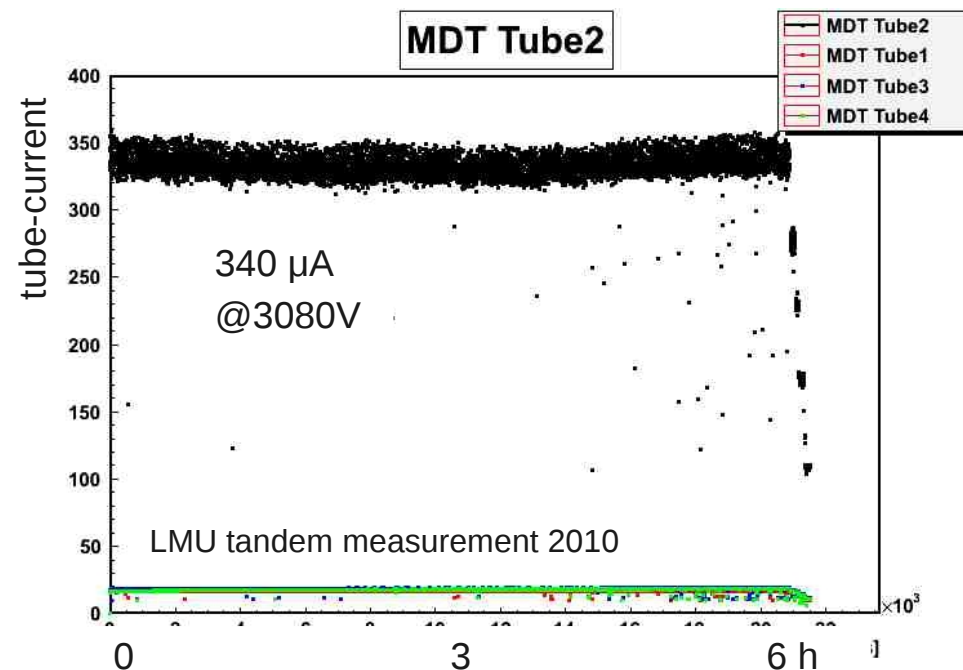
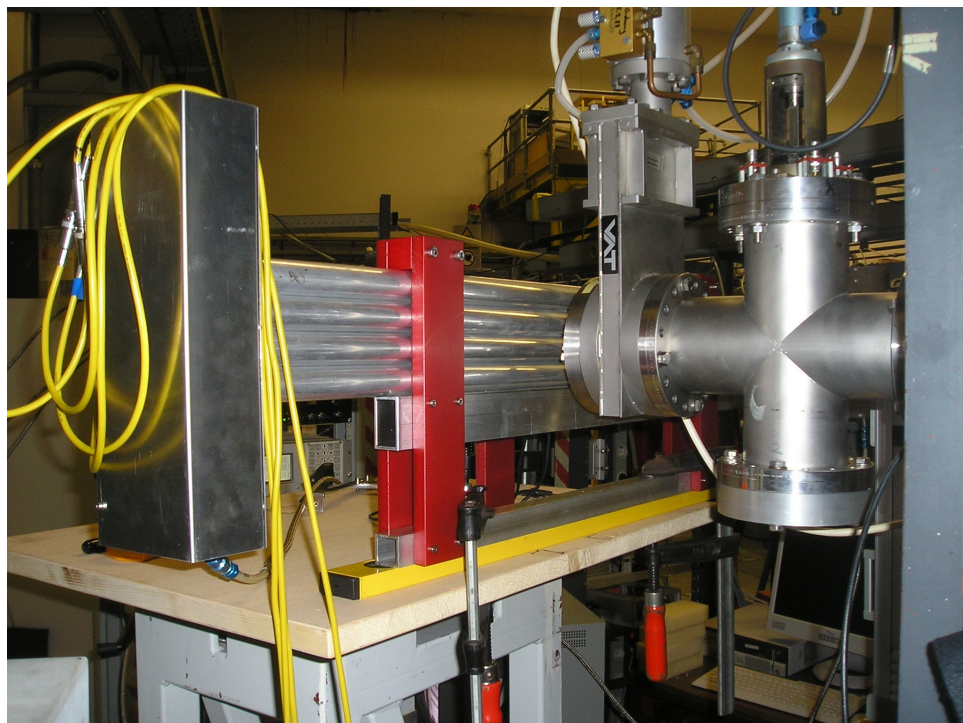
Ar:CO₂:N₂ $\Delta r = 129$ μ m

no background



Ageing Study of Ar:CO₂ 93:7 and Ar:CO₂:N₂ 96:3:1 for 3 cm drift-tubes

No ageing observed ! 1 lifetime ATLAS in 6h



105 nA p 20 MeV
irradiated spot: 7 cm * 1 cm

=> **7 As / 7 cm** = 1 * lifetime ATLAS

Option for 3cm Drift-Tubes @HL-LHC

Ar:CO₂:N₂ 96:3:1 % Vol.

