Beam monitoring during the STT COSY tests. Cluster counting in a time expansion chamber with GEM preamplification stages and FQDC readout.

protons and deuterons with momenta from 2.95 down to 0.6 GeV/c were provided by COSY team into Big Karl external beam line in 2014 and May 2015.

beam tuning and monitoring from COSY control room, experimental counting room

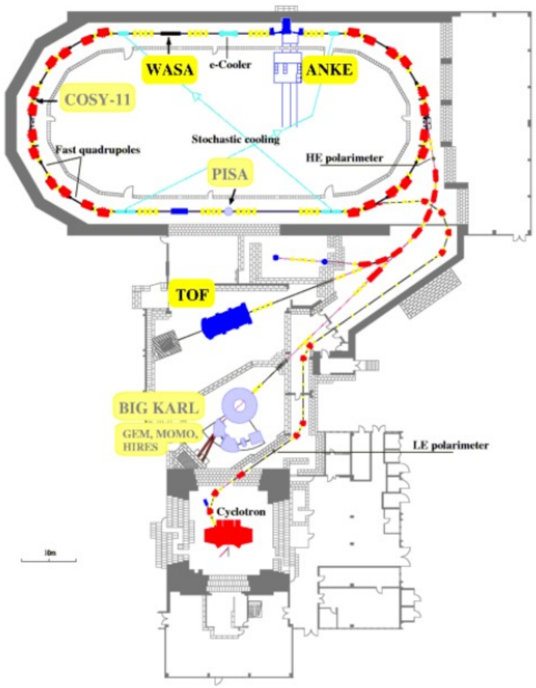
three stations of tracking detectors - DC, straw tubes in addition to STT1 and STT2

two modules of a hybrid detector geometry with GEM foils as preamplifications stages in a drift chamber - GEMDC

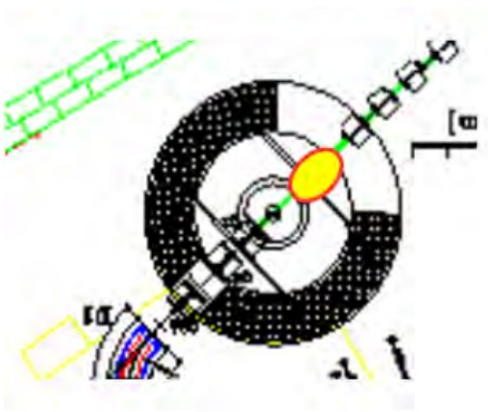
readout -CMP16 and F1 TDC, 240 MHz FQDC, WASA ROOTSORTER and XML on-line interface

monitoring time spectra – beam time structure, channel multiplicities, beam shapes

Tests with the COSY beam



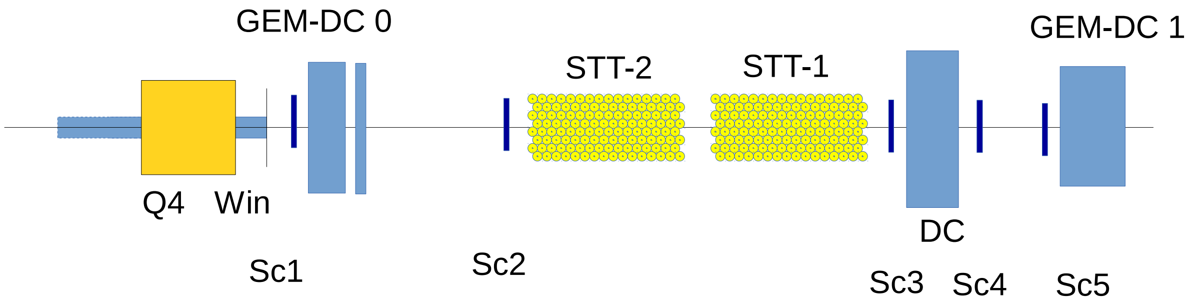
TEST PLACE at BIG KARL

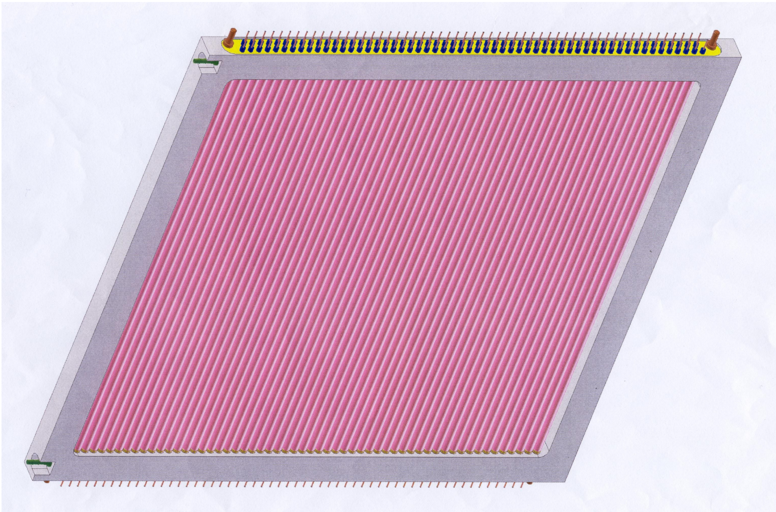


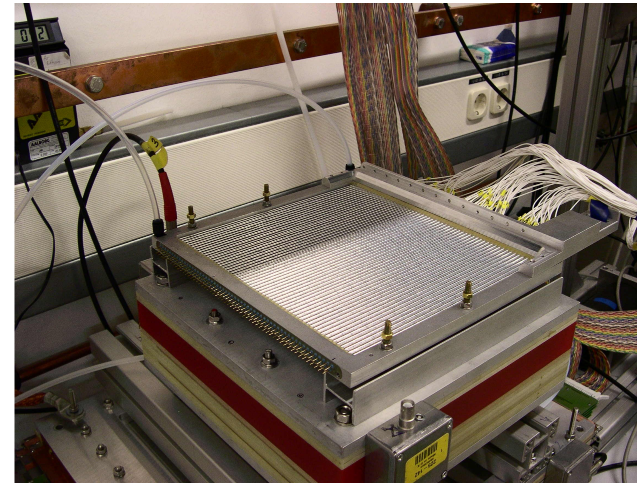
- proton/deutron beam
- energy: 0.4 - 2.6 GeV
- intensity: 10^3 - 10^9

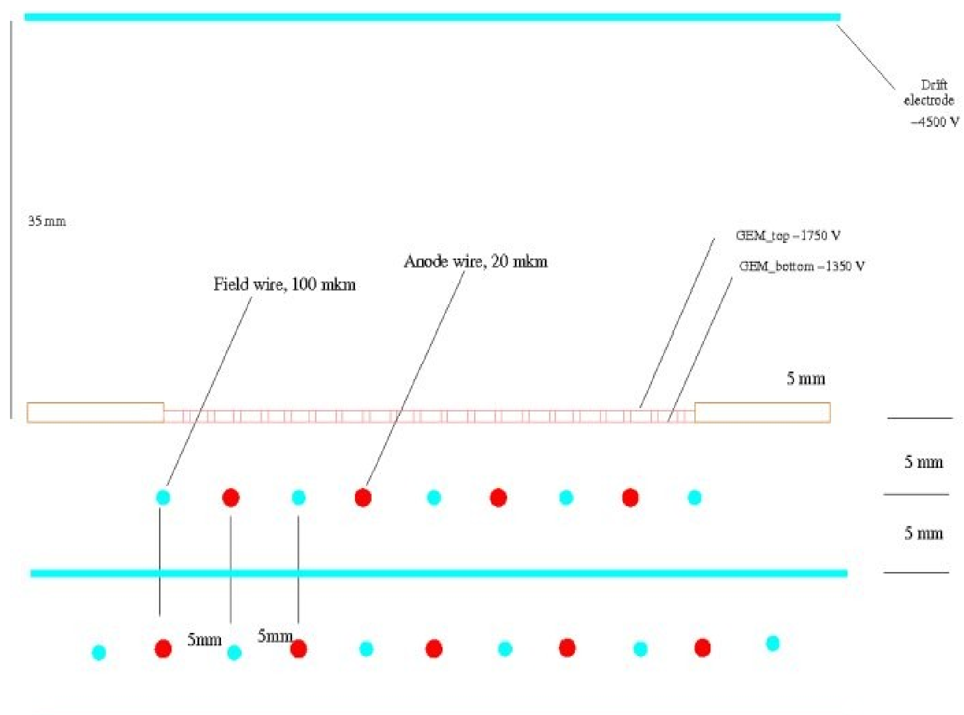
JCHP-FFE CANU Meeting, 16.12.2014, Bad Honnef *K. Pysz*

Big Karl beam setup







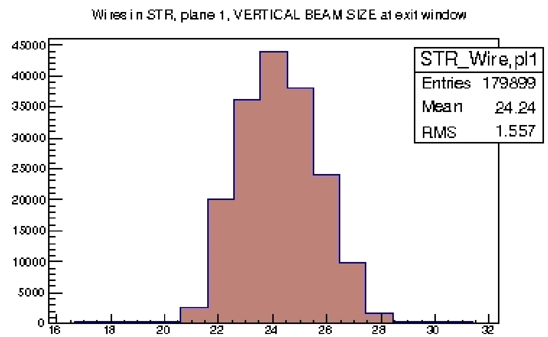

Drift electrode
–4500 V
35 mm
GEM_top –1750 V
GEM_bottom –1350 V
Anode wire, 20 mkm
Field wire, 100 mkm
5 mm
5 mm
5 mm
5mm
5mm

