ATLAS Monitored Drift Tube Chambers for super-LHC

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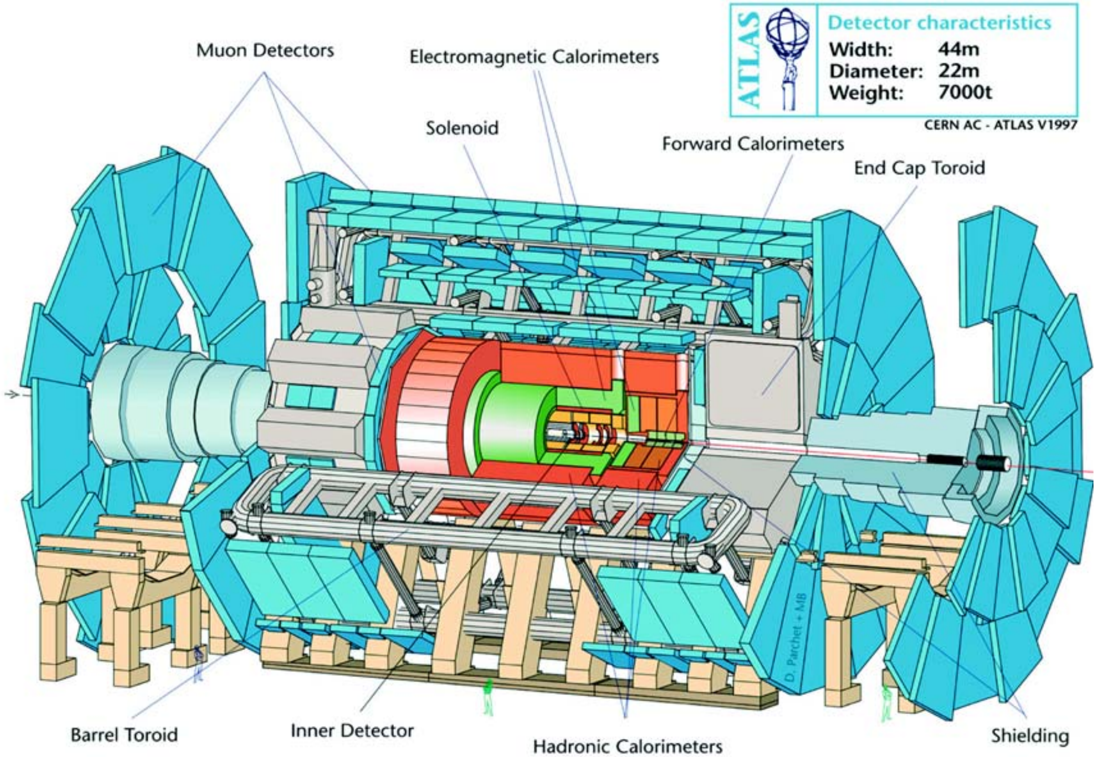
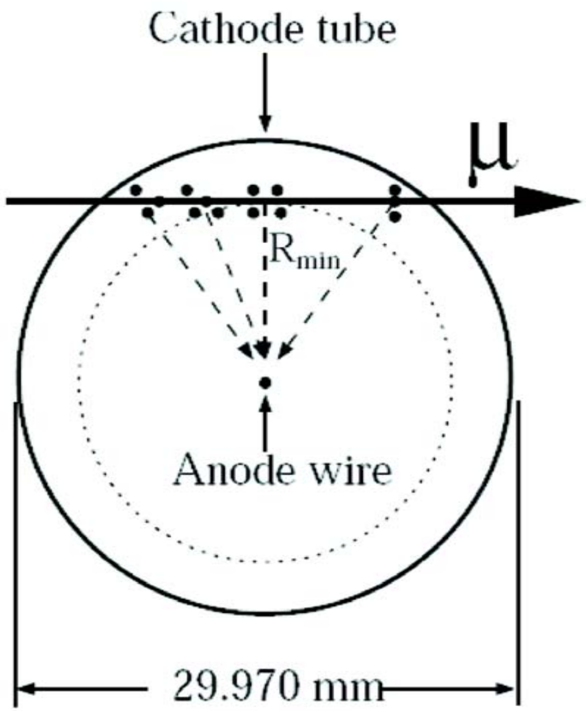
Deutsche
Forschungsgemeinschaft
DFG

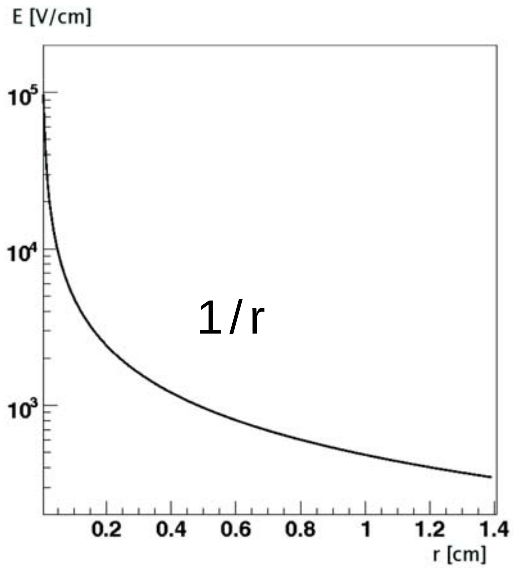
ATLAS Detector



- p-p collisions
- $\Delta p/p$ = 10 % @ 1 TeV
- single tube resolution: < 100 μm

Drift Tube Principle



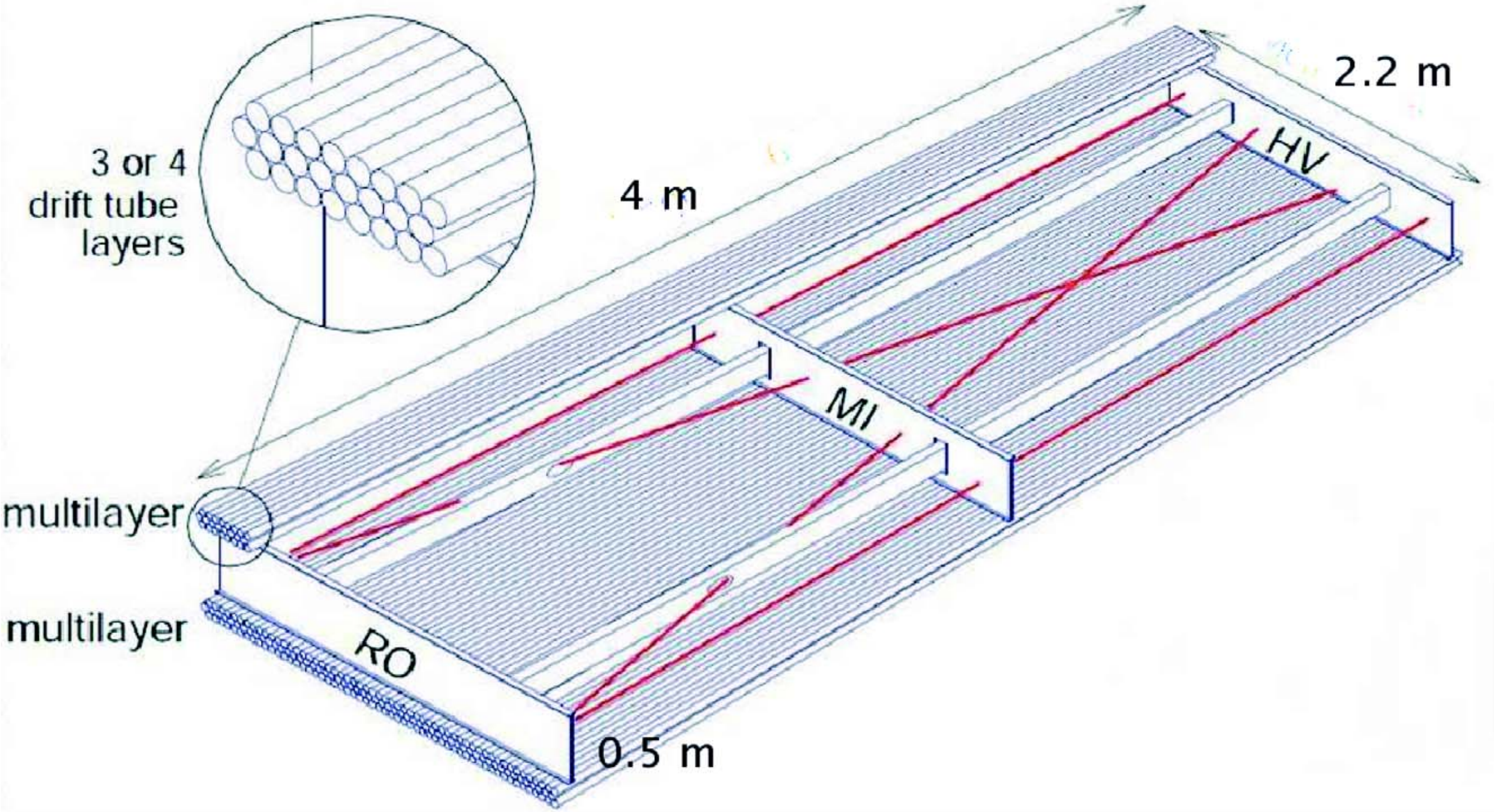


HV = + 3080 V

P = 3 bar Ar/CO2 93/7 %

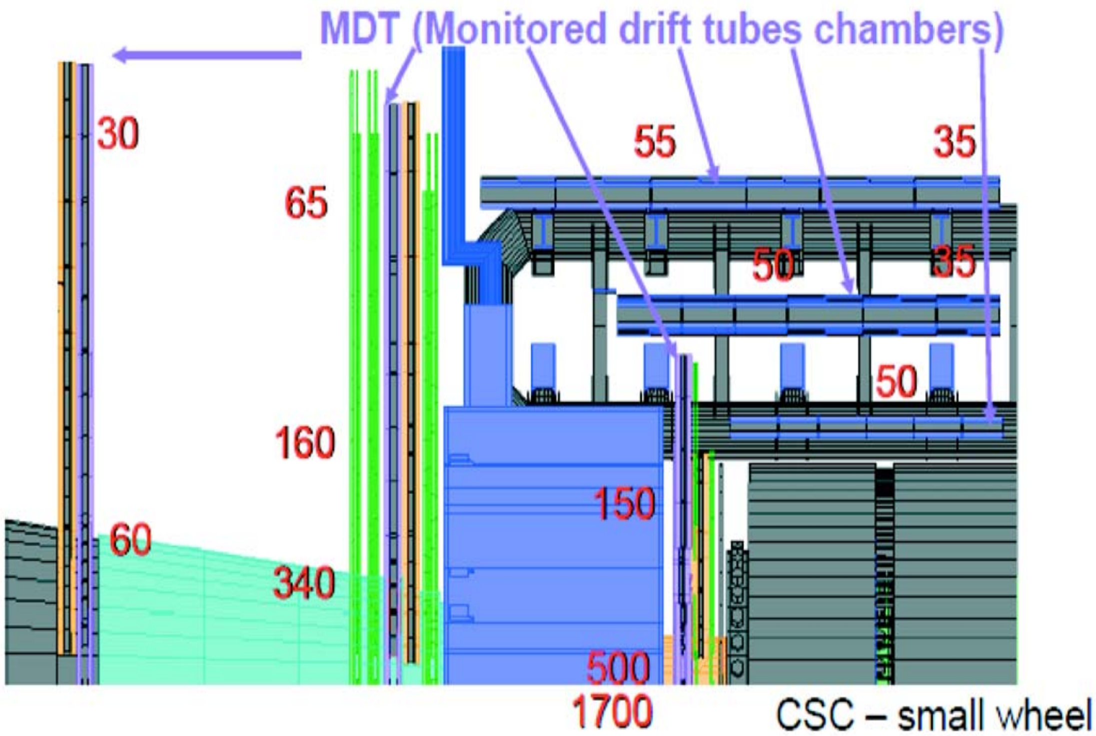
gas gain = 20000

Monitored Drift Tube Chamber



Background @ ATLAS Muon Spectrometer (expected rates)

Baranov et al.: ATL-GEN-2005-001, Geneva 2005



Background rates [Hz/cm^2]

LHC design luminosity 10^34/cm^2s

Safety factor 5

MDT (L=2m, D=3cm):

500 Hz/cm^2,

1.5 kHz/cm,

300 kHz/tube

S-LHC: 10*luminosity => 15 kHz/cm

Space Charge Effects due to Ions

assumptions: 2 dim, μ = const.

$$\frac{dr}{dt} = \mu \cdot E(r) \rightarrow dt = \frac{dr}{\mu \cdot E(r)}$$

charge density:

$$\rho(r) = \frac{N_c G Q}{2\pi\mu r E(r)}$$

Gauss theorem:

$$2\pi r E(r) = \frac{\gamma}{\varepsilon_0} + \frac{1}{\varepsilon_0}\int_a^r 2\pi R \rho(R)\, dR$$

differentiating

$$E(r)^2 + rE(r)\frac{dE(r)}{dr} = \frac{N_c G Q}{2\pi\mu\varepsilon_0}$$

Nc : background rate per unit wire length [1/s]