linear drift gas, strongly reduced space charge fluctuations

$t_{\max}$: 440 ns $\longleftrightarrow$ 680 ns
factor 1.5 less occupancy

no ageing

very small amount of afterpulses,
 $t_{\max}(\text{Ar:CO}_2\text{:N}_2)$ never longer than $t_{\max}(\text{Ar:CO}_2)$

no streamer observed @ gas gain 20000

Regions of Highest Background @ LHC and HL-LHC

Micromegas Detectors

features:

excellent position resolution

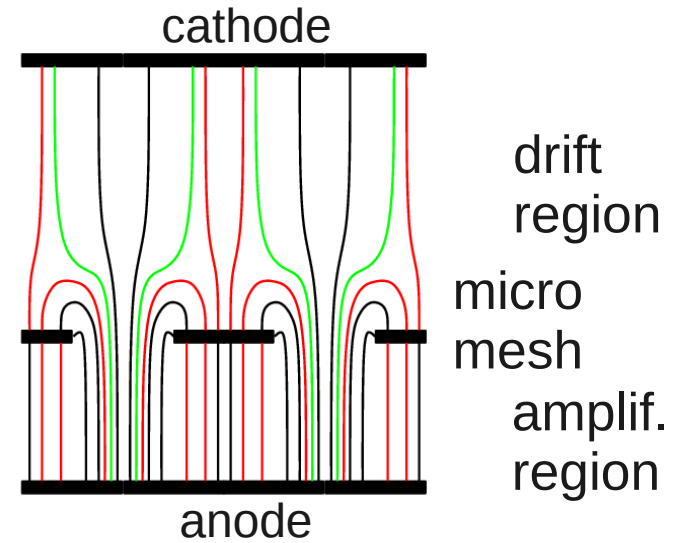
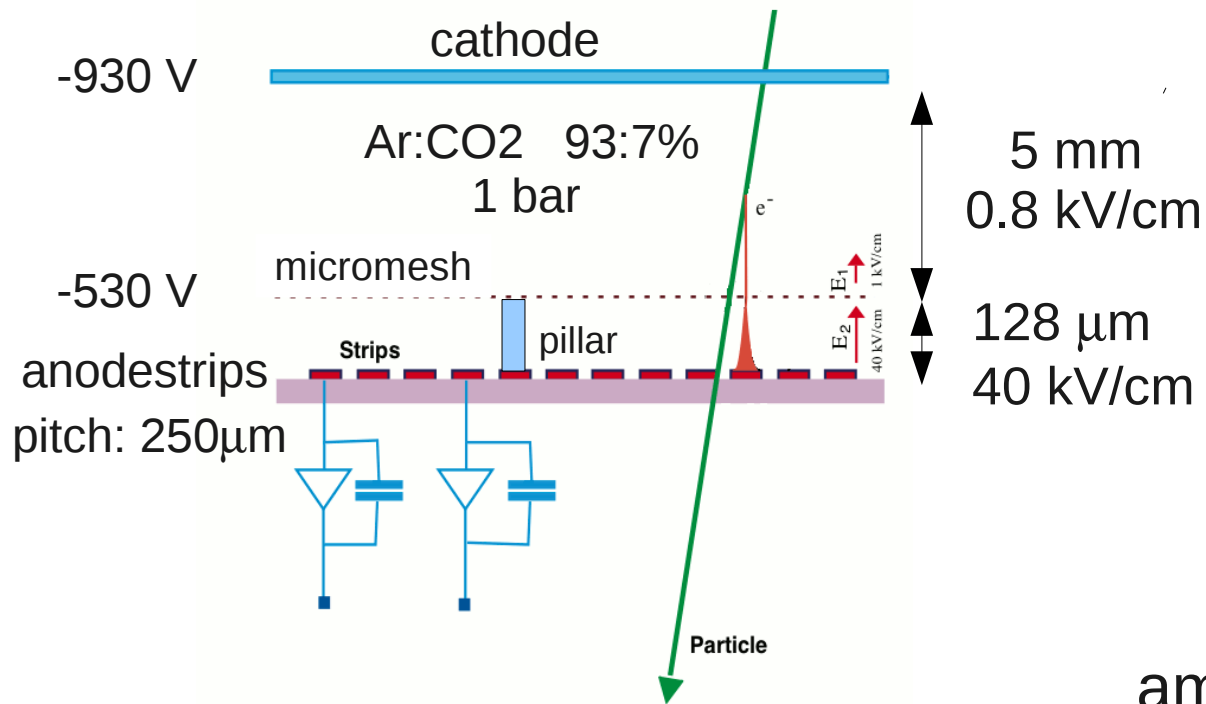
trigger capability