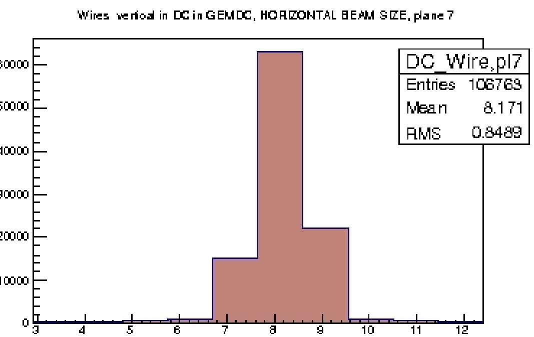
run9857, 0.6 GeV/c, protons

vertical | horizontal

Pitch 0.41 cm

FWHM~1.4 cm



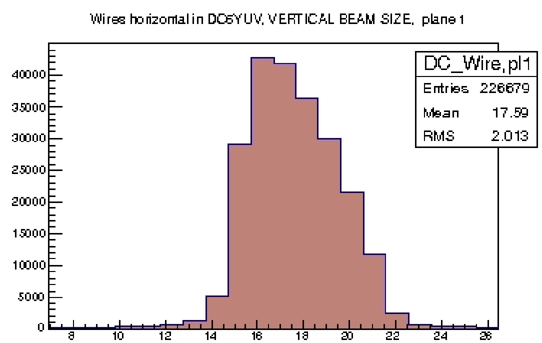


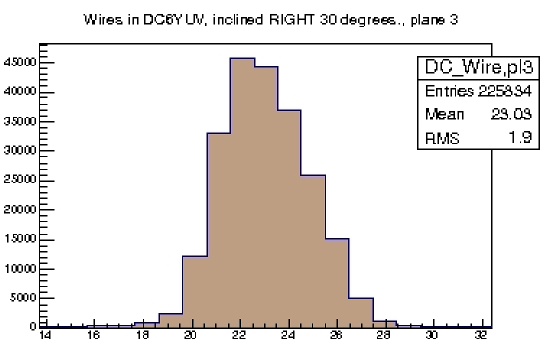
Pitch 1.0 cm

FWHM<~1 cm

Pitch 1.0 cm

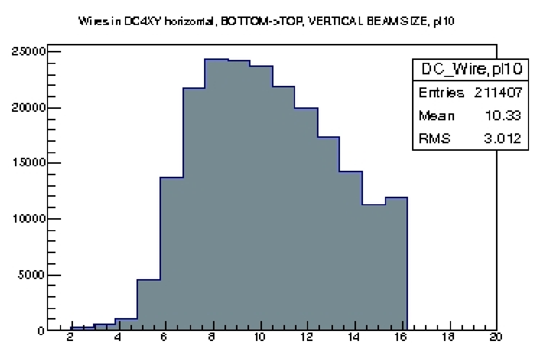
FWHM~5 cm

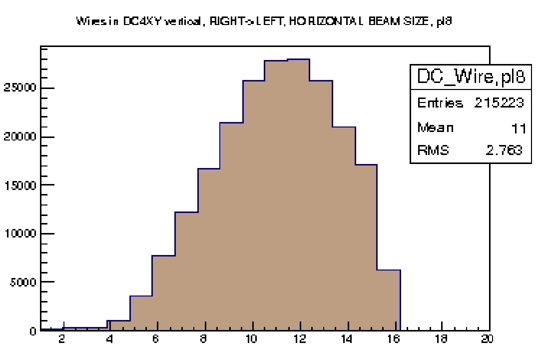




Pitch 1.0 cm

FWHM~11 cm





Pitch 1.0 cm

FWHM~8 cm

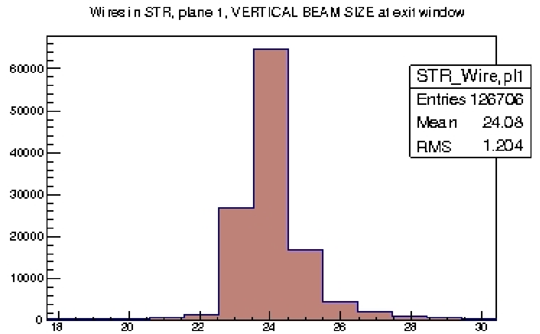
run 9748, protons, 0.8 GeV/c

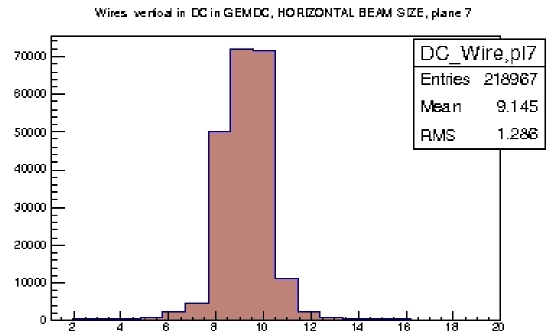
vertical

horizontal

Pitch 0.41 cm

FWHM~0.4 cm



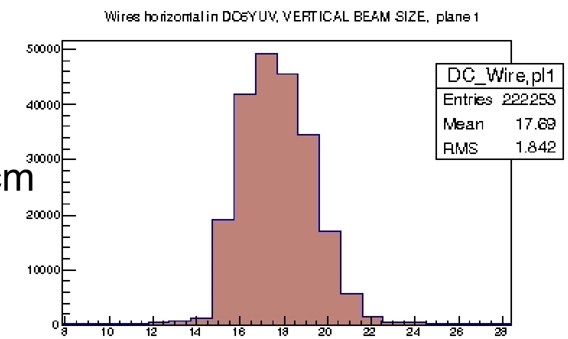


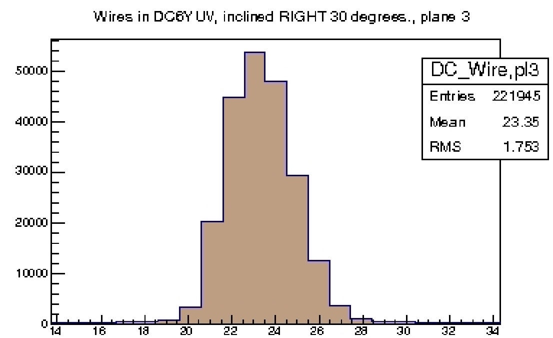
Pitch 1.0 cm

FWHM~3.0 cm

Pitch 1.0 cm

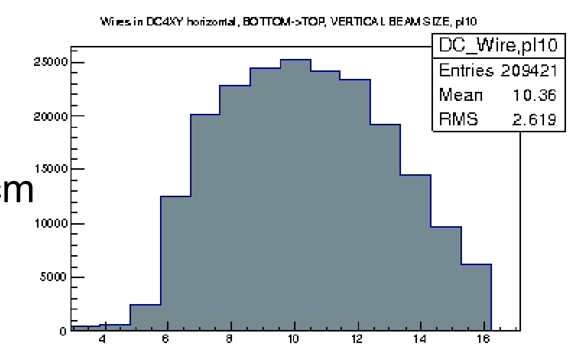
FWHM~4.0 cm

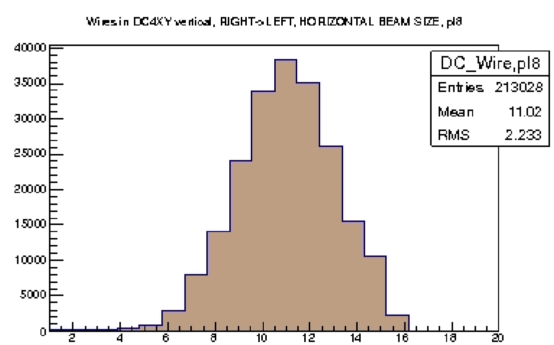




Pitch 1.0 cm

FWHM~8.5 cm





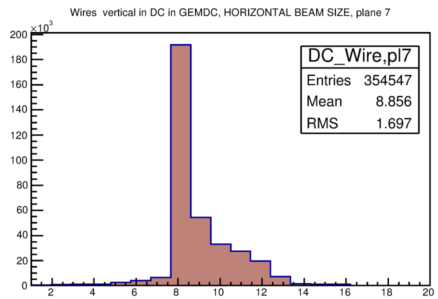
Pitch 1.0 cm

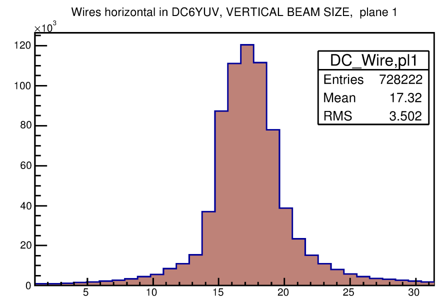
FWHM~5.0 cm

run 10614, beam shapes, protons 1.0 GeV/c

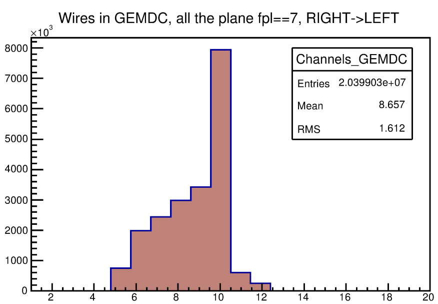
horizontal | vertical

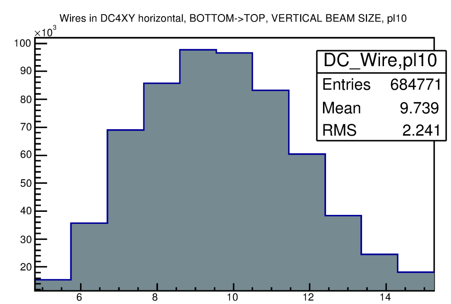
Pitch 1.0 cm



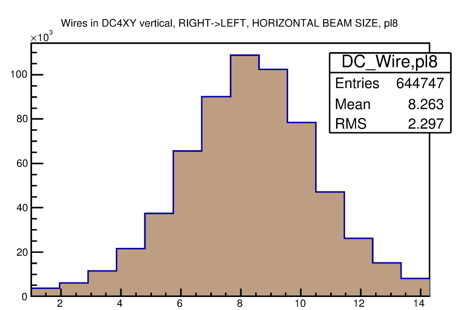


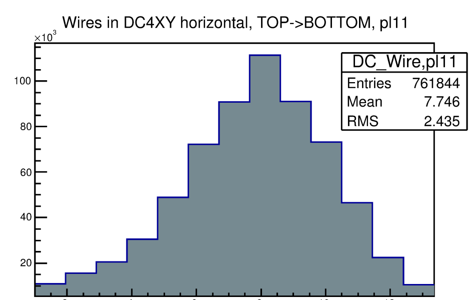
Pitch 1.0 cm



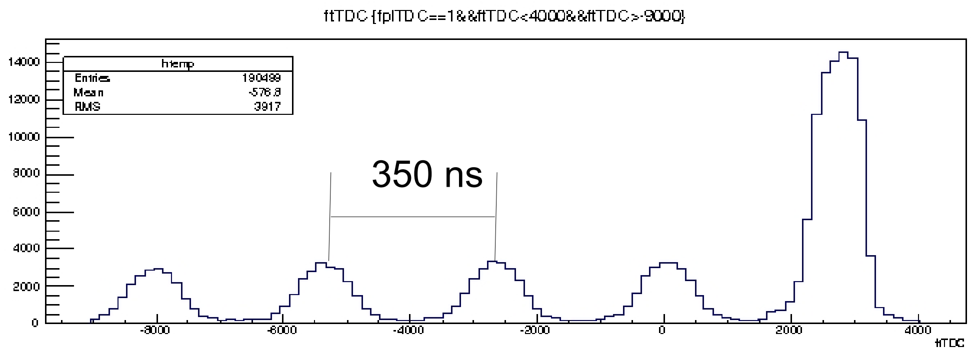


Pitch 1.0 cm