Q : average charge deposit per event

G : gas gain

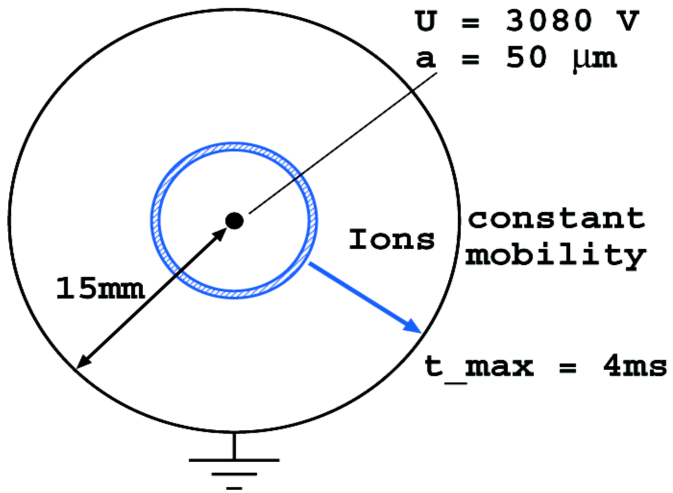
μ : ion mobility

V : high voltage on wire (3080 V)

b : tube radius (1.46 cm)

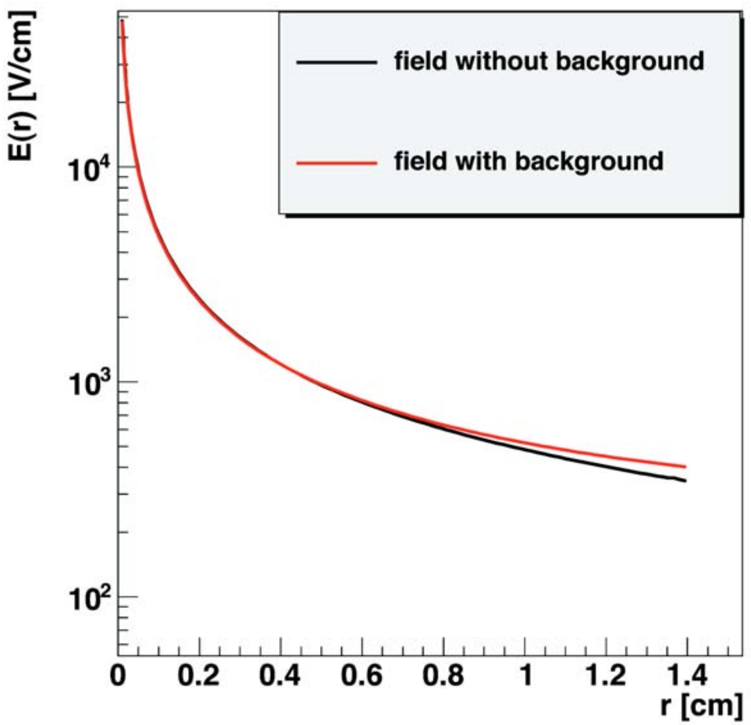
a : wire radius (25 μm)

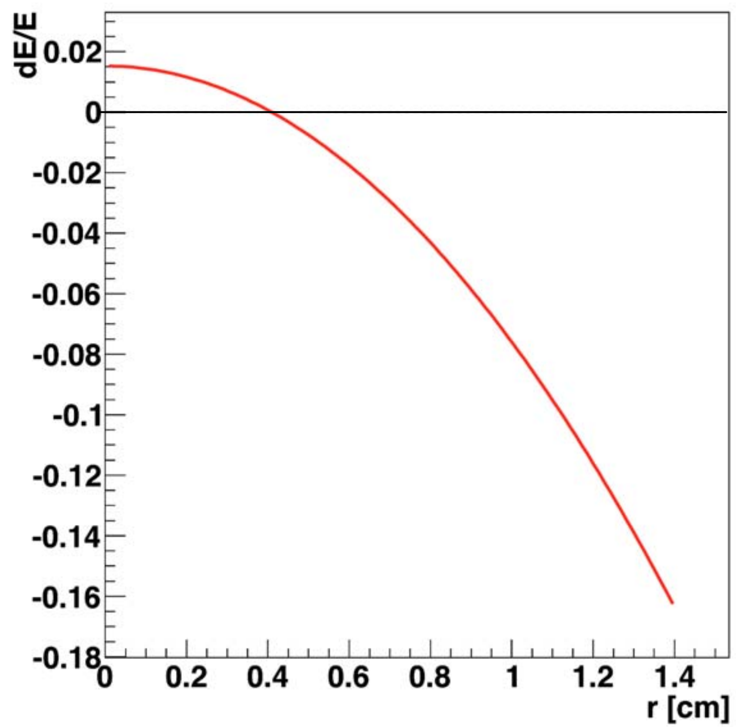
γ : line charge on the anode wire



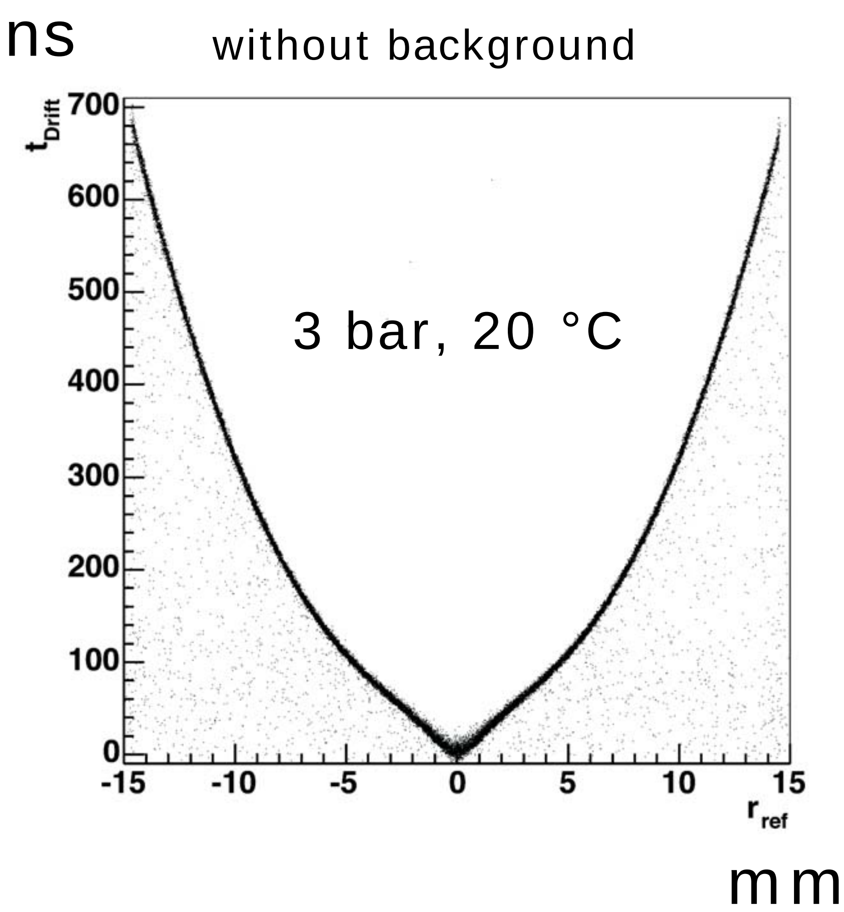
Change of Electric Field (30 mm ∅ Tubes)

$$E(r) = \sqrt{c1}\,\frac{k}{r}\sqrt{1+\frac{r^2}{k^2}} \qquad c1 = \frac{N_c G Q}{2\pi\mu\varepsilon_0} \qquad \int_a^b E(r)dr = V$$

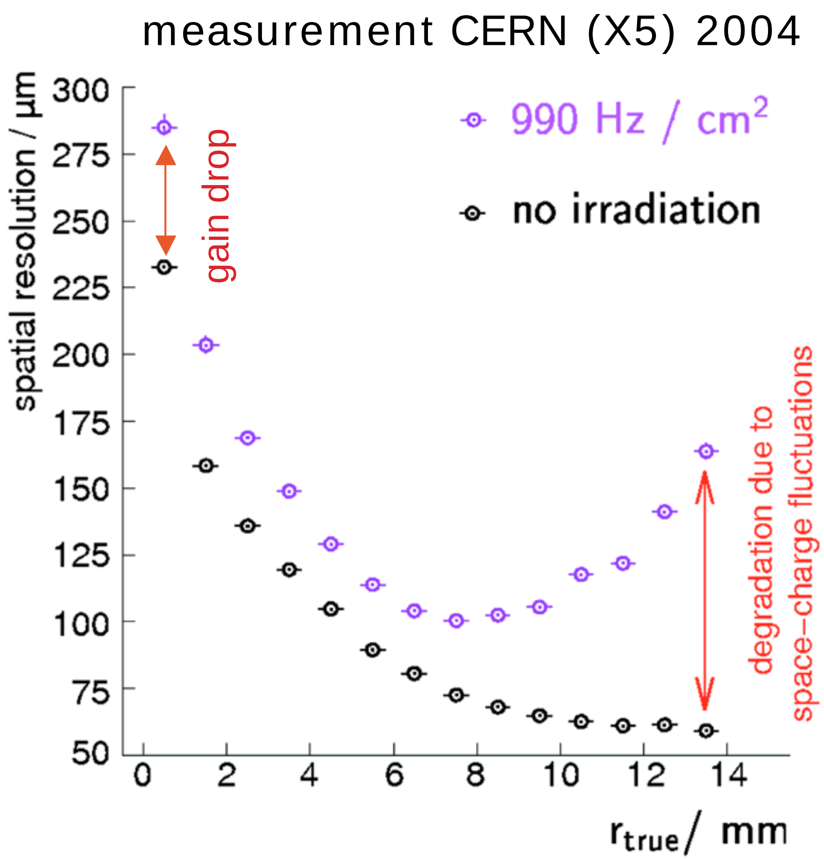




Ar:CO2 = 93:7



ns
without background
t_{Drift}
700
600
500
400
300
200
100
0
-15
-10
-5
0
5
10
15
r_{ref}
3 bar, 20 °C
mm



measurement CERN (X5) 2004
spatial resolution / µm
300
275
250
225
200
175
150
125
100
75
50
0
2
4
6
8
10
12
14
r_{true}/ mm
gain drop
990 Hz / cm^2
no irradiation
degradation due to
space−charge fluctuations