high rate capability

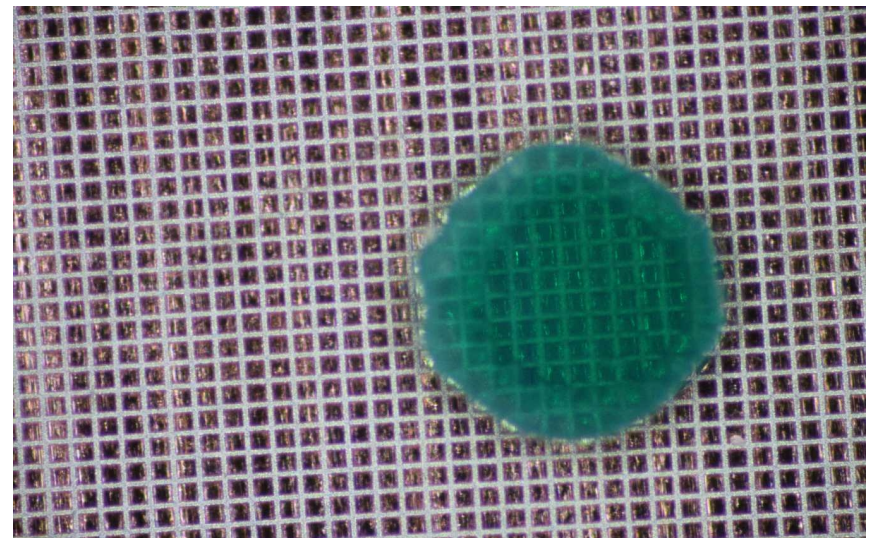
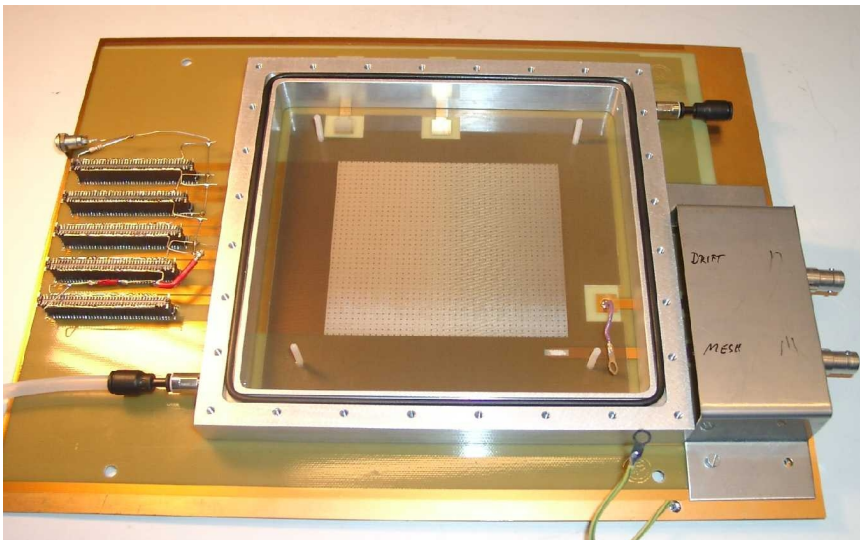
multiple track resolution

X_{strip} , t_{strip} => position and angle of μ -track

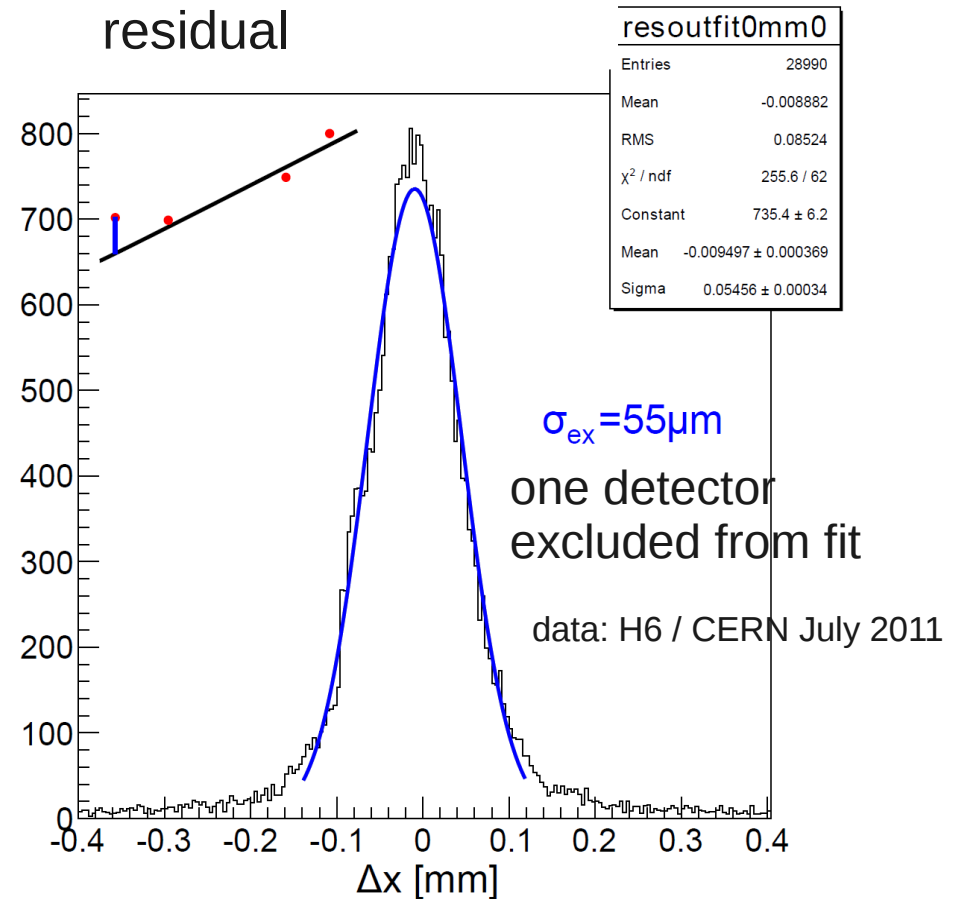
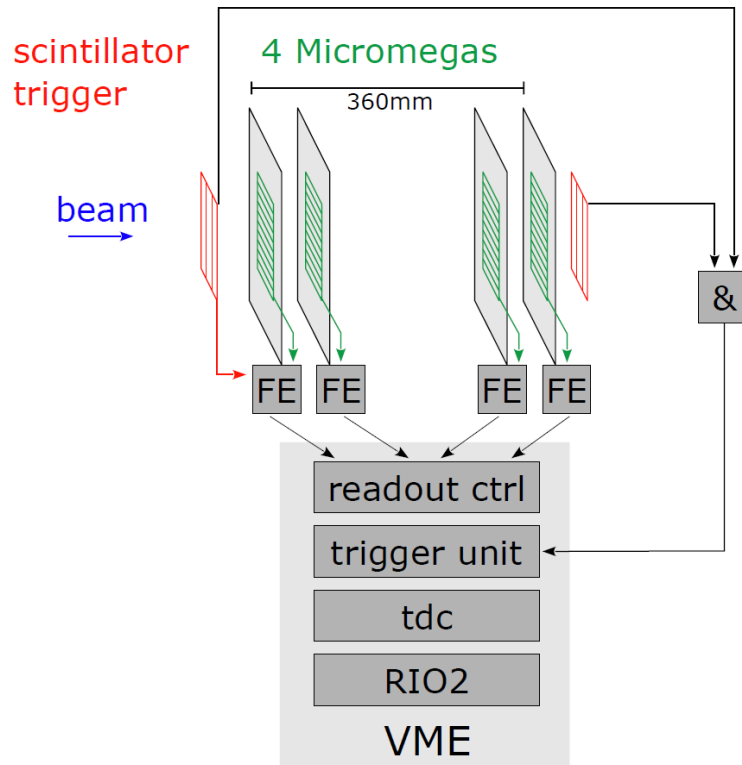
MicroMeGaS Detector 9x10 cm²