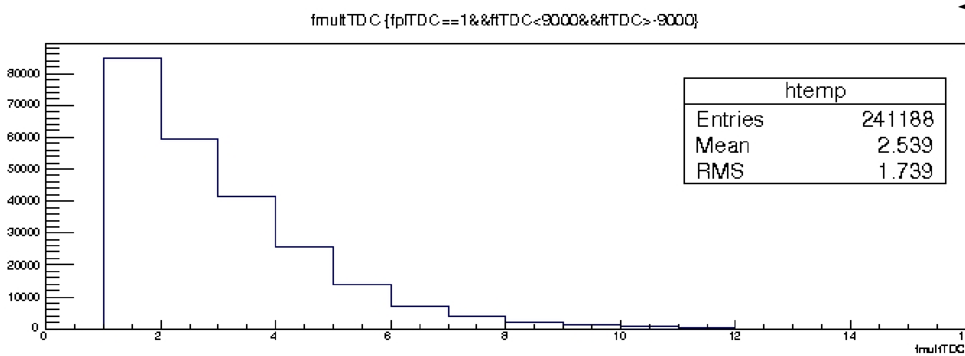


run 6082, 03.12.2011, protons, 2.95 GeV/c, ~ 400 kHz/straw

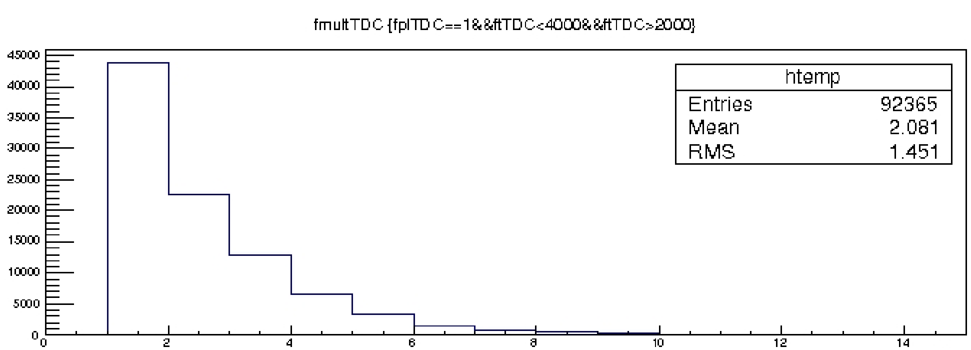


time structure in DC

time



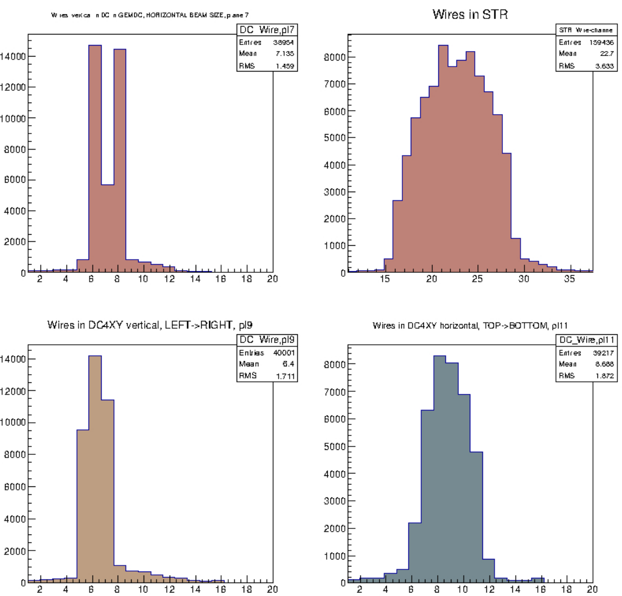
multiplicity in big window



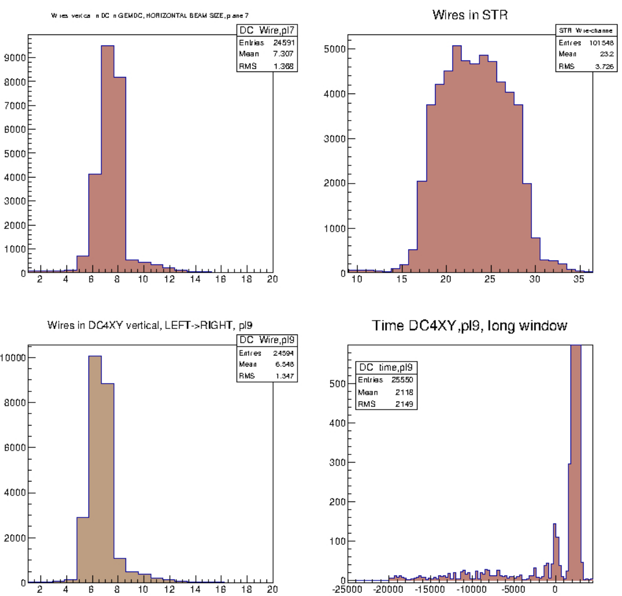
multiplicity in basic window

abnormal beam shapes

run11209

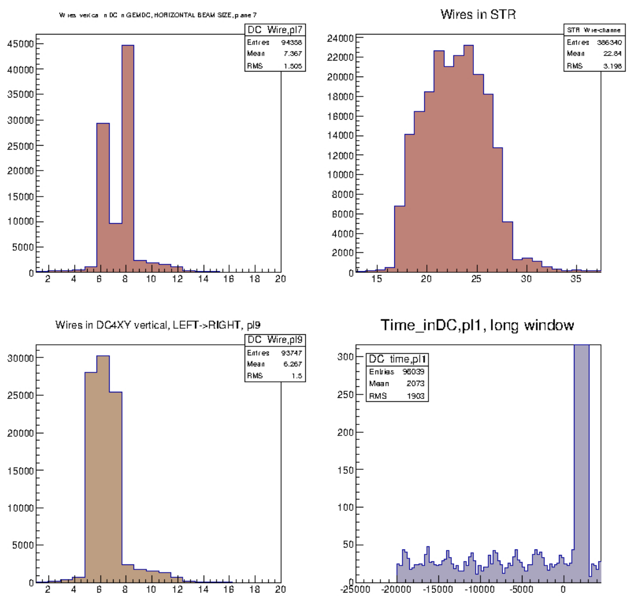


run 11216



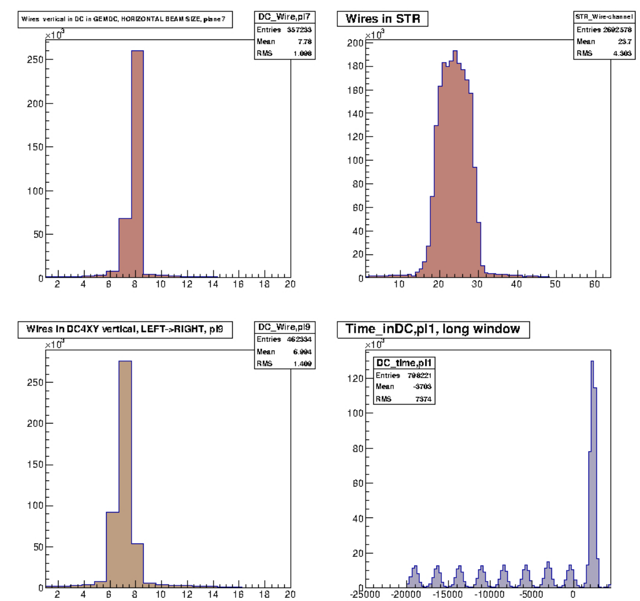
abnormal beam shapes

run11217

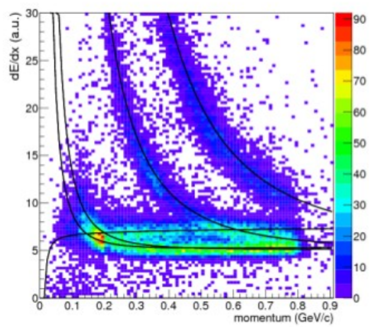


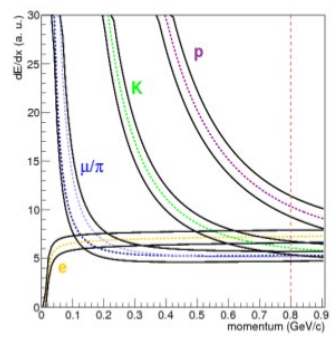
normal beam shapes

run 11235



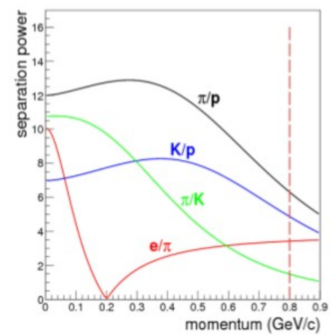
Simulations of dE/dx for PANDA-STT





Simulations for PANDA-STT

- FEE response included
- energy loss derived from charge collection
- truncation mean applied



If energy resolution < 10 %

- H. Walenta, NIM v.161, 1979, p.146

$$\sigma/\mu = 0.41 * n^{-0.43} * (Xp)^{-0.32}$$

n - *samplings number,*
X *– thickness in cm,*
P *– pressure in atm*

For PANDA STT, radial track, 27 hits, dE/dx resolution 8%

Table 1
Summary of dE/dx performance of present large scale detectors. The dE/dx resolutions are given for single isolated tracks and for tracks in multi-hadronic events (parenthesis), where available.