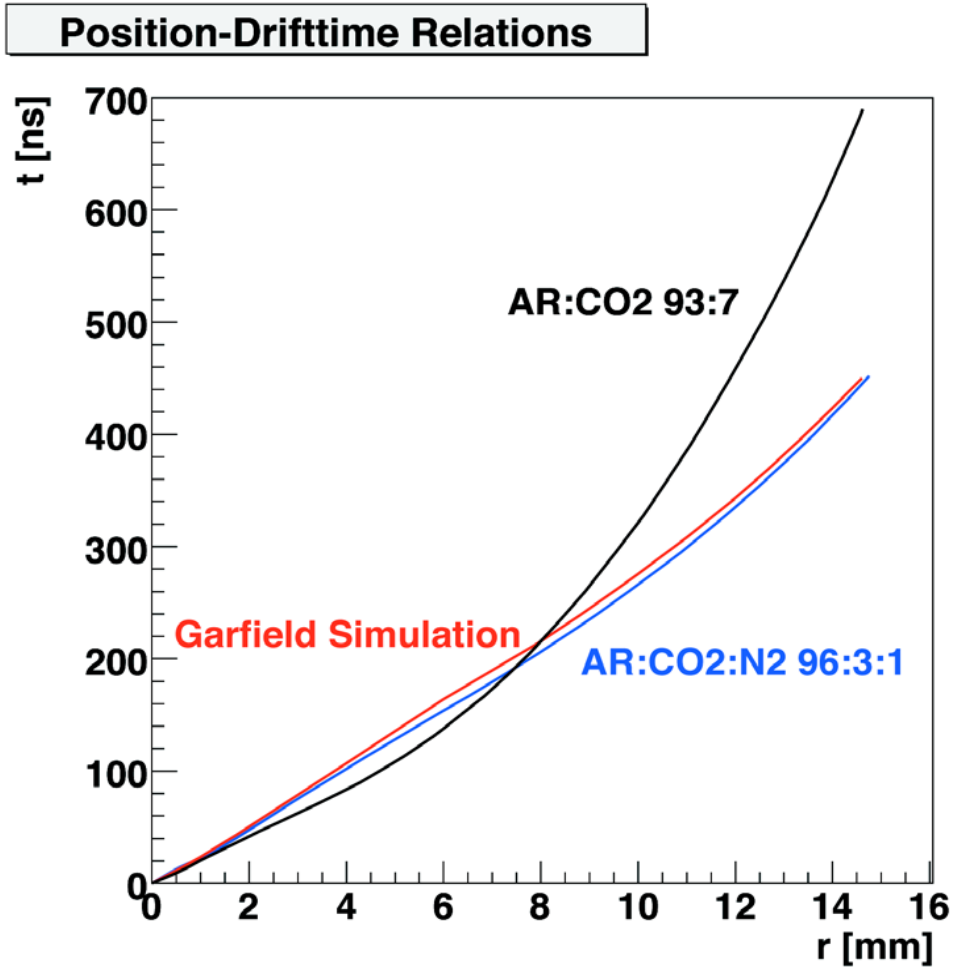
Overview

- Barrel Region:
  - faster and linear drift gas

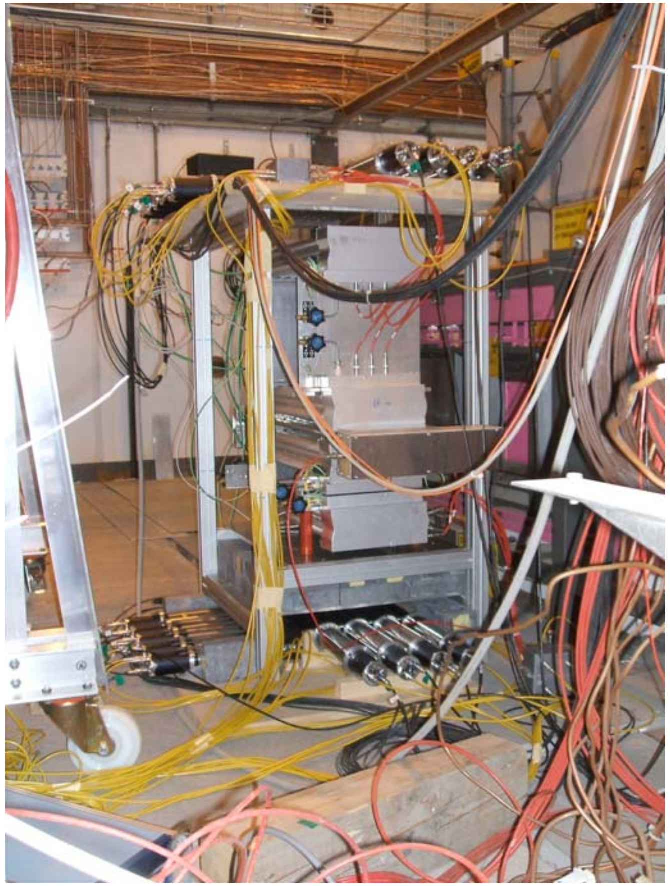
- High Rate Endcap Region:
  - 15 mm drift tube detectors

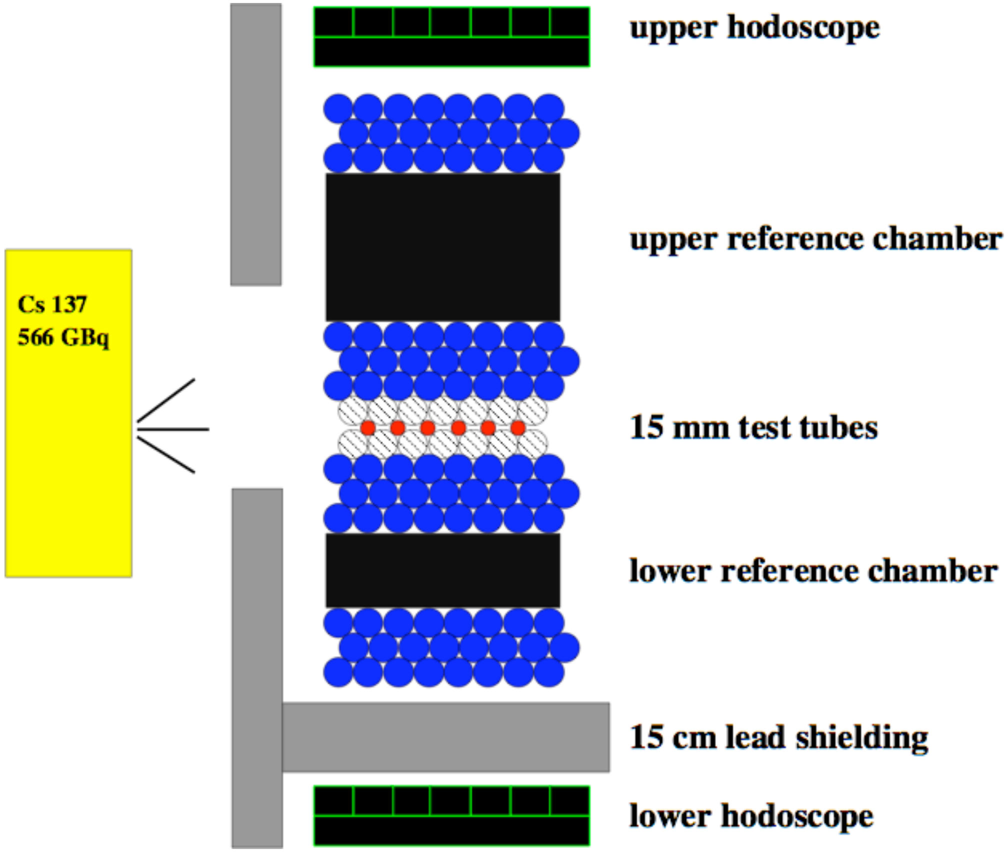
GIF Test 2009 (Alternative Drift Gas)

Alternative Gas

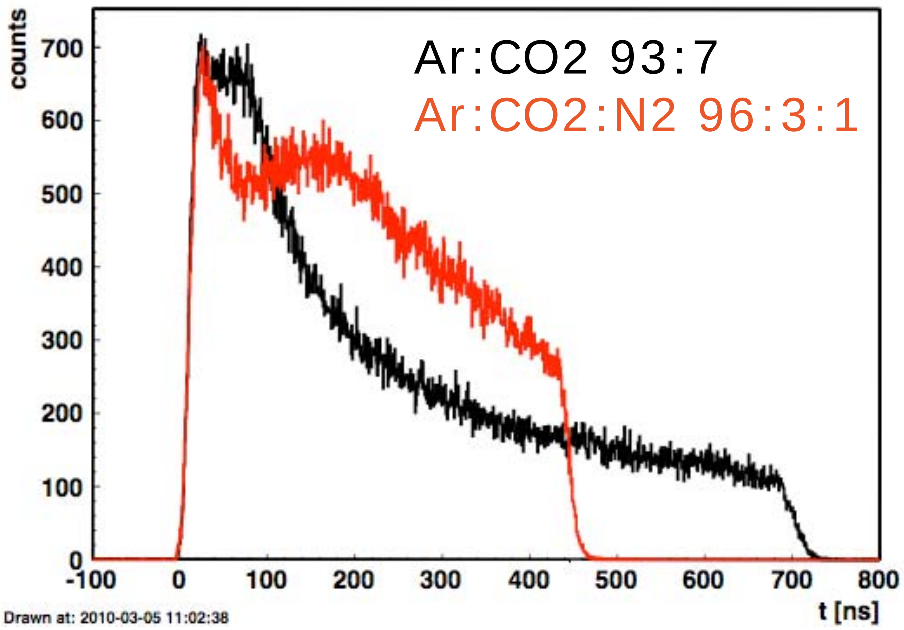


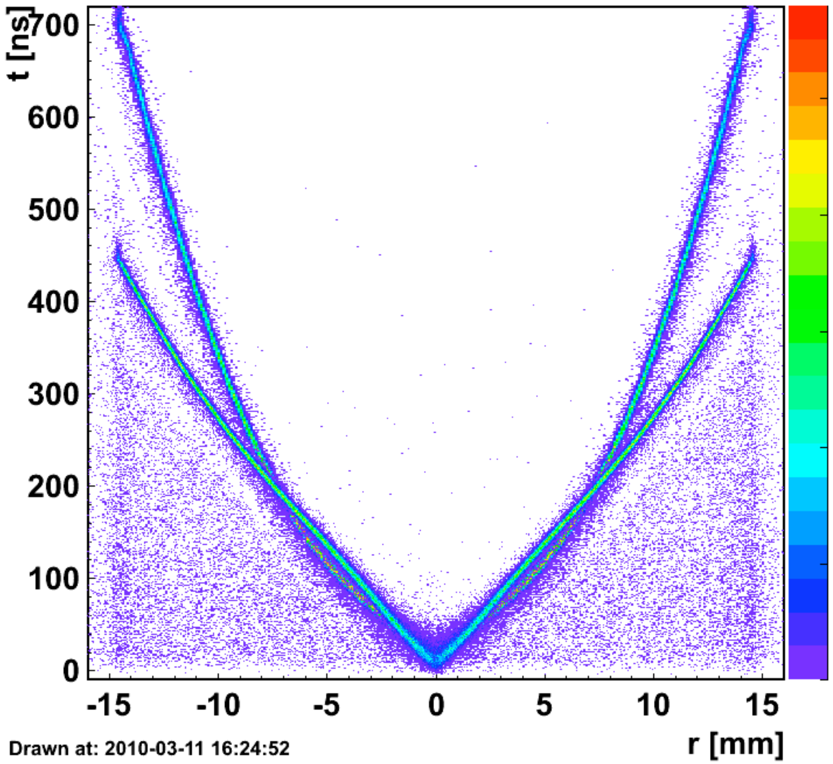
Setup @ GIF/CERN 2009



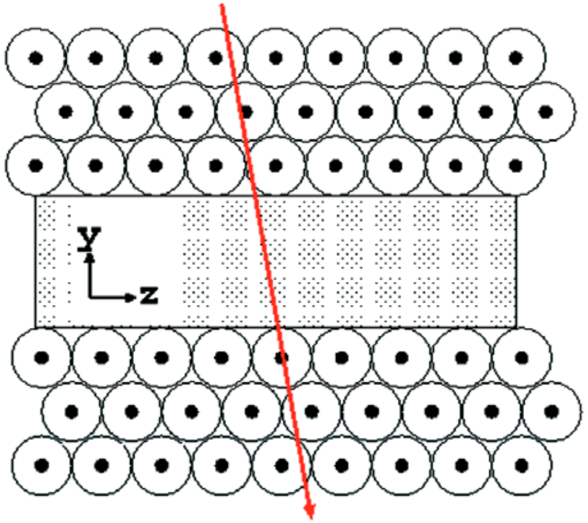


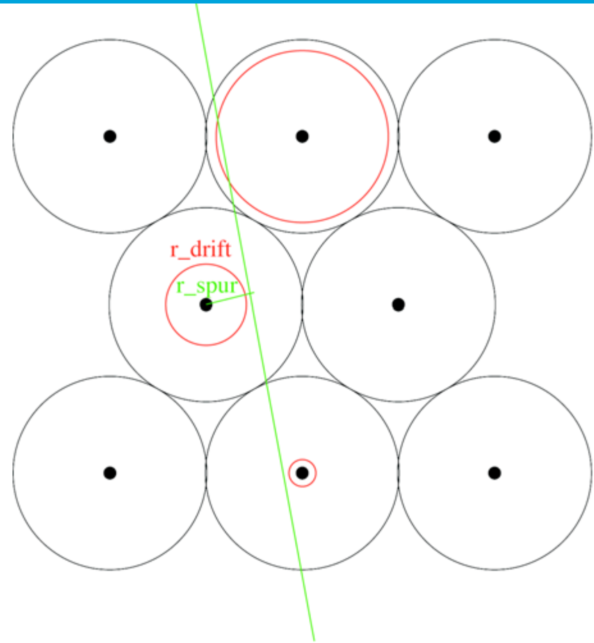
Drift spectra & rt-relation





Tracking

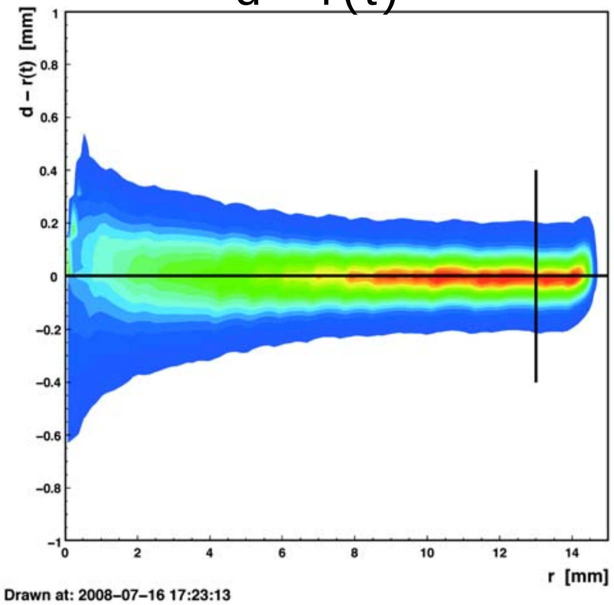


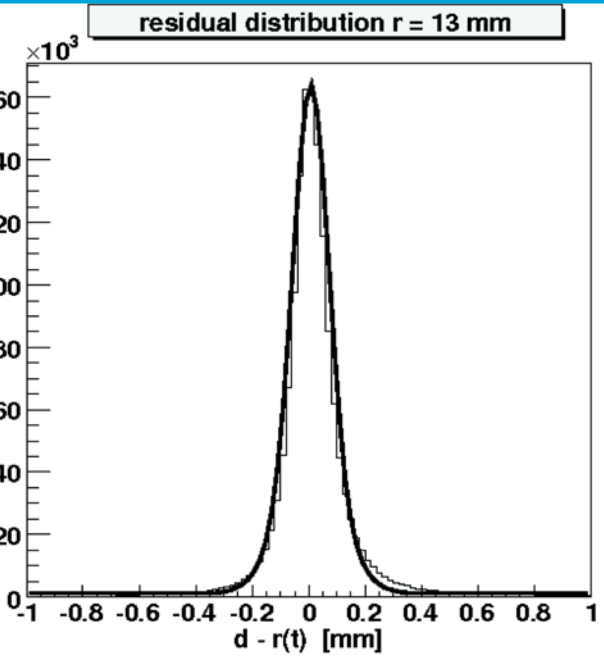


$$\chi^2 = \sum_{i=1}^{n} \frac{\left(r_{drift,i} - r_{spur,i}\right)^2}{\sigma\left(r_{drift,i}\right)^2}$$