amplifying mesh including pillar



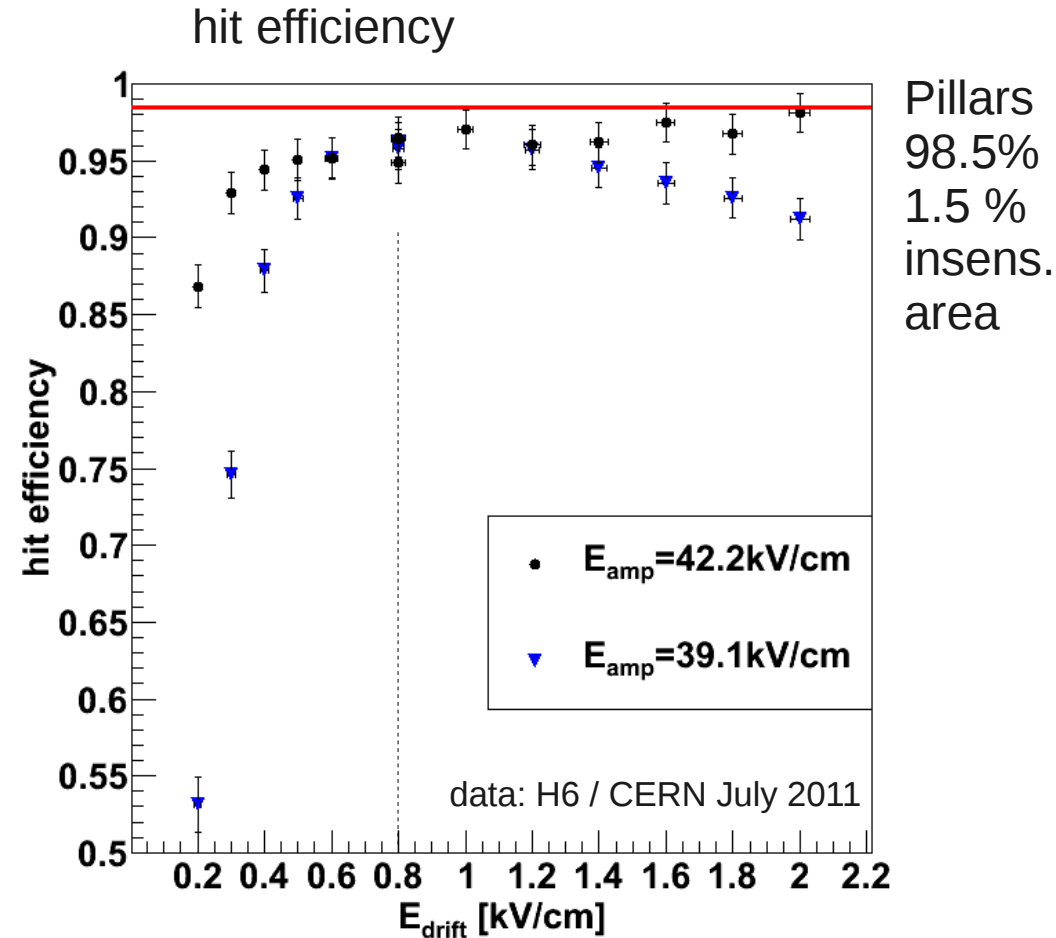
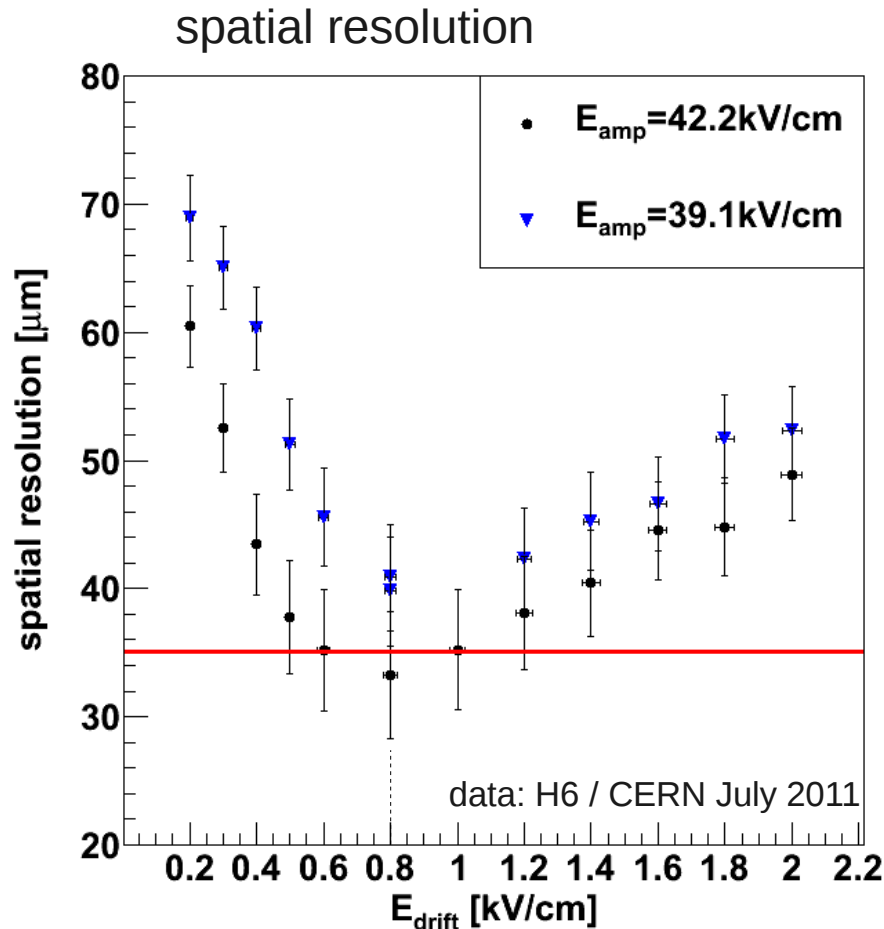
Determination of Spatial Resolution with 160 GeV π^- @H6 / CERN using tracking telescope