Detector	Type	Size ($\varnothing \times L$)	B (T)	Gas mixture	No. of samples	Sampling length	dE/dx res. (σ/mean)	Trunc. mean	Ref.
ALEPH (LEP)	TPC	3.6 m × 4.4 m	1.5	Ar/CH_4 (91/9), 1 bar	338	4 mm	4.5%	8–60%	[12]
ARGUS (DORIS)	drift ch.	1.7 m × 2 m	0.8	C_3H_8/methylal (97/3), 1 bar	36	18 mm	4.1% (4.4%)	10–70%	[18]
BES (BEPC)	jet cells	2.3 m × 2.1 m	0.4	$Ar/CO_2/CH_4$ (89/10/1), 1 bar	54	5 mm	9.0%	70%	[19]
CDF (TEVATRON)	jet cells	2.6 m × 3.2 m	1.5	$Ar/C_2H_6/C_2H_6O$ (49.6/49.6/0.8), 1 bar	32	12 mm	7.0%	n.a.	[20]
CLEO II (CESR)	drift ch.	1.9 m × 1.9 m	1.5	Ar/C_2H_6 (50/50), 1 bar	51	14 mm	6.2% (7.1%)	50%	[21]
CRISIS (TEVATRON)	jet ch.	1 m × 1 m × 3 m	–	Ar/CO_2 (80/20), 1 bar	192	15 mm	3.2%	75%	[22]
DELPHI (LEP)	TPC	2.4 m × 2.7 m	1.2	Ar/CH_4 (80/20), 1 bar	192	4 mm	5.7% (6.2%)	80%	[11]
D0 FDC (TEVATRON)	jet ch.	1.2 m × 0.3 m	–	$Ar/CH_4/CO_2$ (93/4/3), 1 bar	32	8 mm	12.7%	70%	[23]
H1 (HERA)	jet ch.	1.7 m × 2.2 m	1.13	Ar/C_2H_6 (50/50), 1 bar	56	10 mm	8.0%	[a]	[4]
JADE (PETRA)	jet ch.	1.6 m × 2.4 m	0.48	$Ar/CH_4/iC_4H_{10}$ (88.7/8.5/2.8), 4 bar	48	10 mm	6.5% (7.2%)	5–70%	[9]
KEDR (VEPP-4M)	jet cells	1.1 m × 1.1 m	2.0	DME (100), 1 bar	42	10 mm	10%	5–70%	[24]
MARK II (SLC)	drift ch.	3.0 m × 2.3 m	0.475	$Ar/CO_2/CH_4$ (89/10/1), 1 bar	72	8.33 mm	7.0%	5–75%	[25]
NA49 (SPS)	TPC	4 m × 4 m × 1.2 m	–	$Ar/CH_4/CO_2$ (90/5/5), 1 bar	100	40 mm	4.4%	10–70%	[26]
OBELIX (LEAR)	jet ch.	1.6 m × 1.4 m	0.5	Ar/C_2H_6 (50/50), 1 bar	40	15 mm	12%	70%	[27]
OPAL (LEP)	jet ch.	3.6 m × 4 m	0.435	$Ar/CH_4/iC_4H_{10}$ (88.2/9.8/2), 4 bar	159	10 mm	2.8% (3.2%)	70%	[28]
SLD (SLC)	jet cells	2 m × 2 m	0.6	$CO_2/Ar/iC_4H_{10}$ (75/21/4), 1 bar	80	6 mm	7.0%	n.a.	[29]
TOPAZ (TRISTAN)	TPC	2.4 m × 2.2 m	1.0	Ar/CH_4 (90/10), 3.5 bar	175	4 mm	4.4% (4.6%)	65%	[14]
TPC/2γ (PEP)	TPC	2.0 m × 2.0 m	1.375	Ar/CH_4 (80/20), 8.5 bar	183	4 mm	3.0%	65%	[16]
ZEUS (HERA)	jet cells	1.7 m × 2.4 m	1.43	$Ar/CO_2/C_2H_6$ (90/8/2), 1 bar	72	8 mm	8.5%	n.a.	[30]

[a] Gaussian transformation used, see Section 2.2.

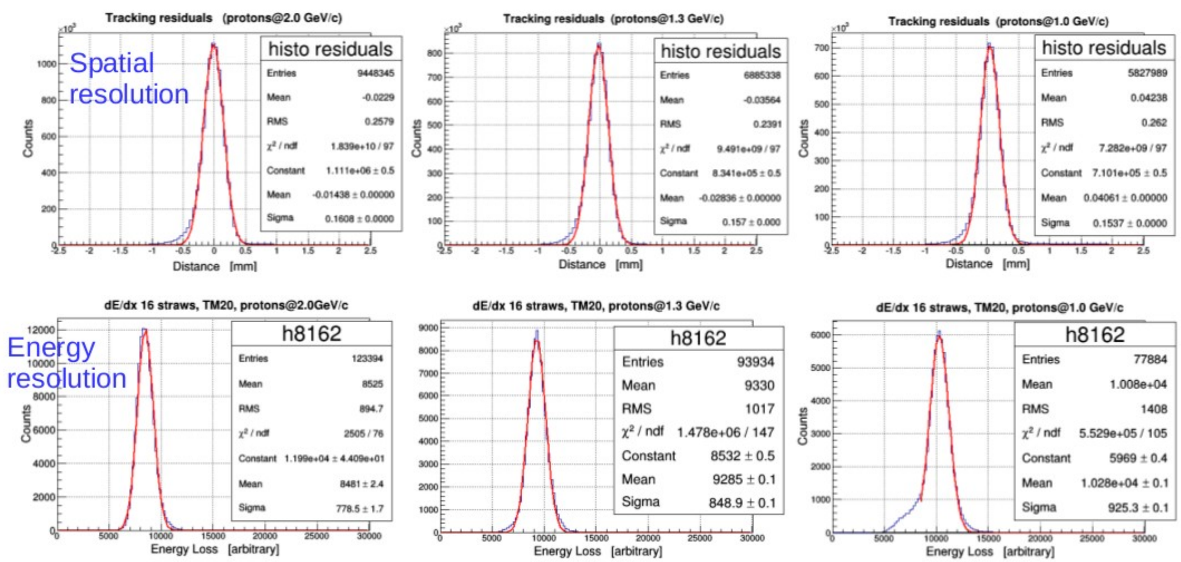
A fit to the single track resolutions results in:

$$\frac{\sigma(dE/dx)}{dE/dx} = 5.5L^{-0.36} \quad (\%) \tag{11}$$

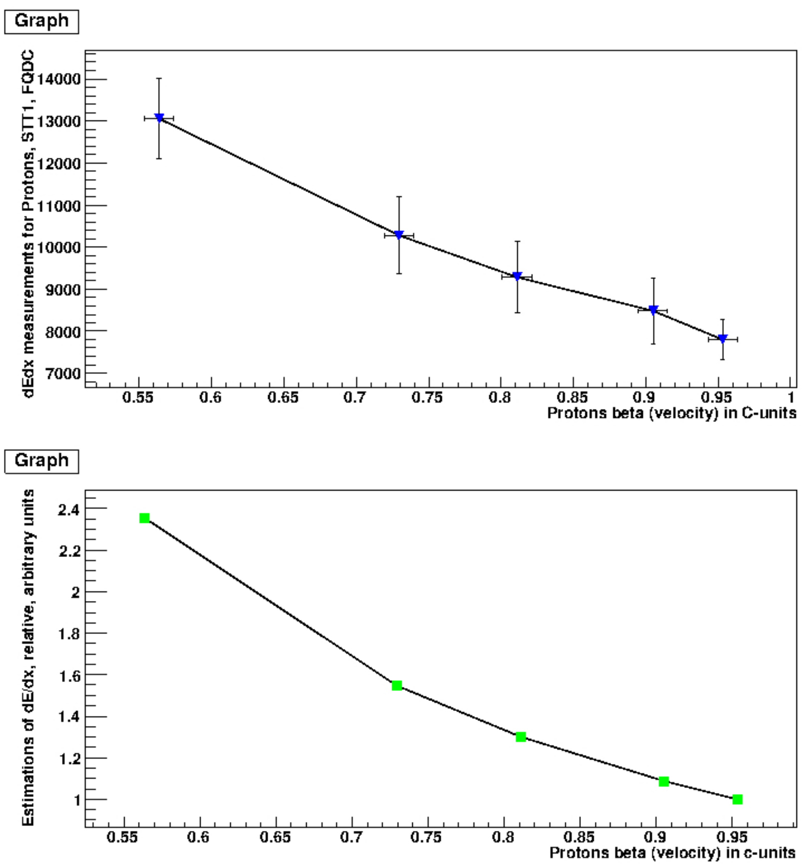
very similar to the result by Lehraus indicating that the systematics of present large detectors are well under control. A summary of the detectors is given in Table 1. The best achieved dE/dx resolutions were obtained with the high