Residual

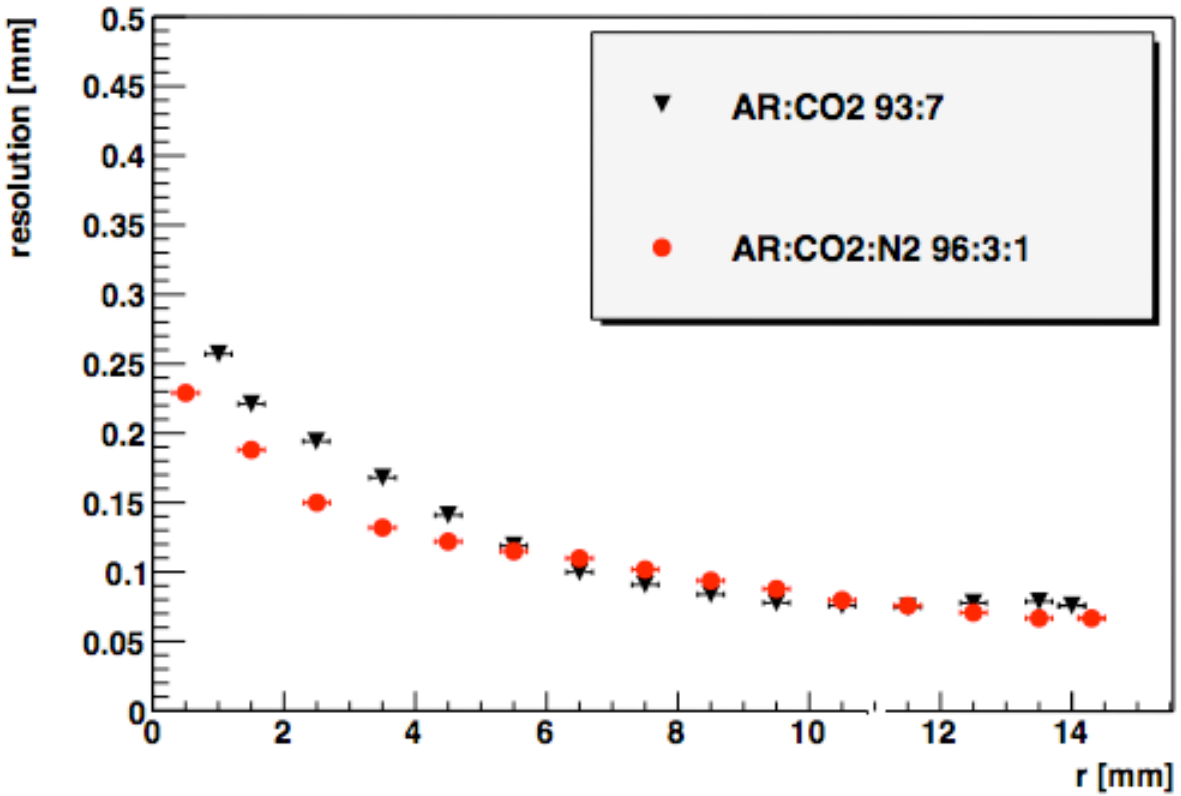
d - r(t)





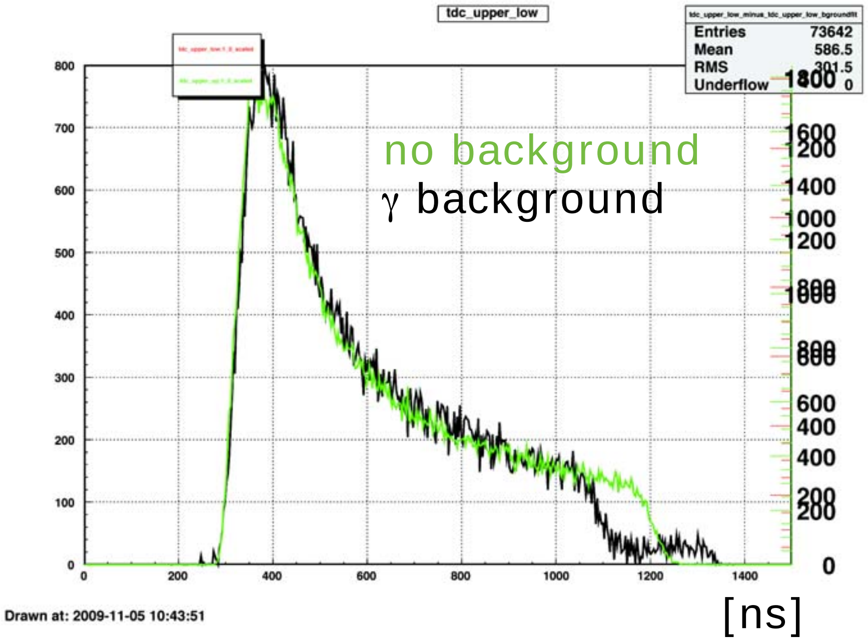
$$a * \exp\left(-0.5 * \left(\frac{x-\mu}{\sigma}\right)^2\right) + b * \exp\left(-0.5 * \left(\frac{x-\mu}{3\sigma}\right)^2\right)$$

Width of Residual without γ - Background

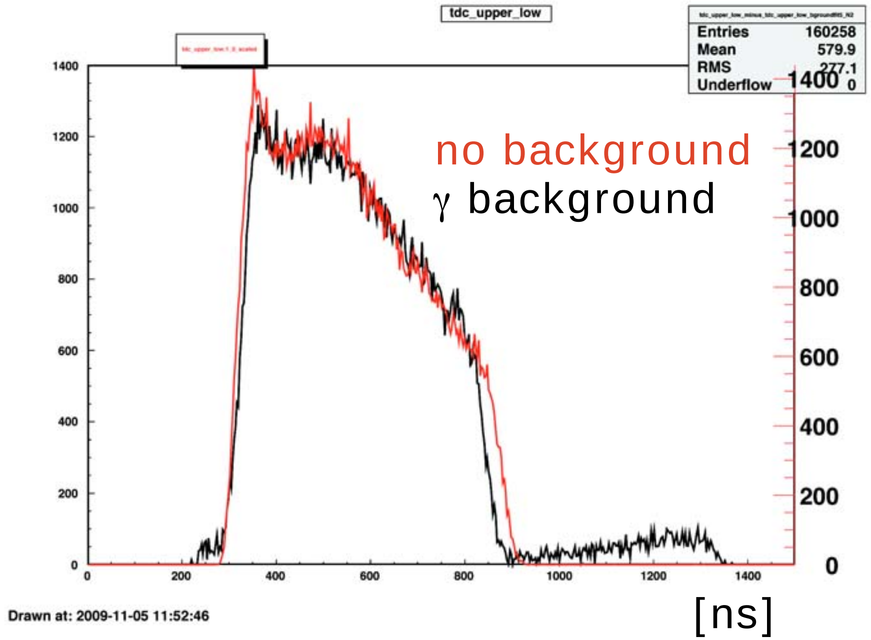


Drift Spectra @ 1700 Hz/cm^2

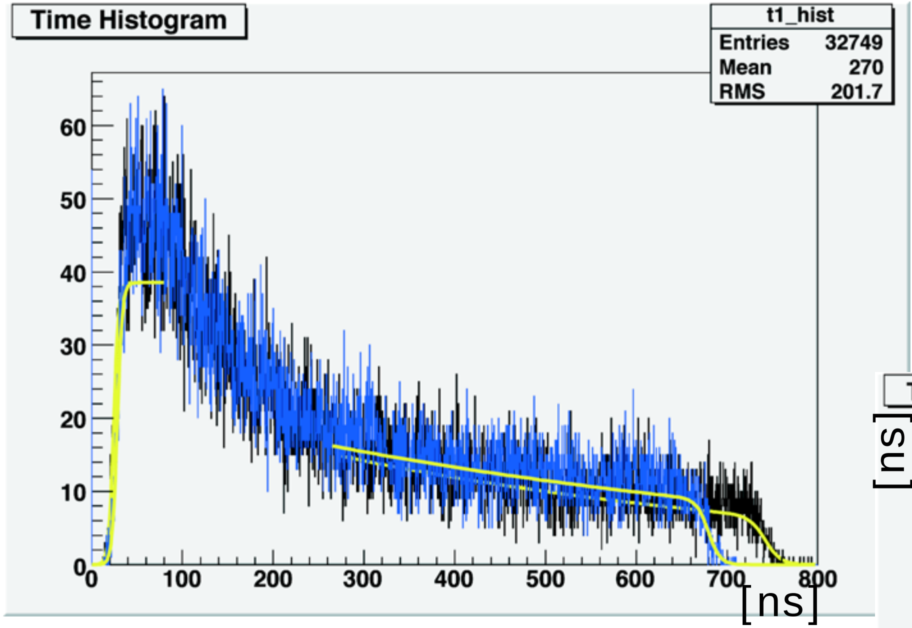
Ar:CO2 93:7



Ar:CO2:N2 96:3:1



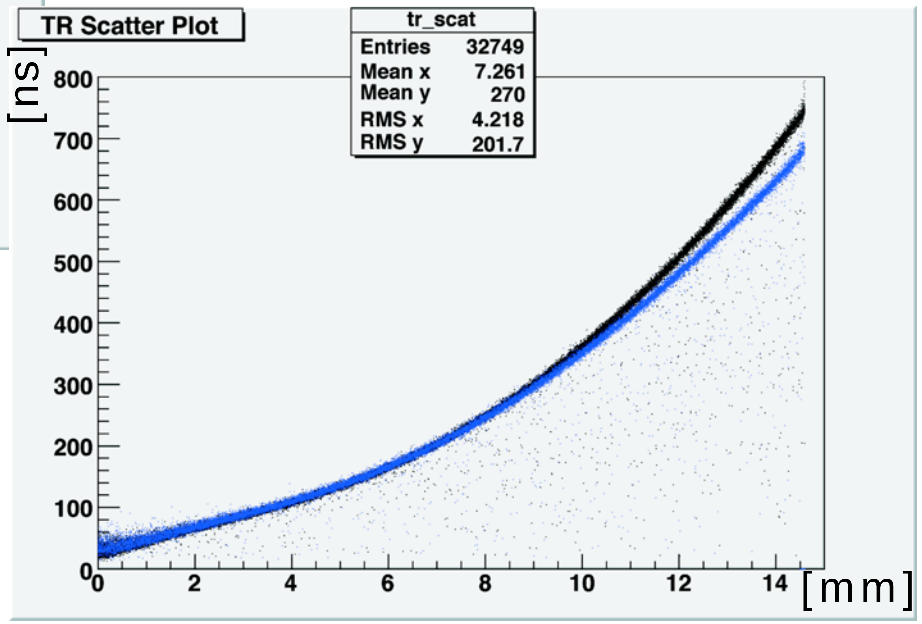
Charge Effects on Big Tubes (Simulation)