$$\sigma_{sr} = \sqrt{\sigma_{ex}^2 - \sigma_{track}^2}$$

4 standard micromegas: copper strips, 250 μm pitch

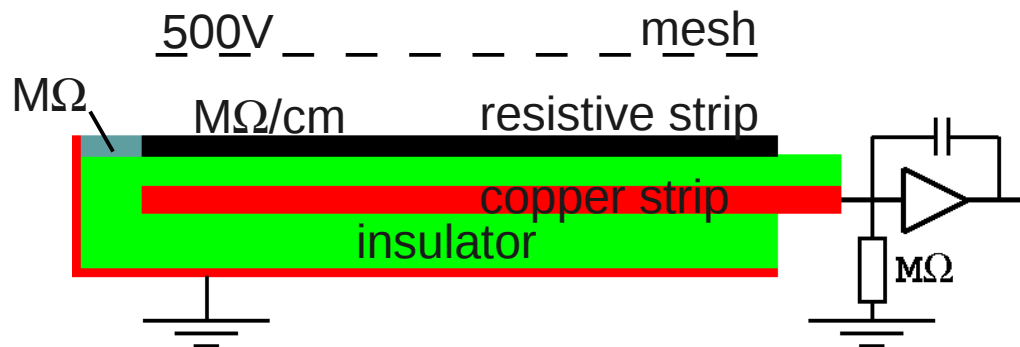
$9 \times 10 \text{ cm}^2$ Gassiplex readout



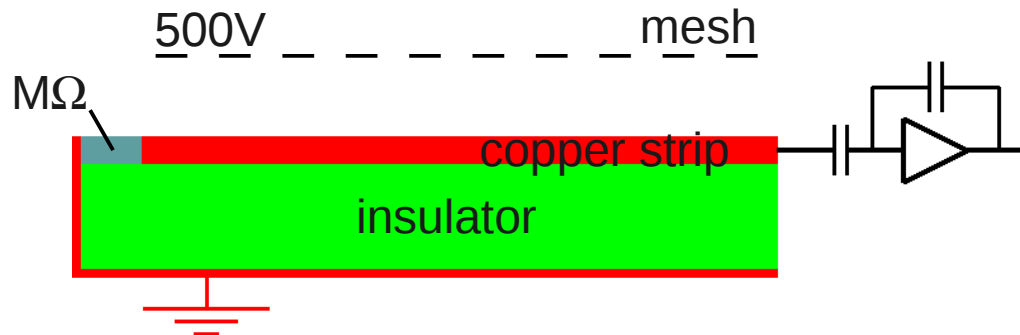
spatial resolution 35 μm @ 160 GeV π , orthogonal beam
tracking resolution < 20 μm to test large structures w. 4 micr.
efficiency > 99 % @ Ar:CO₂ 85:15 1 bar