December '14 test - preliminary results

2.0 GeV/c | 1.3 GeV/c | 1.0 GeV/c



dE/dx measured by classical method in STT1 and estimations, for protons with momenta : 0.64, 1.0, 1.3, 2.0, 2.95 GeV/c

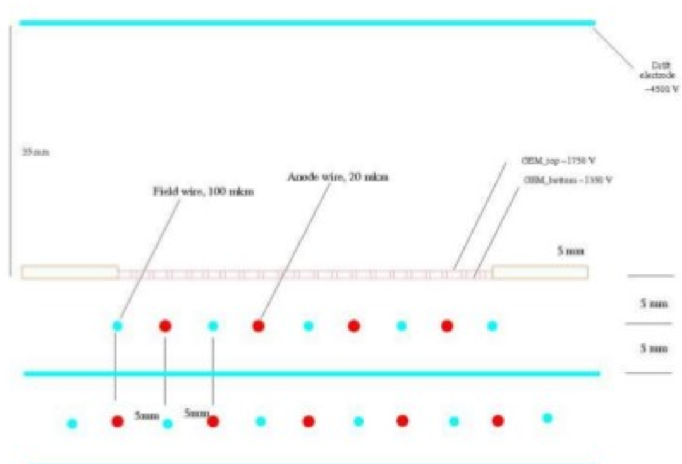


dE/dx~beta^(**-1.63**)

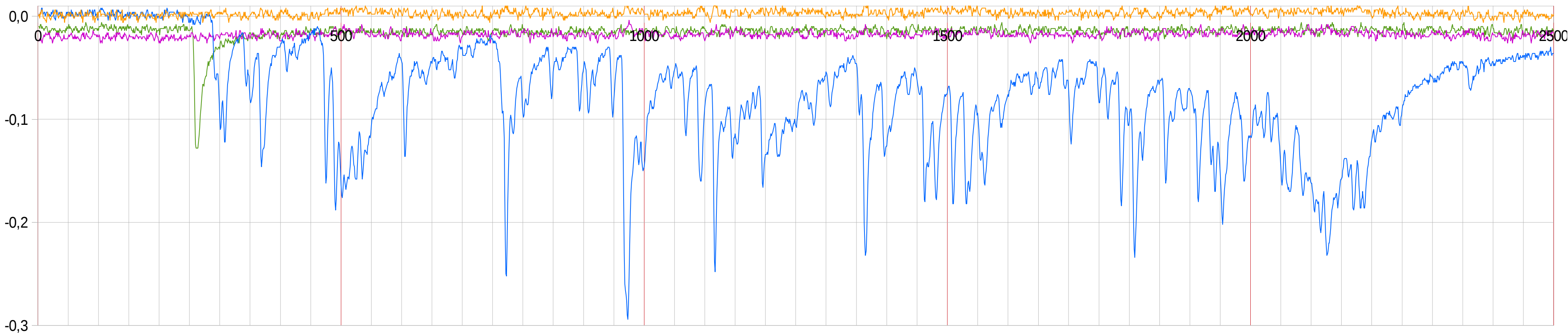
NIM, A367, 1995, p.248

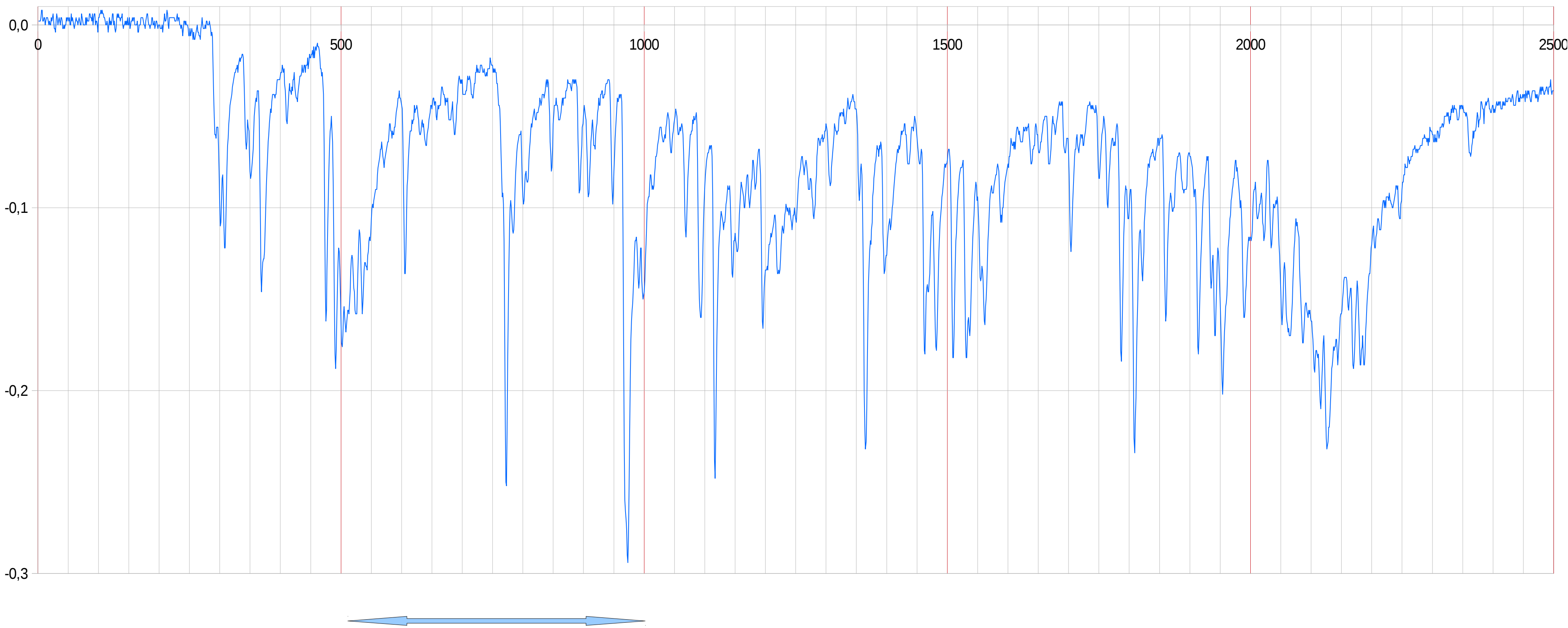
Table 1: Details of the GEM-DC

Parameter	GEM-DC 0	GEM-DC 2
N of stacked GEM foils	2	3
Active area of DC / cm^2	16 x 16	
GEM foil thickness / µm	50	
Area of GEM foils / cm^2	10 x 10	
Hole diameter / µm	70	
Hole pitch / µm	140	
Drift gap / mm	35	
Drift electrode	Al	Carbon
Gas mixture	Ar / Ethane 80:20	
HV_{drift}	2440	3430
$HV_{GEM\text{-}top}$	2350	3350
HV_{DC}	1400	1400