Ar:CO2 93:7

no background

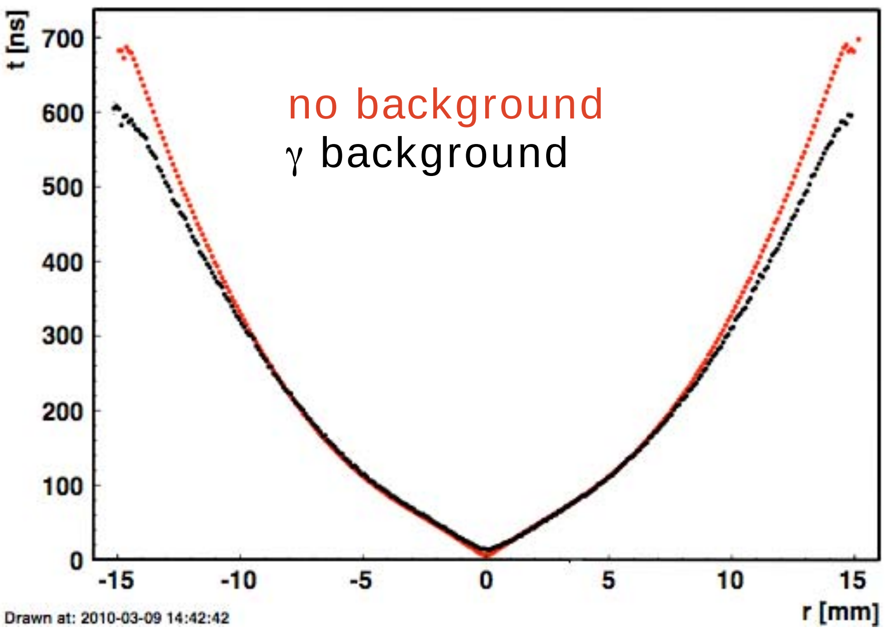
γ background

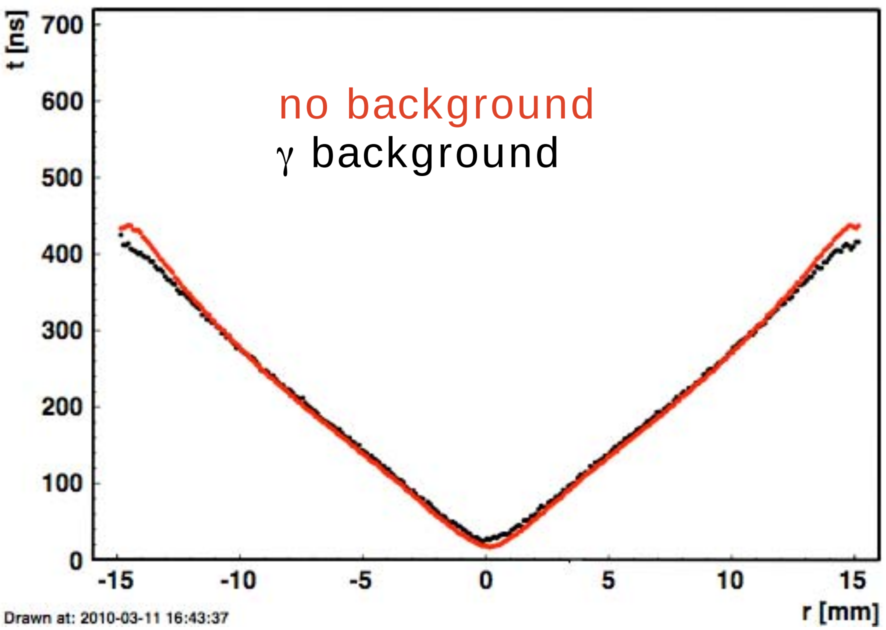


Rt-relation @ 1700 Hz/cm^2

Ar:CO2 93:7

Ar:CO2:N2 96:3:1

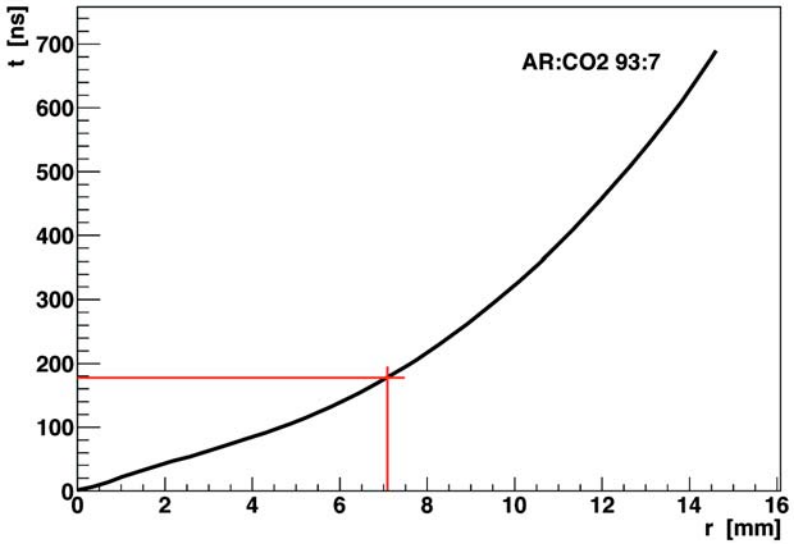


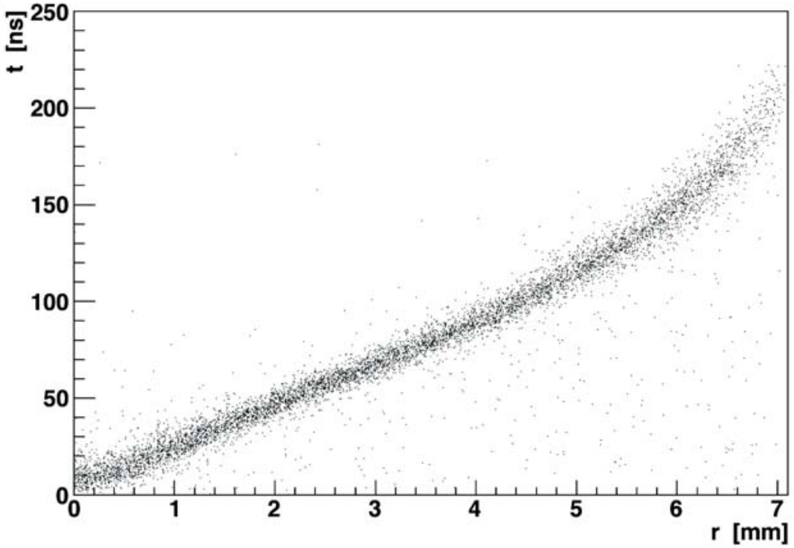


H8 Muon Beam (15 mm ∅ Tubes)

Expectations for 15 mm Ø Tubes

measurement without background



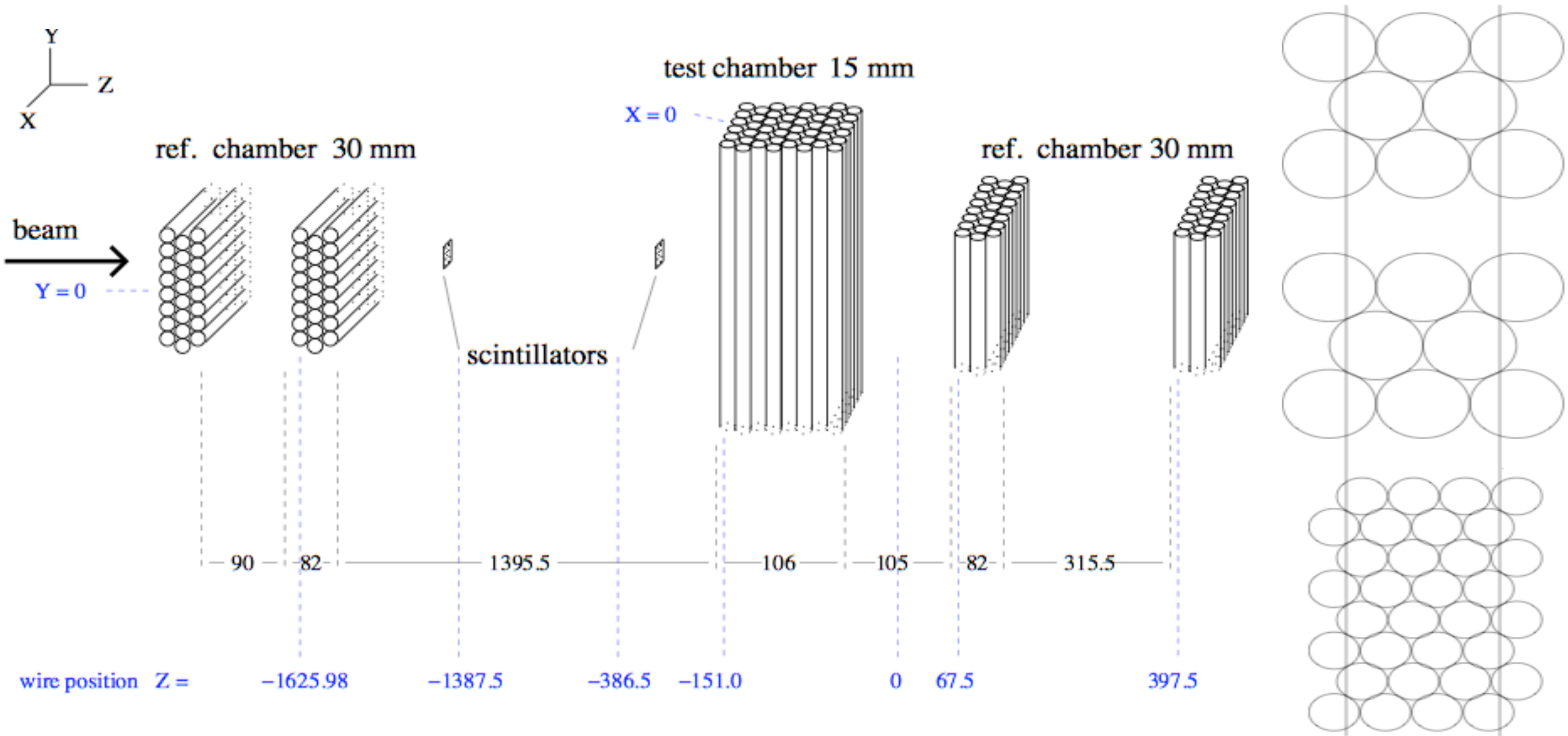


$$t_{\max}\left(D = 15mm\right) \approx \frac{1}{4} t_{\max}\left(D = 30mm\right)$$

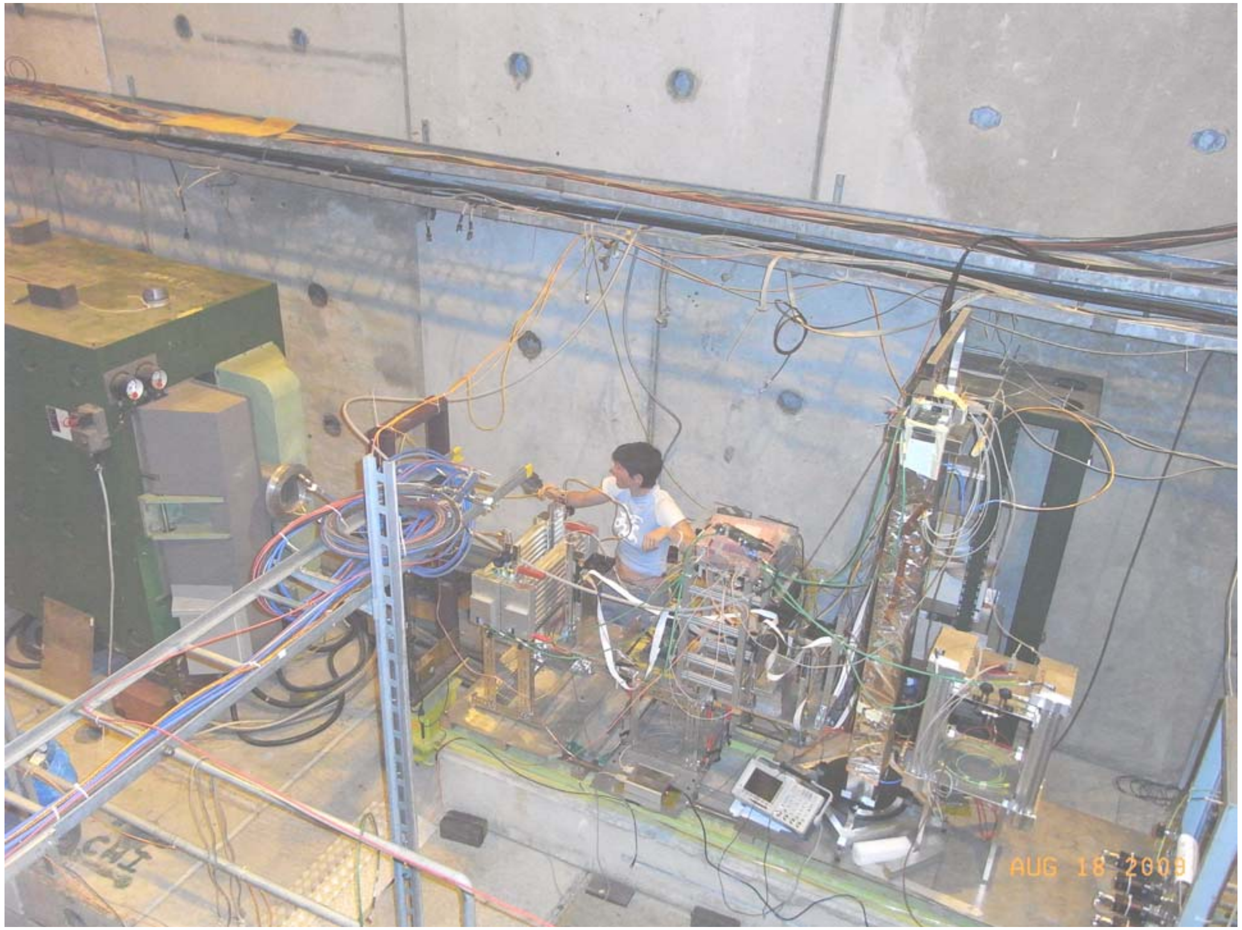
half cross section area

$\Rightarrow$ expected background sensitivity reduced by almost one order of magnitude