Two Approaches to Reduce Sensitivity to Discharges

resistive strip technology



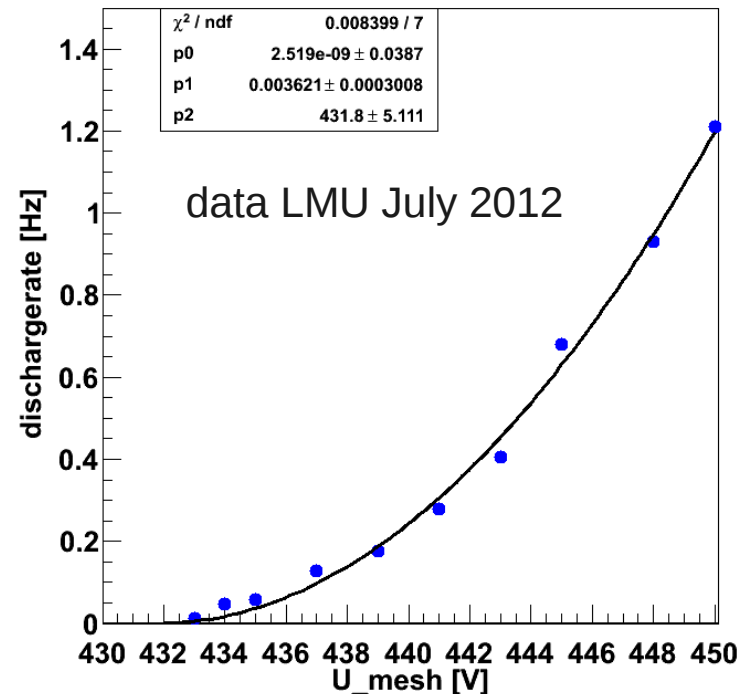
floating strip technology



idea:

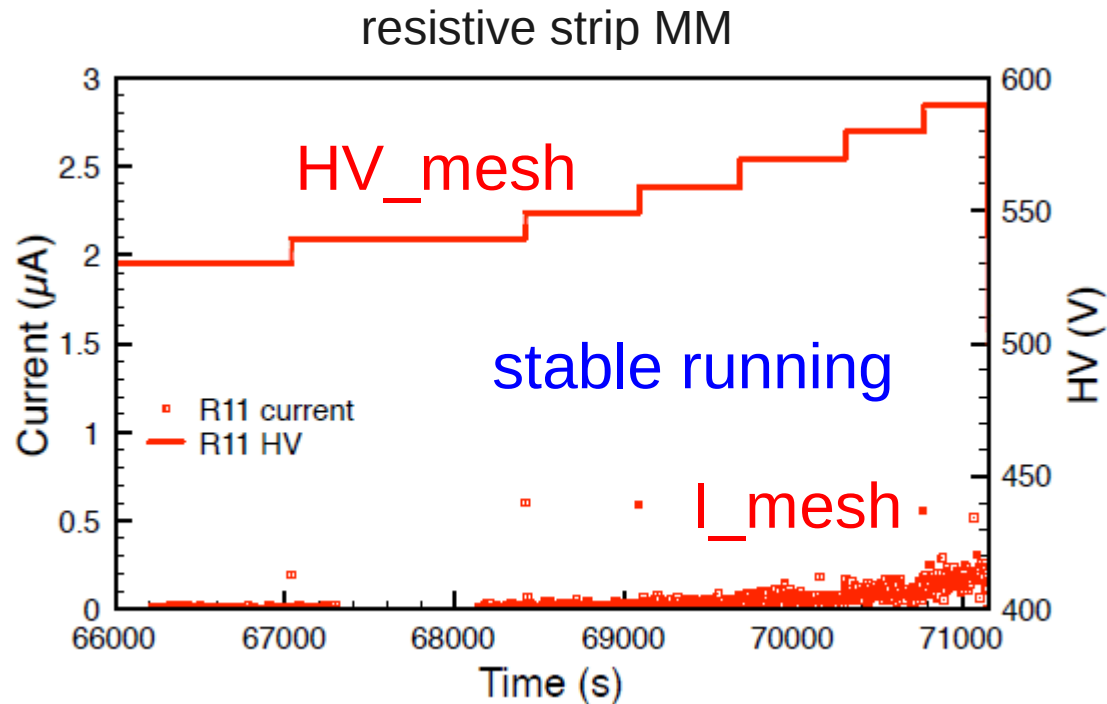
discharge loads upper strip
discharge stops as potential
on strip rises

fast recovery process, ageing ?