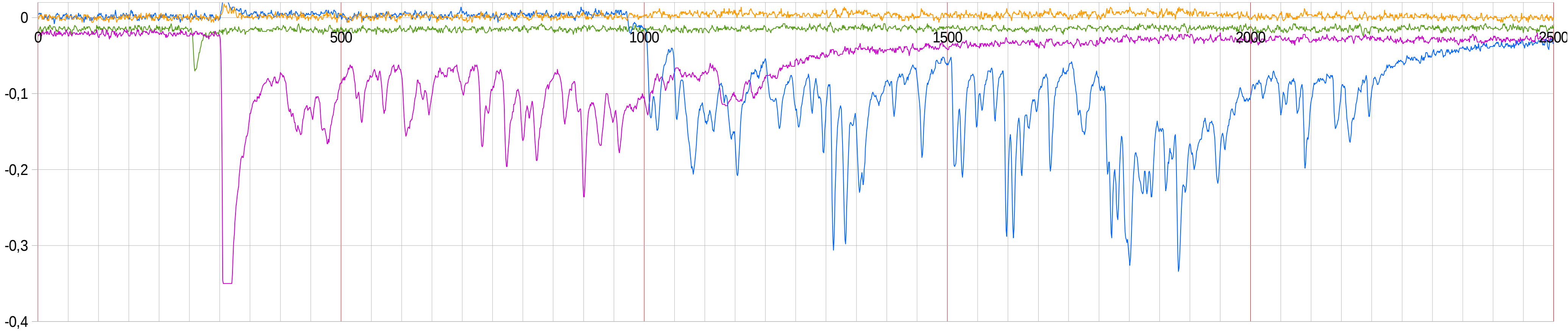
File 0001



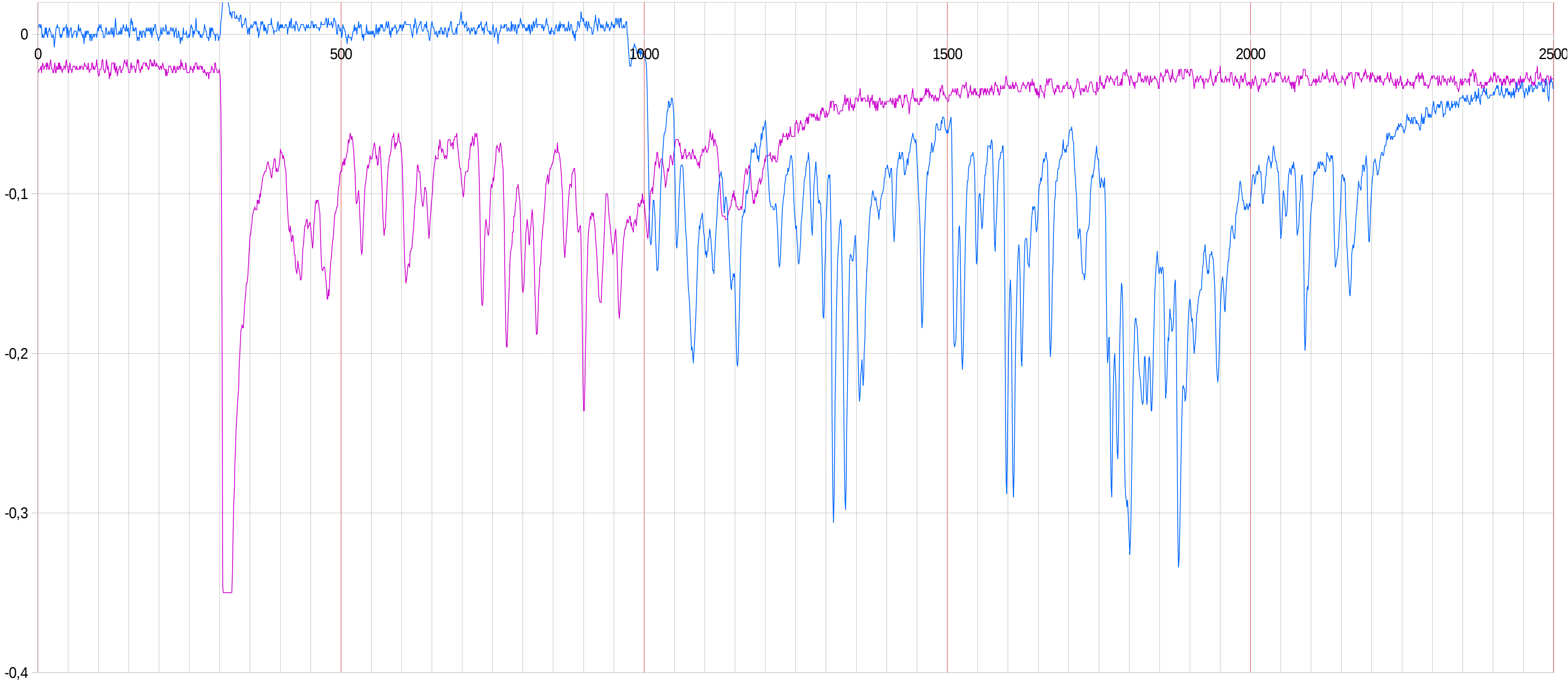


1 mksec

File 0011

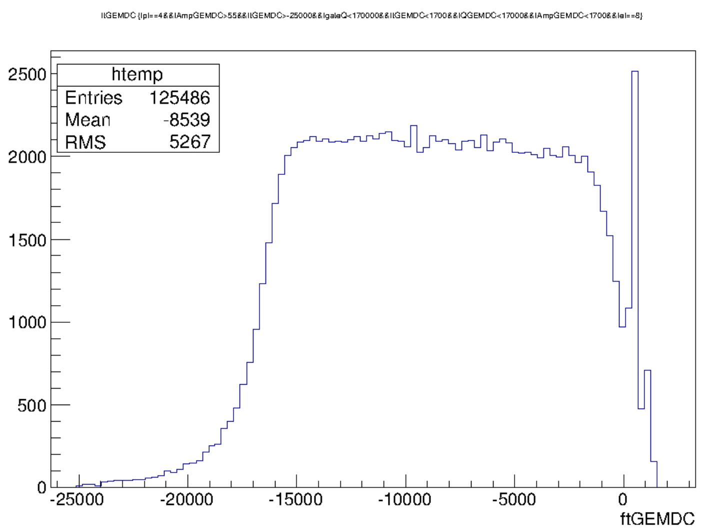


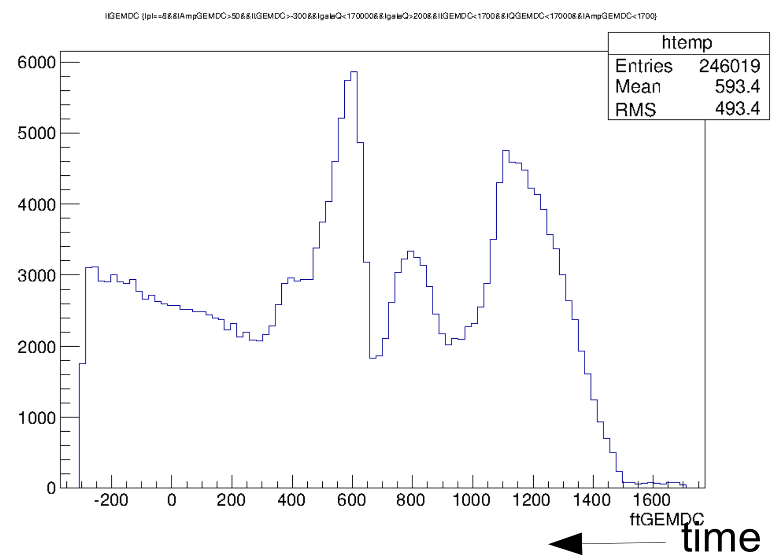
0
-0,1
-0,2
-0,3
-0,4
0
500
1000
1500
2000
2500



0
-0,1
-0,2
-0,3
-0,4
0
500
1000
1500
2000
2500

Time spectrum in GEMDC

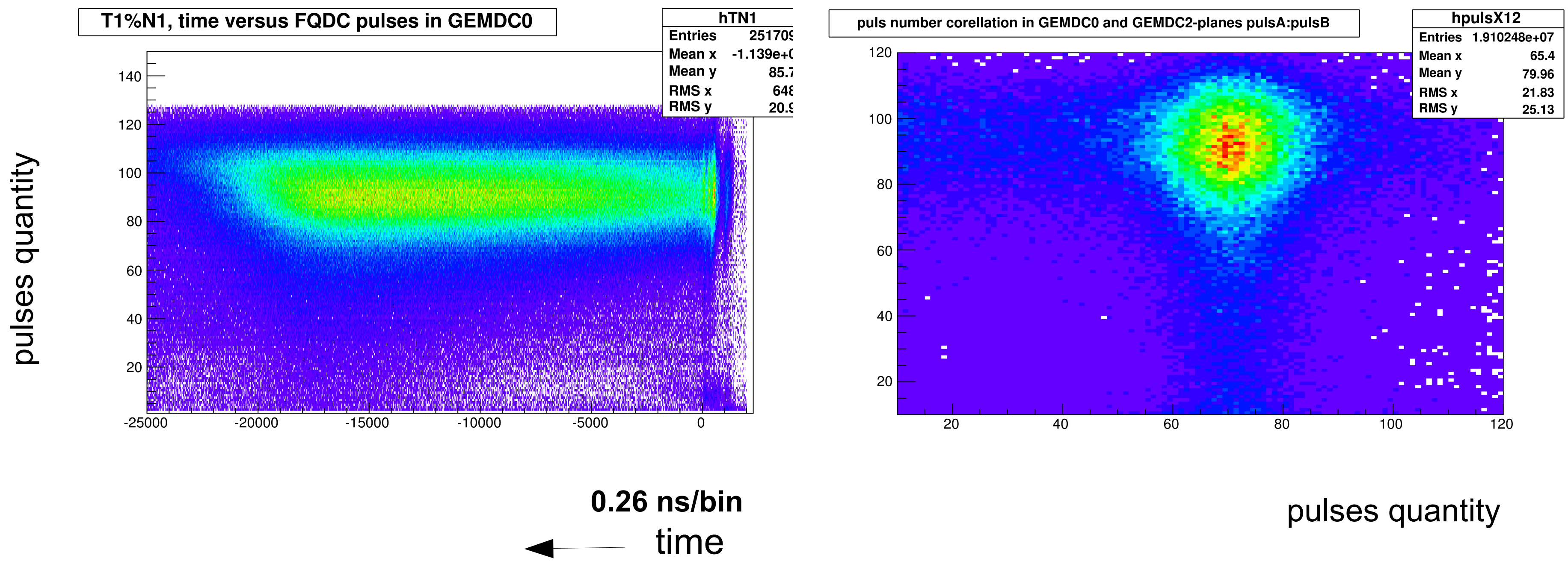




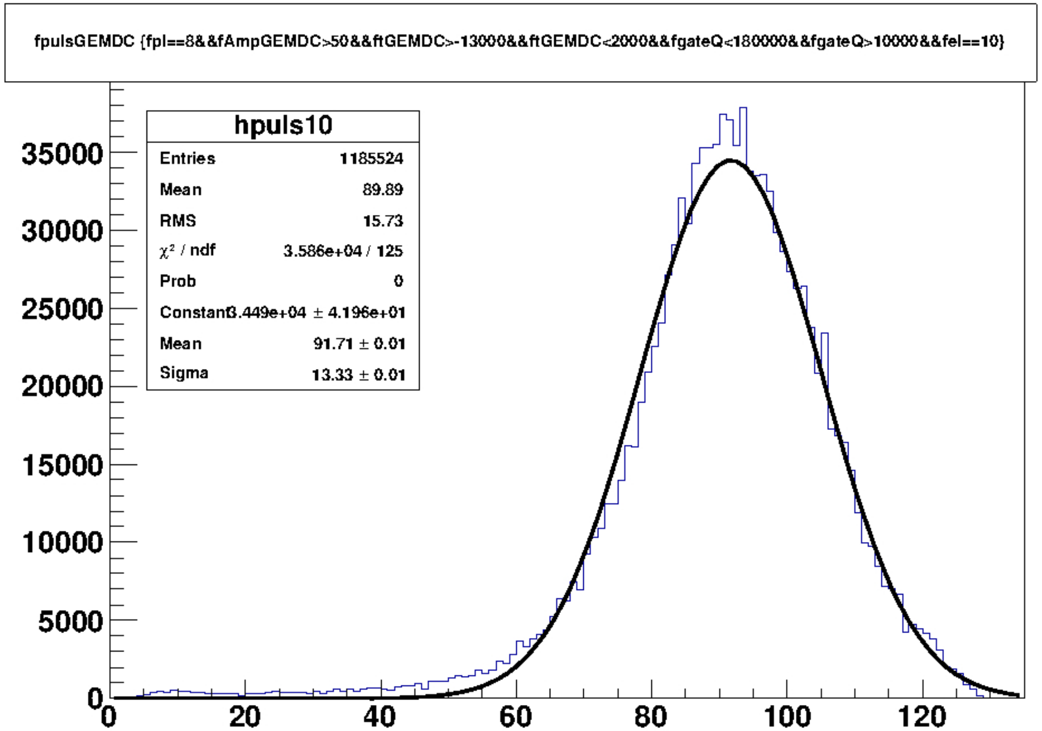
time

0.26 ns/bin

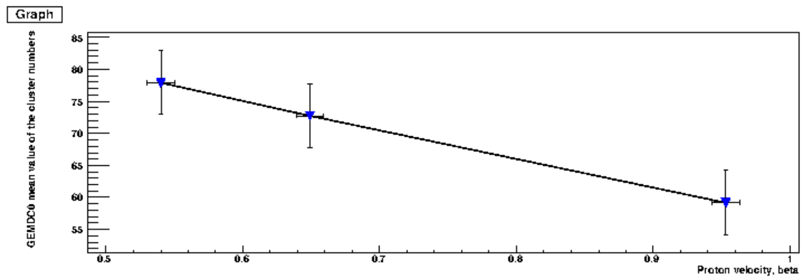
correlation number of clusters versus time (a) in GEMDC0 and number of clusters registered in GEMDC2, run 11448, protons, 0.8 GeV/c