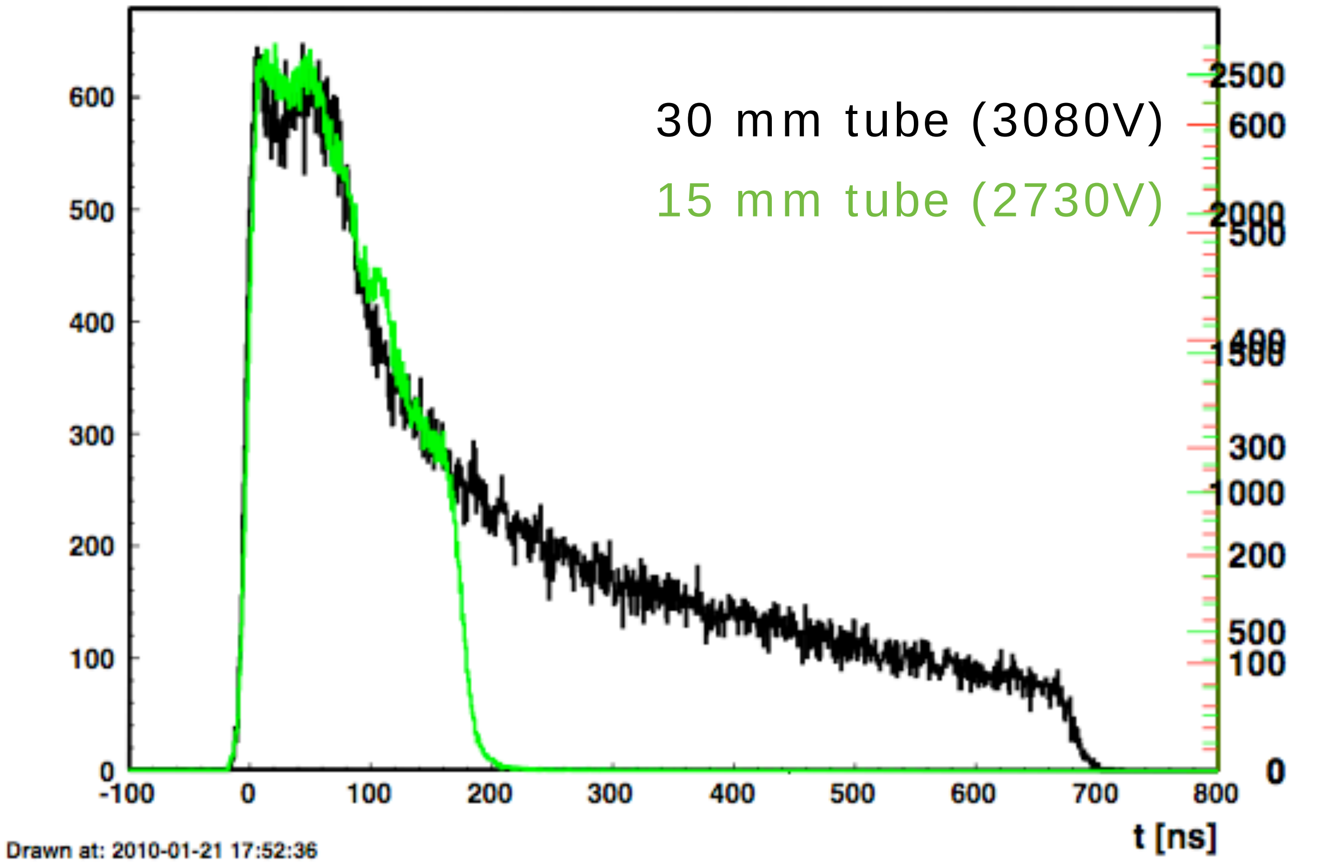
Setup @ H8 (140 GeV μ)



Setup @ H8

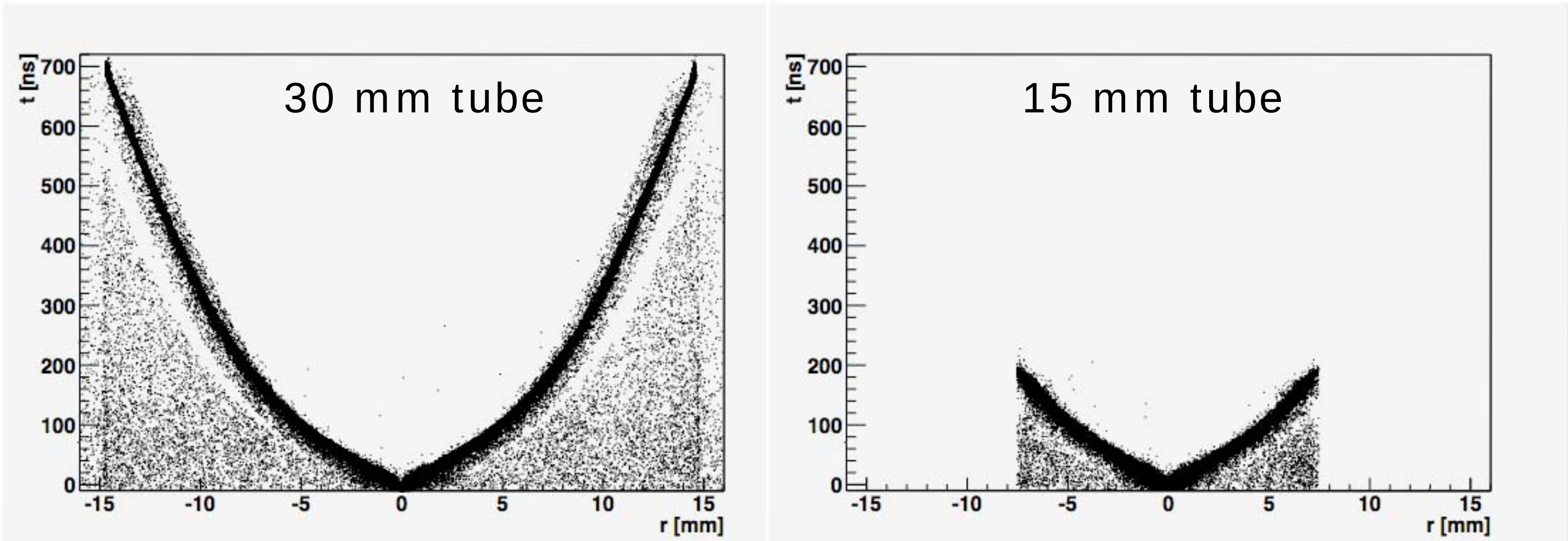


Drift Spectrum (H8)

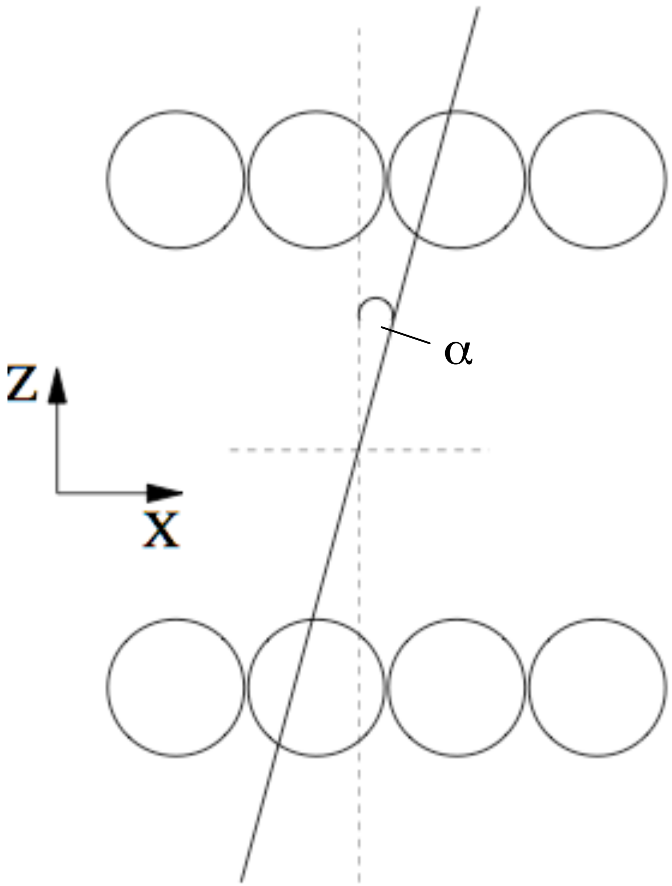


Ar:CO2 93:7
P = 3 bar

rt - Relation (H8)