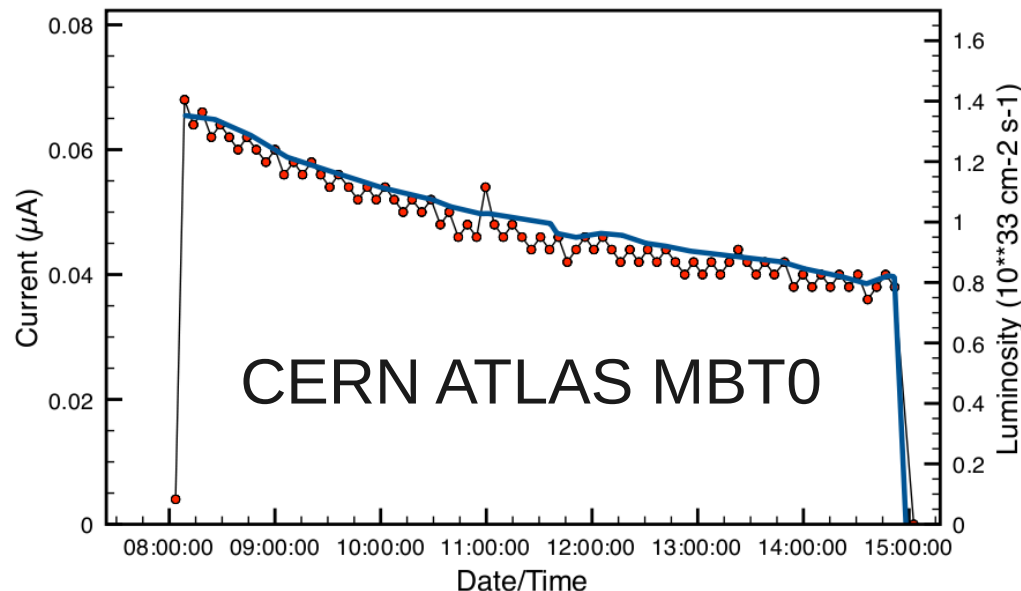
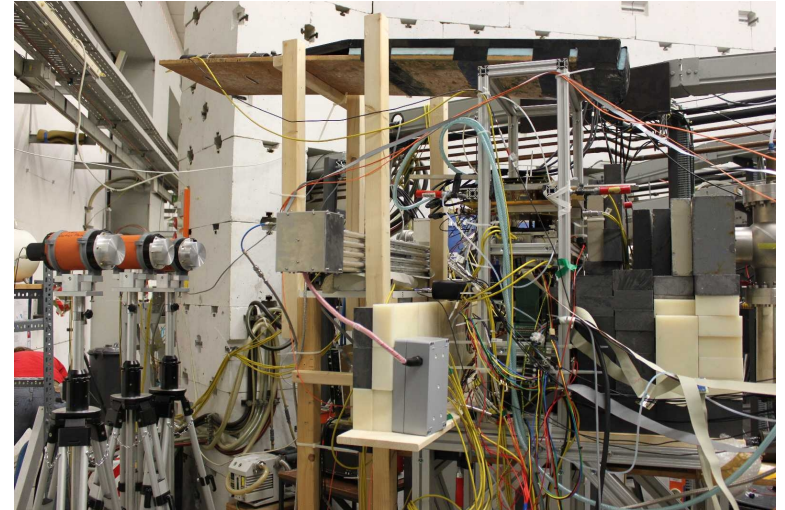


5.8 MeV α induce discharges @ $3 \cdot 10^8 \text{ e}^-/\text{mm}^2$

Resistive Strip MM in 11 MeV Neutron Beam @ LMU



$10^7 \text{ n /cm}^2 \text{ s}$ $30 \times 30 \text{ cm}^2$



MBT0 ATLAS

minimum bias trigger region
very high background rates

detector current scales
similar to luminosity

stable running, ageing-test

Summary: High Precision μ Tracking at HL-LHC

Ar:CO₂:N₂ 96:3:1 option for regions of medium hit-rates @ HL-LHC
fast linear drift-gas using 3cm MDT hardware,
e.g. Big-Wheel

micromegas:

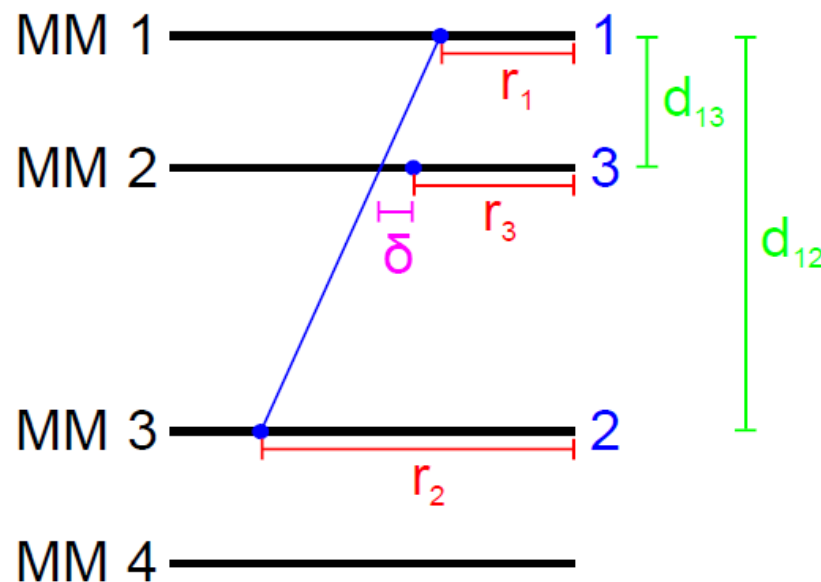
- excellent position resolution $\Delta r = 34 \mu\text{m}$
- 4 – 8 MM-detectors: track-res $< 20 \mu\text{m} \Rightarrow$ test of large structures
- efficiency $> 99 \%$ @ 1 bar Ar:CO₂
- resistive strip technology reduces deadtime due to discharges
- ageing test in MBT region ongoing

future projects:

- new Small-Wheel: MICROME GAS as tracking chambers +
TGC (thin gap chamber) as trigger chambers
- 2m * 0.6 m large MM structures currently under investigation
- construction of 2*4 layer module ongoing

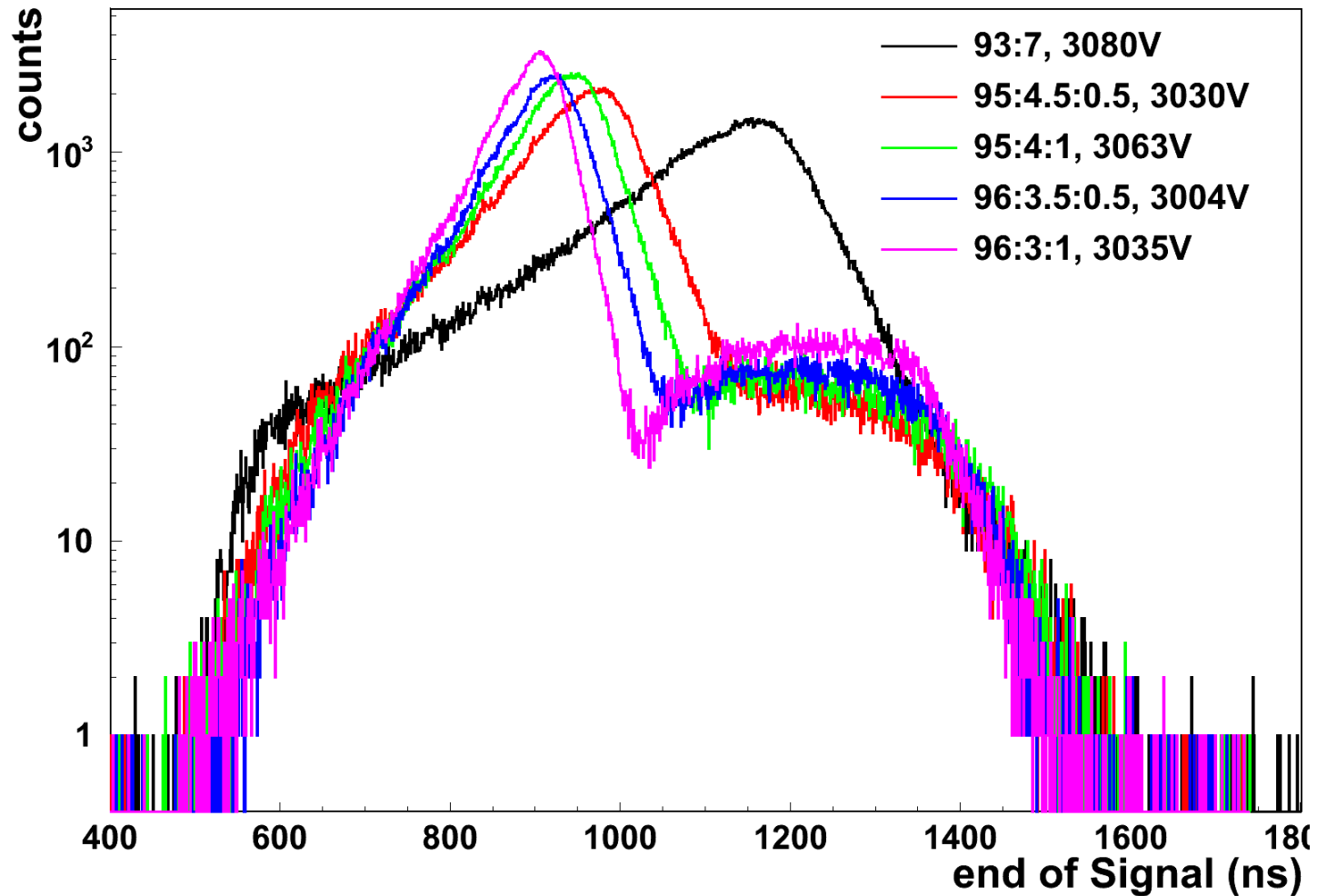
Backup

Determination of Spatial Resolution – 3 Layer Method



- interpolate **track prediction** by two detectors into 3rd and compare with measured hit in that detector
- $\delta = r_3 - r_2 \frac{d_{13}}{d_{12}} - r_1 \left(1 - \frac{d_{13}}{d_{12}}\right) \rightarrow$
 $(\Delta\delta)^2 = (\Delta r_3)^2 + \left(\frac{d_{13}}{d_{12}} \Delta r_2\right)^2 + \left[\left(1 - \frac{d_{13}}{d_{12}}\right) \Delta r_1\right]^2$
- 4 different triplett-equations & 4 $\Delta r_i \rightarrow$ solvable system

Investigation: End of Analog Signal



Ar:CO₂:N₂ 93:6:1 % Vol
very small amount of afterpulses,
 $t_{\max}$ never longer than at Ar:CO₂

Analog Signal: Ar:CO₂ 93:7 %