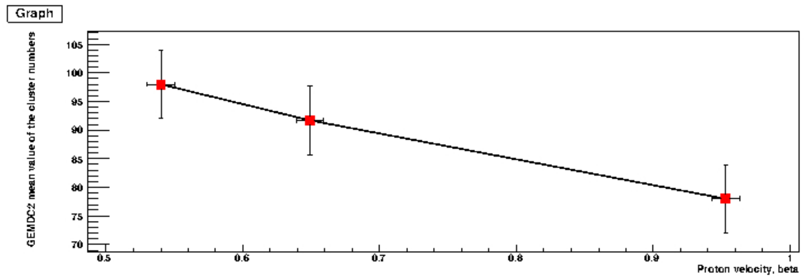
number of clusters registered in GEMDC2, run 11448, protons, 0.8 GeV/c



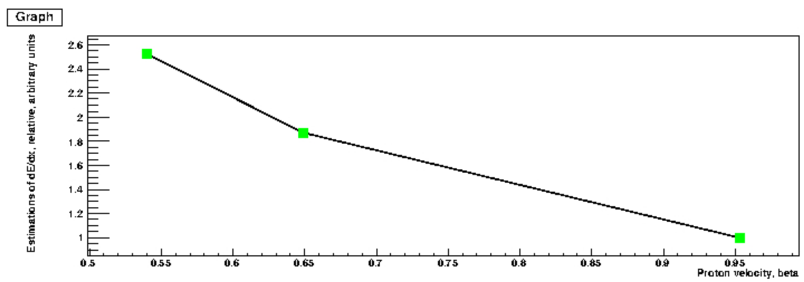
dE/dx by cluster counting-measurements and estimations, for protons 0.6, 0.8, 2.95 GeV/c, May 2015



GEMDC0, double GEM



GEMDC2, tripple GEM



dE/dx~beta^(**-1.63**)

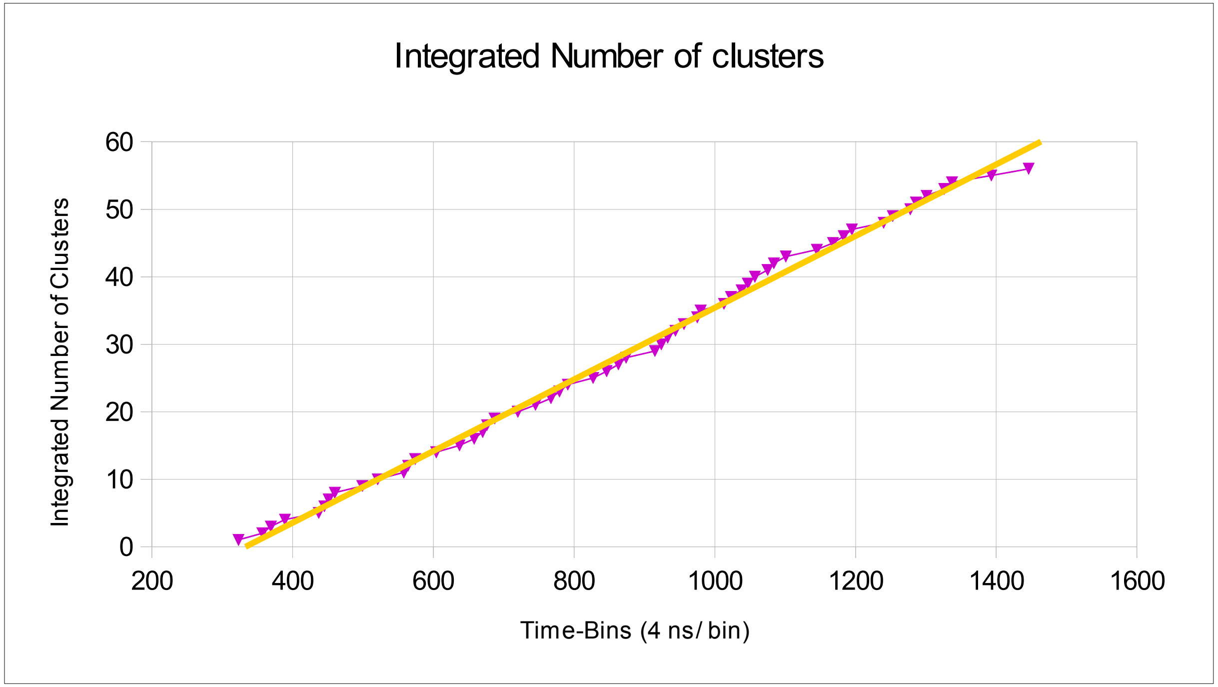
Summary

On-line control of the beam profiles, timing, multiplicities using additional gas coordinate detectors, histogram control

could be used off-line qualitatively during beam data analysis

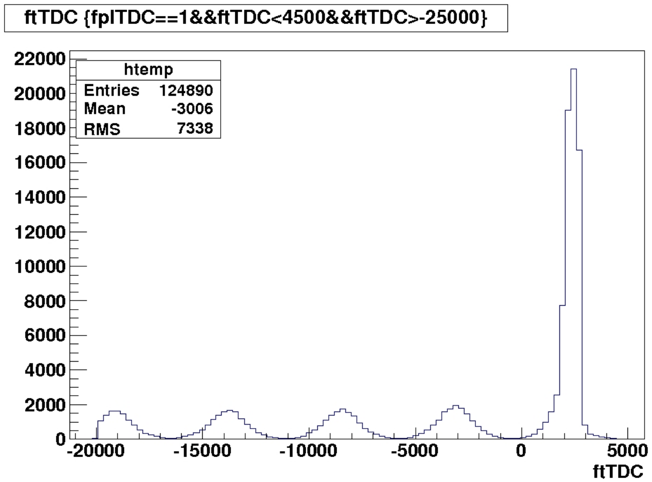
An alternative approach for dE/dx using GEM preamplification stages in a wire chamber GEMDC – tested with beams at different momenta

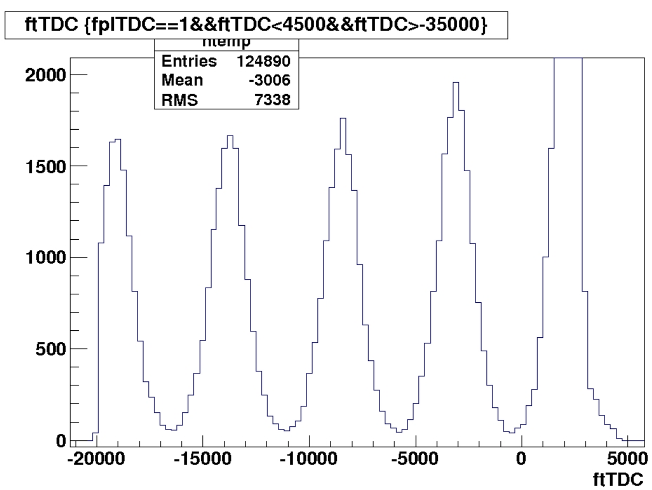
GEMDC signal pattern – a complicated time structure used for testing of the FQDC FPGA algorithm


Integrated Number of clusters
Integrated Number of Clusters
60
50
40
30
20
10
0
200
400
600
800
1000
1200
1400
1600
Time-Bins (4 ns/ bin)

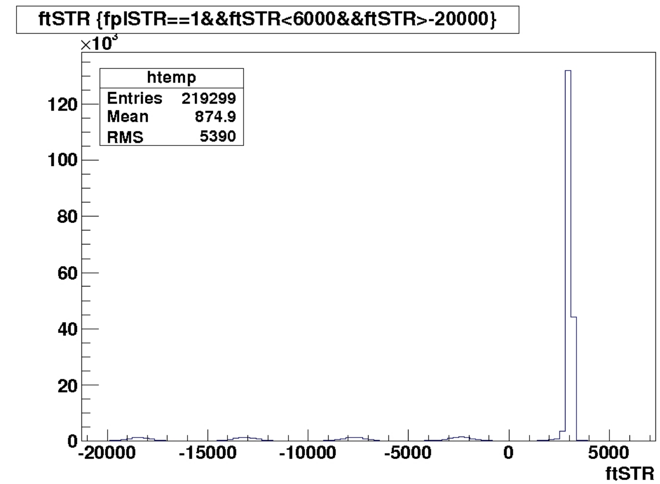
beam time structure in July 2014 COSY test