Track Parameter

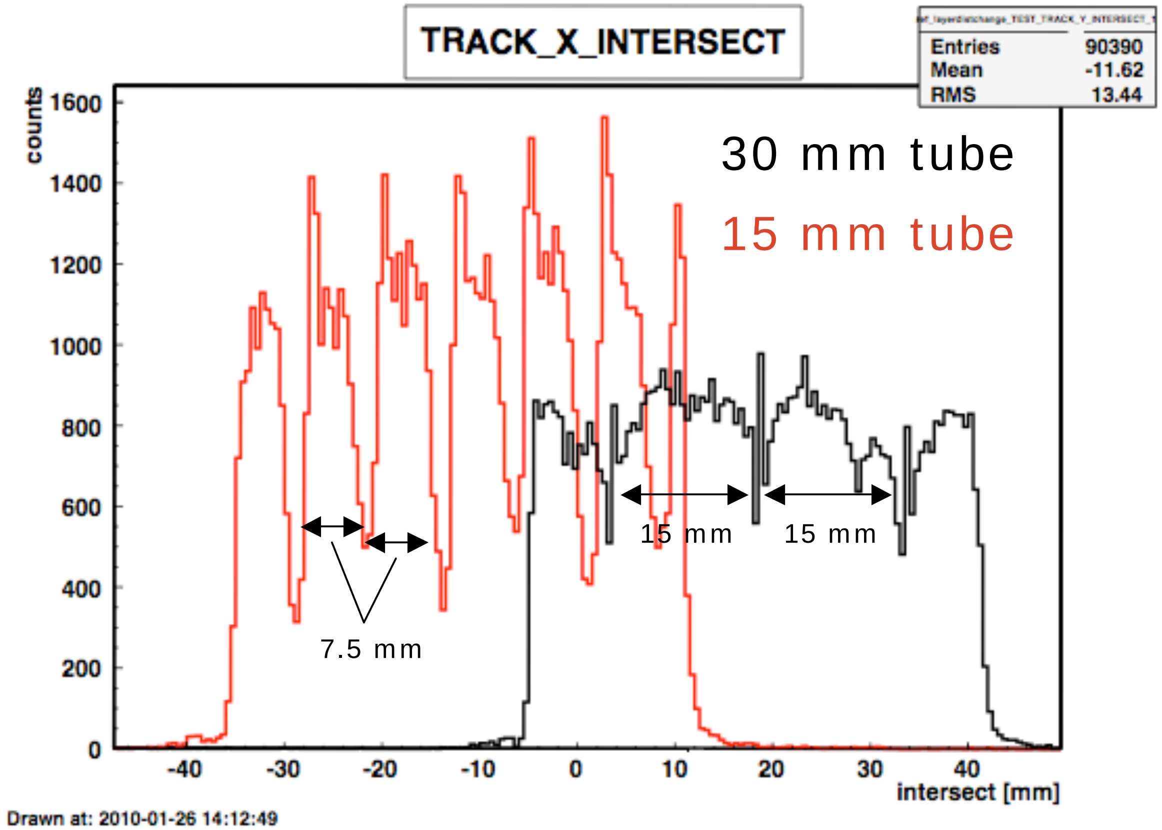


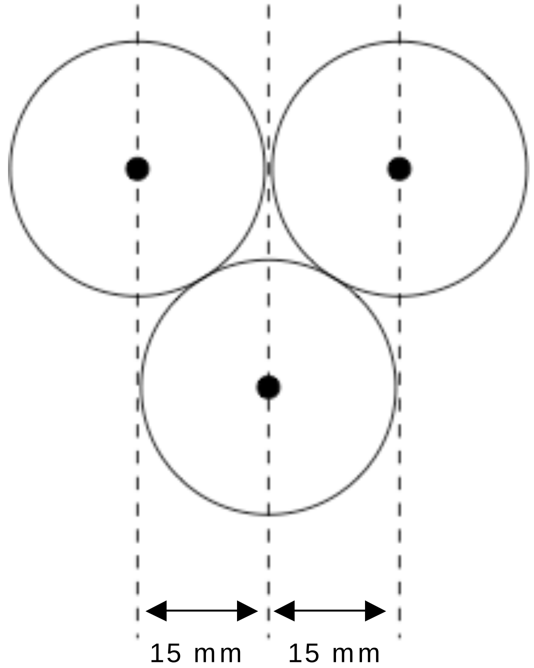
$x = az + b \quad (a = \tan\alpha)$

$a = 0$ => vertical track

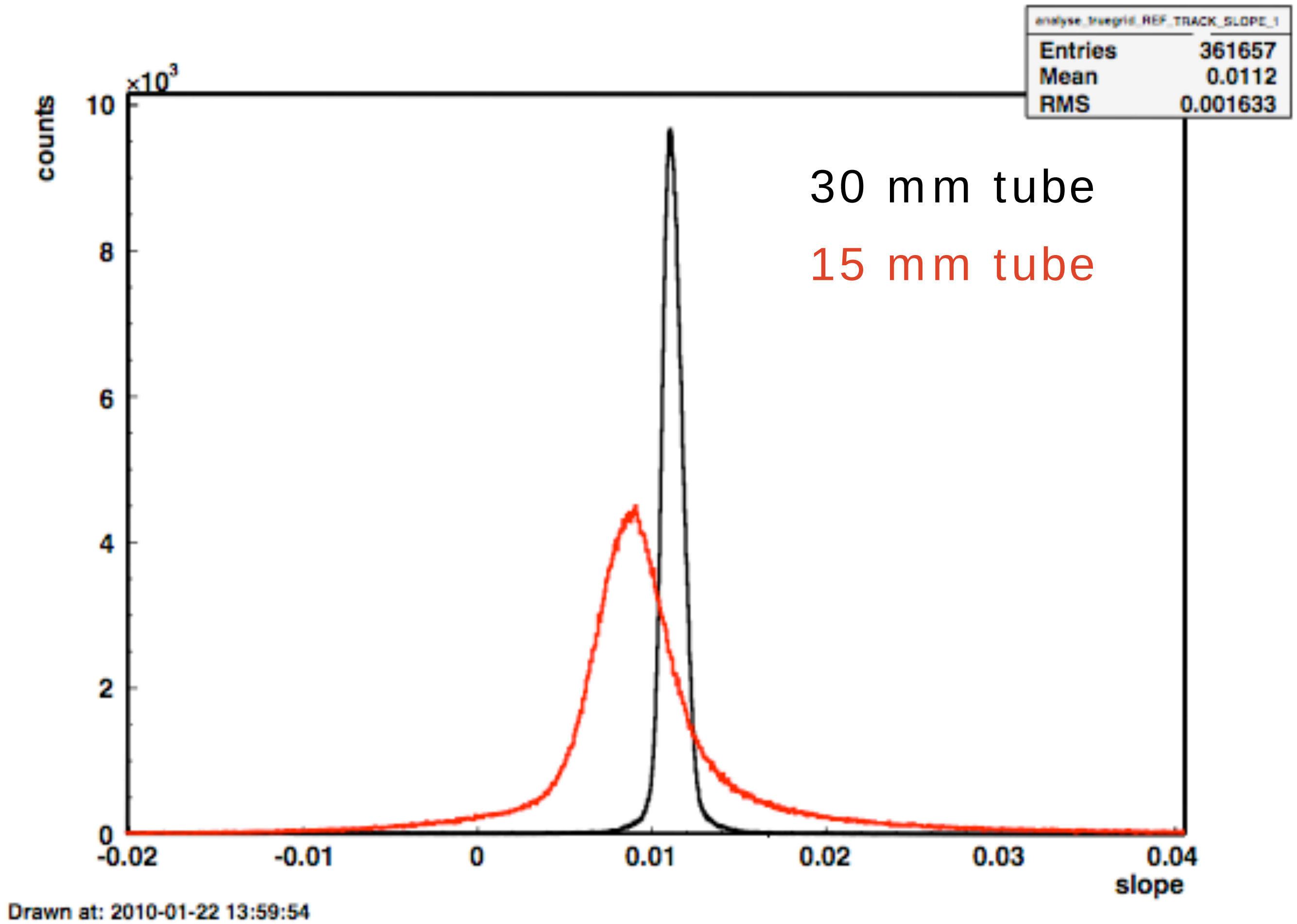
$z = 0$ => x axis intercept

Track X Intercept

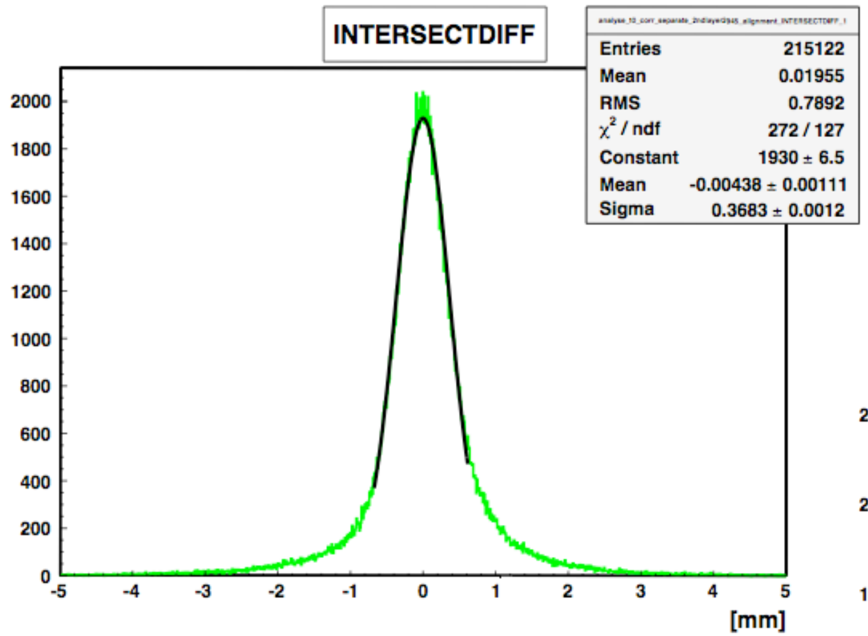


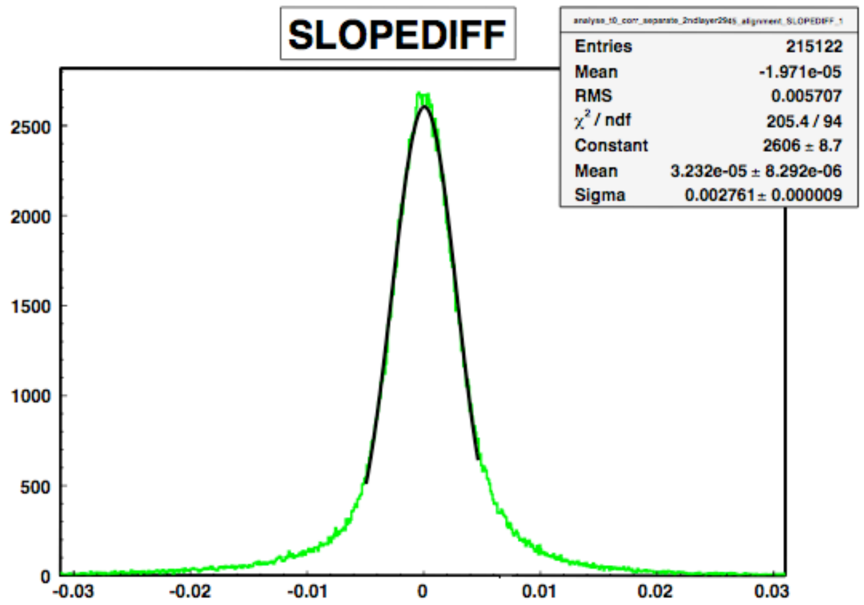


Track Slope


analyse_truegrid_REF_TRACK_SLOPE_1
Entries 361657
Mean 0.0112
RMS 0.001633
counts
×10³
10
8
6
4
2
0
-0.02
-0.01
0
0.01
0.02
0.03
0.04
slope
30 mm tube
15 mm tube
Drawn at: 2010-01-22 13:59:54

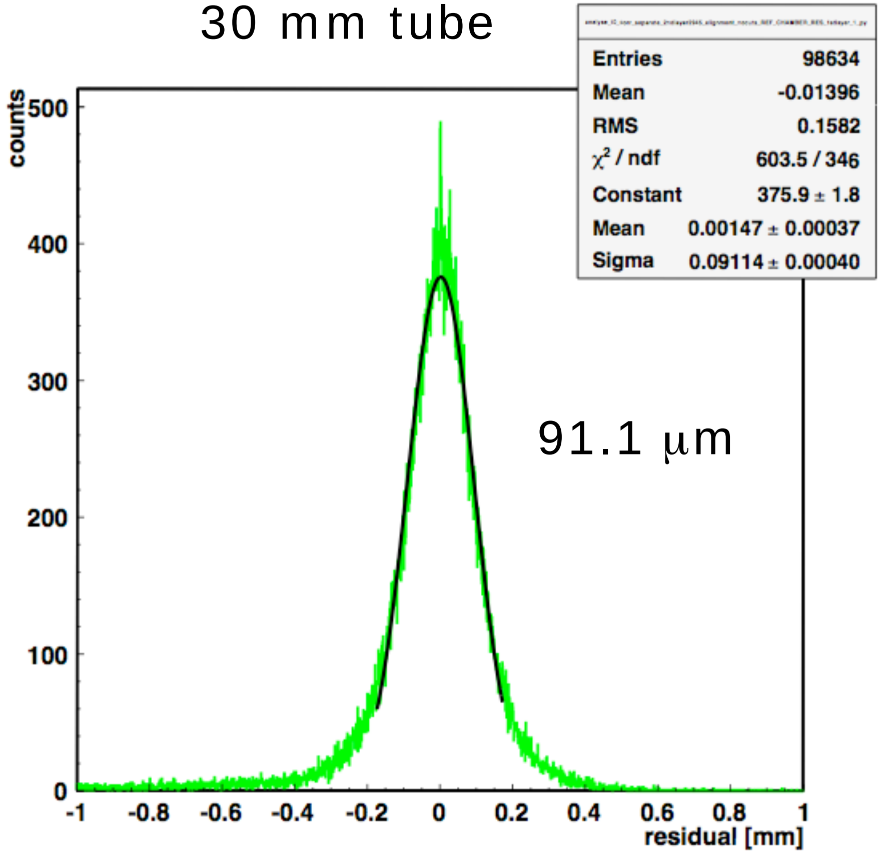
Alignment of Chambers





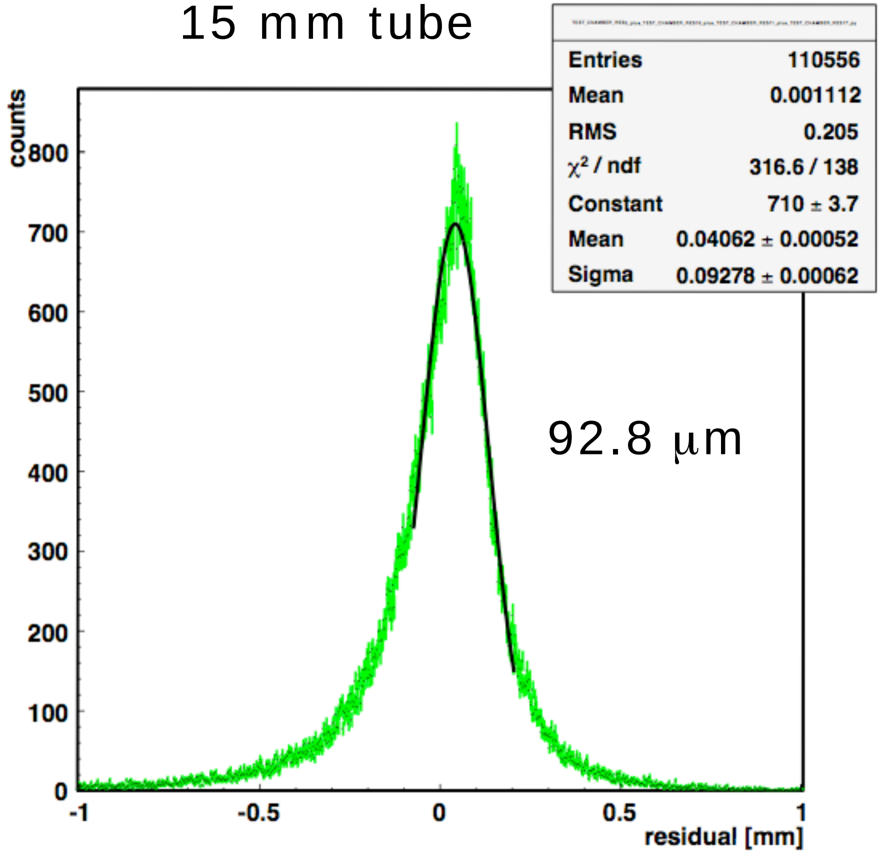
Overall Width of Residual

30 mm tube



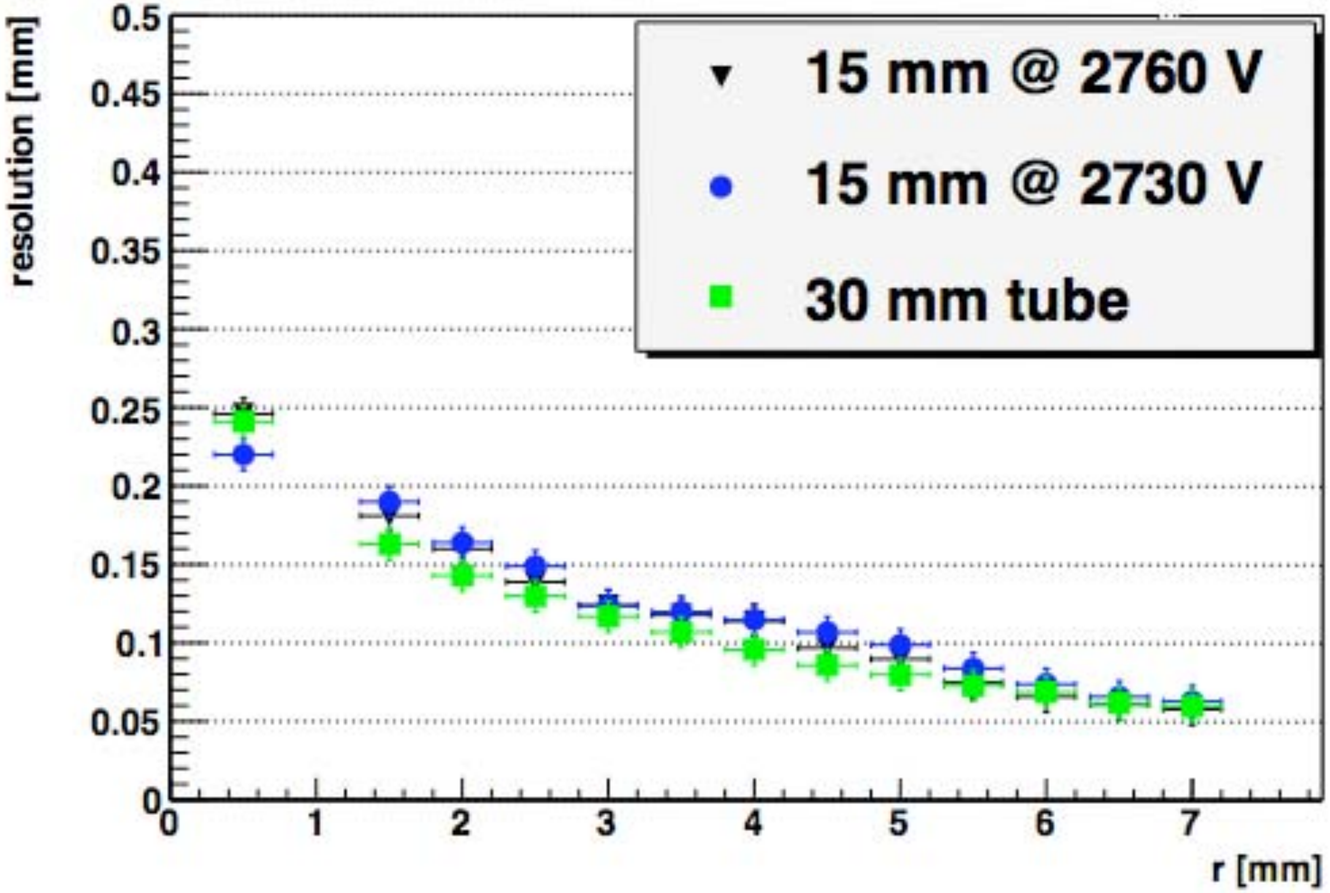
0 … 7.1 mm

15 mm tube



0 … 7.1 mm

Width of Residual vs Radius



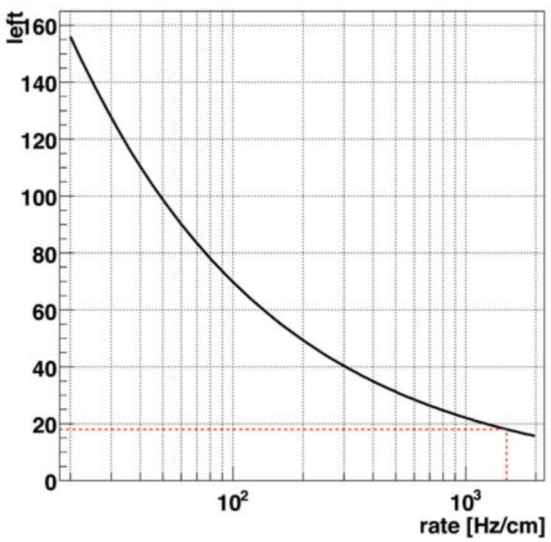
Summary

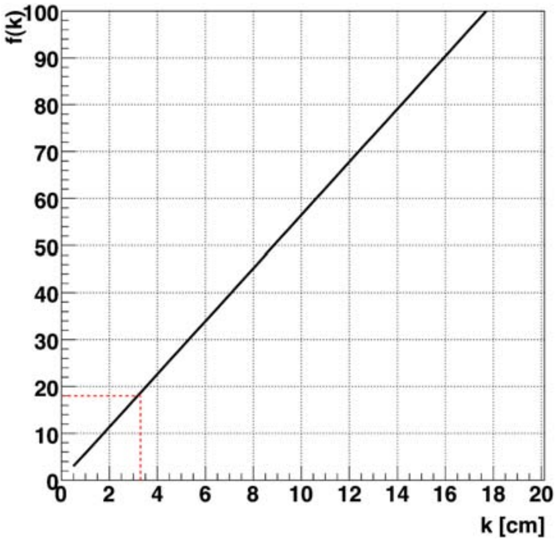
- test of a chamber prototype with 96 drift tubes of ø 15 mm
- single tube resolution is in average 93 μm (16 tubes)
- resolution results are in agreement with expectations from 30 mm ø tubes
- single tube resolution of N_2 gas mixture similar to $Ar:CO_2$ 93:7
- t_max = 450 ns <----> 720 ns and linear position-drifttime-relation
- indications show that 30 mm ø tube resolution is less sensitive to γ -background using $Ar:CO_2:N_2$ gas mixture

Backup Slides

k parameter

$$E(r) = \sqrt{c1}\,\frac{k}{r}\sqrt{1+\frac{r^2}{k^2}} \qquad c1 = \frac{N_c G Q}{2\pi\mu\varepsilon_0}$$



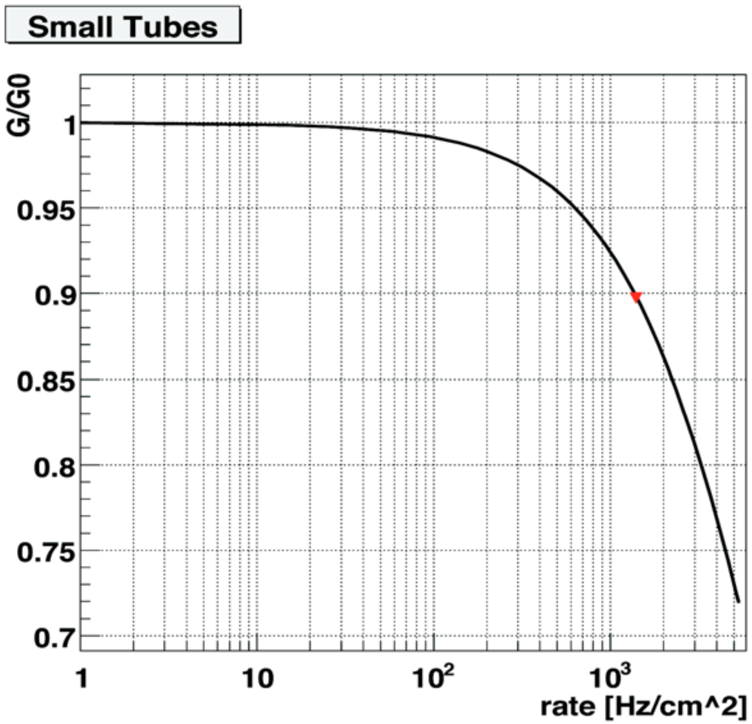


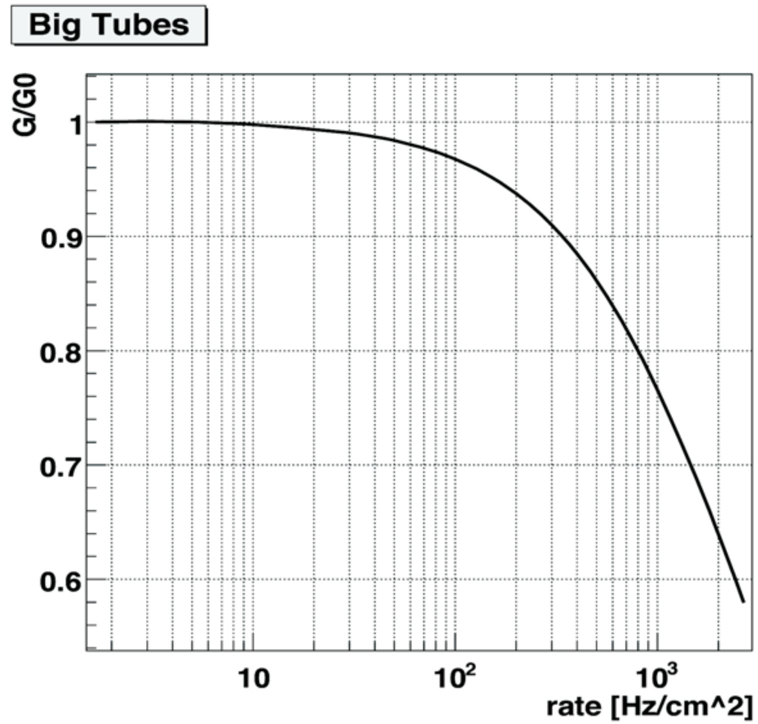
k = 3.3 cm

$$\int_a^b E(r)\,dr = V \qquad => \qquad V\sqrt{\frac{2\pi\mu\varepsilon_0}{N_c G Q}} = k\ln\frac{b\left(k^2 + k\sqrt{k^2+a^2}\right)}{a\left(k^2 + k\sqrt{k^2+b^2}\right)} + \sqrt{k^2+b^2} - \sqrt{k^2+a^2}$$

Gain Drop

gas gain depends on el. field via line charge => gain drop



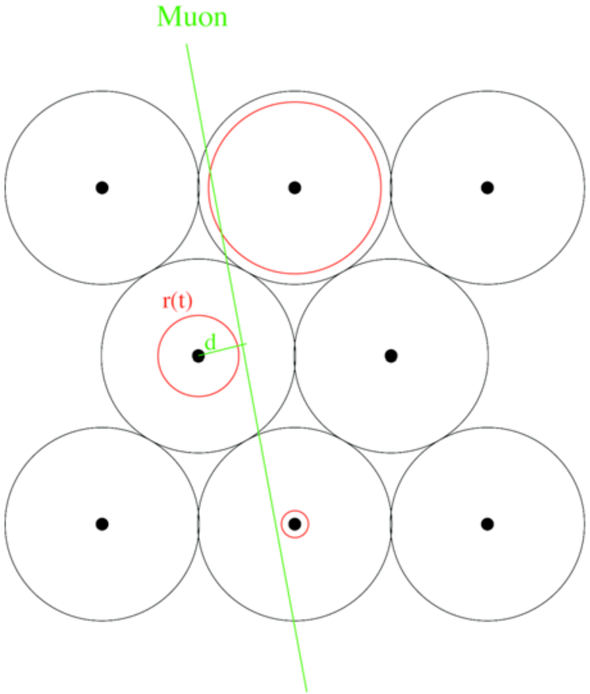


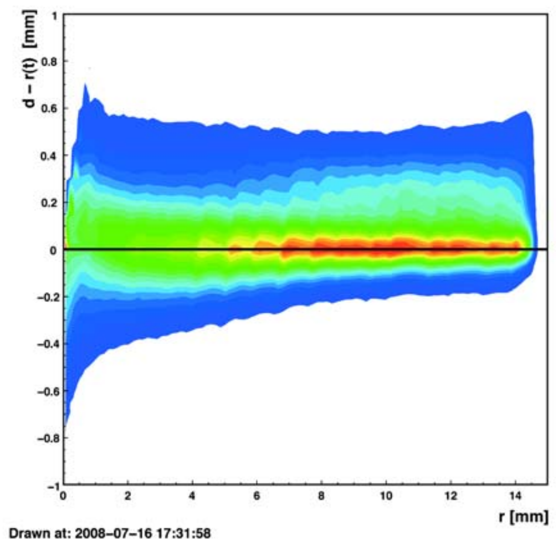
$$G = \left[\frac{\gamma}{2\pi\mu\varepsilon_0 E_{\min}}\right]^{\frac{\gamma \ln 2}{2\pi\varepsilon_0 \Delta V}}$$

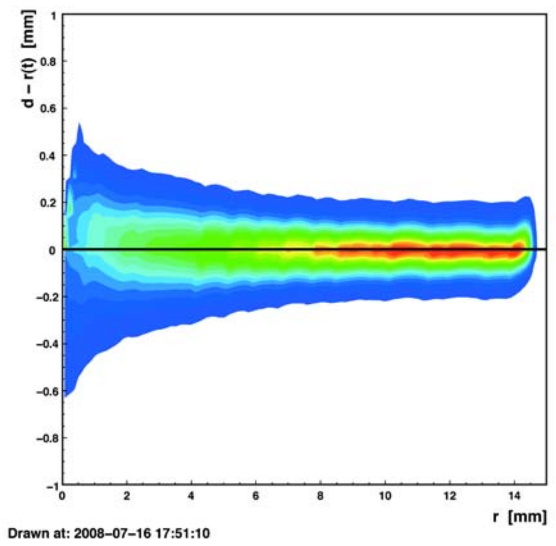
ΔV = 34.15 V (average ionisation potential)

E_min = 70.6 kV/cm (min el. field for avalanche)

Residual (CRFM Garching)







$$\Delta(t) = \langle d - r(t) \rangle$$

$$r'(t) = r(t) - \Delta(t)$$