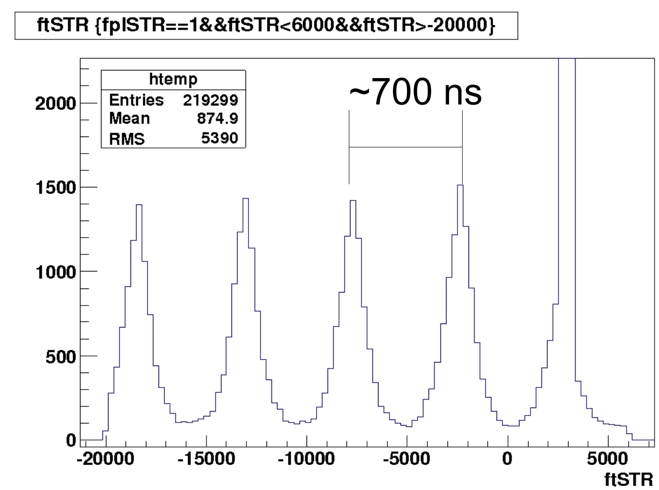
run9664,19.07.2014, 2.95 GeV/c, ~ 10kHz, mult.~1.5



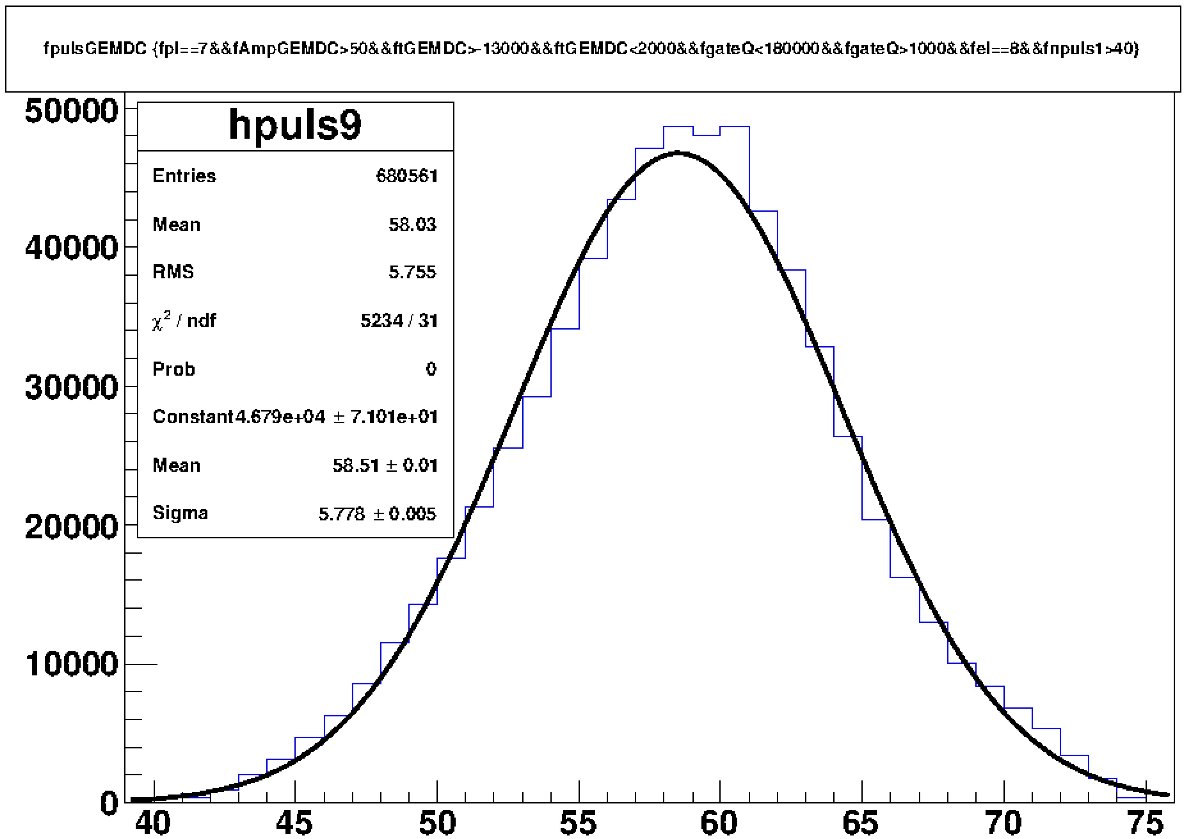


run9705, 20.07.2014, 2.95 GeV/c, mult.~1.15





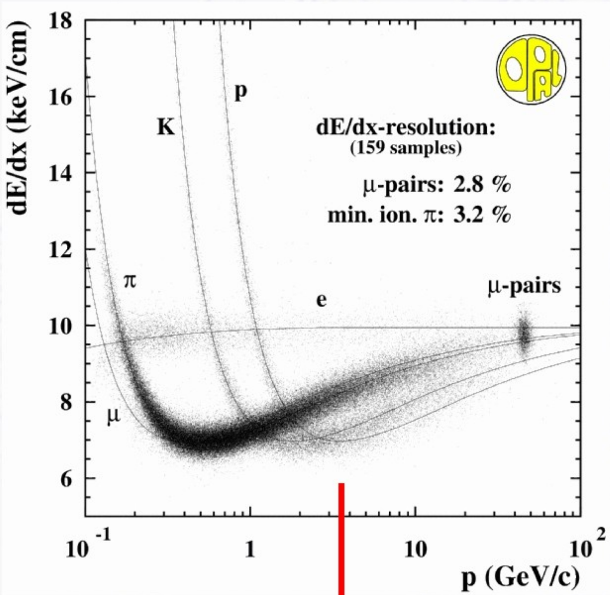
number of clusters and registered in GEMDC0, run 10099, deuterons, 2 GeV/c

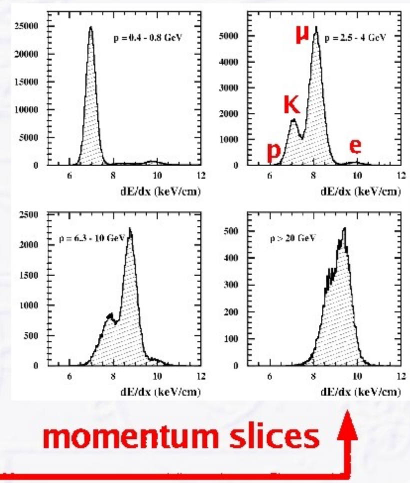


PANDA, Uppsala, May 2015, V. Serdyuk

dE/dx at Large Detectors

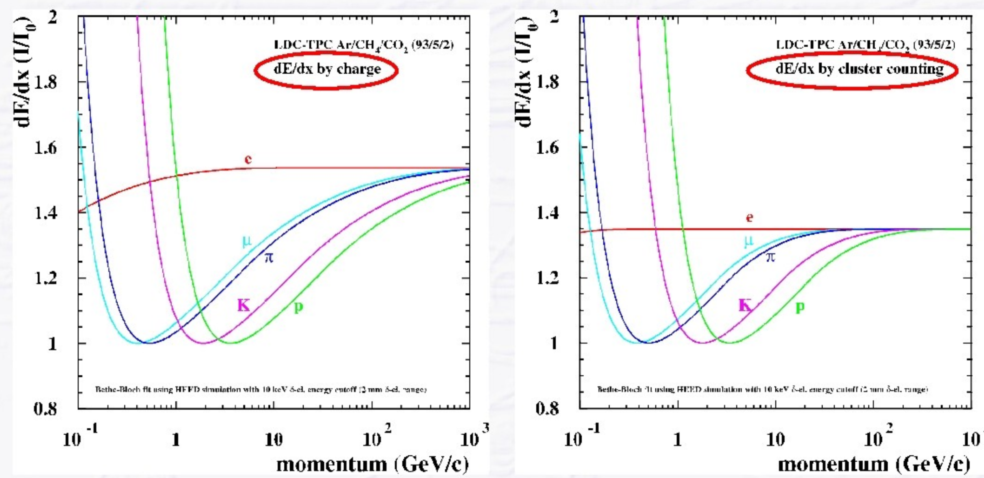
- OPAL Jet Chamber
  - → 1.6 m track length
  - → 4 bar pressure





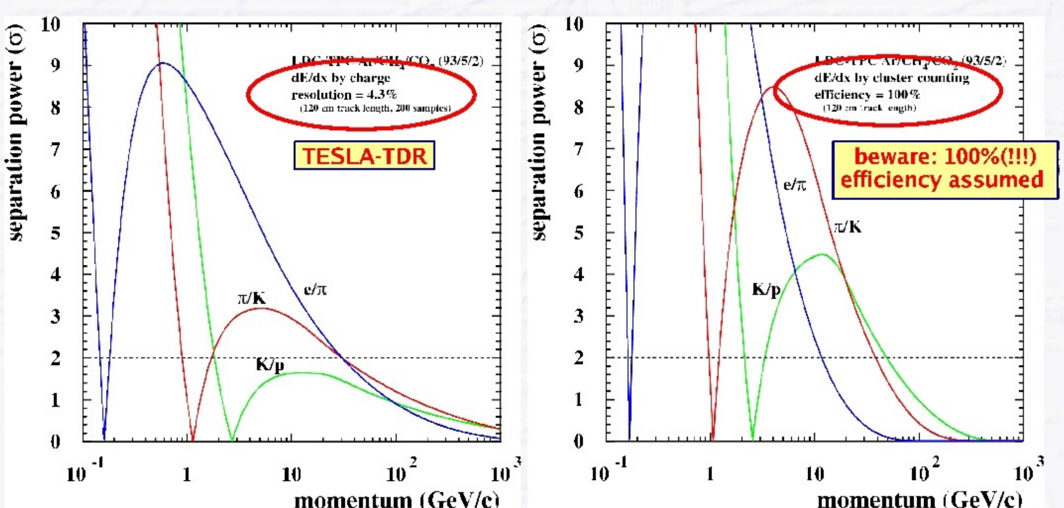
Bethe-Bloch
(charge measurement + cluster counting)

- Relativistic rise looks quite different
  - → Fermi plateau reached much earlier with cluster counting
    - particle separation for cluster counting stops at lower momenta

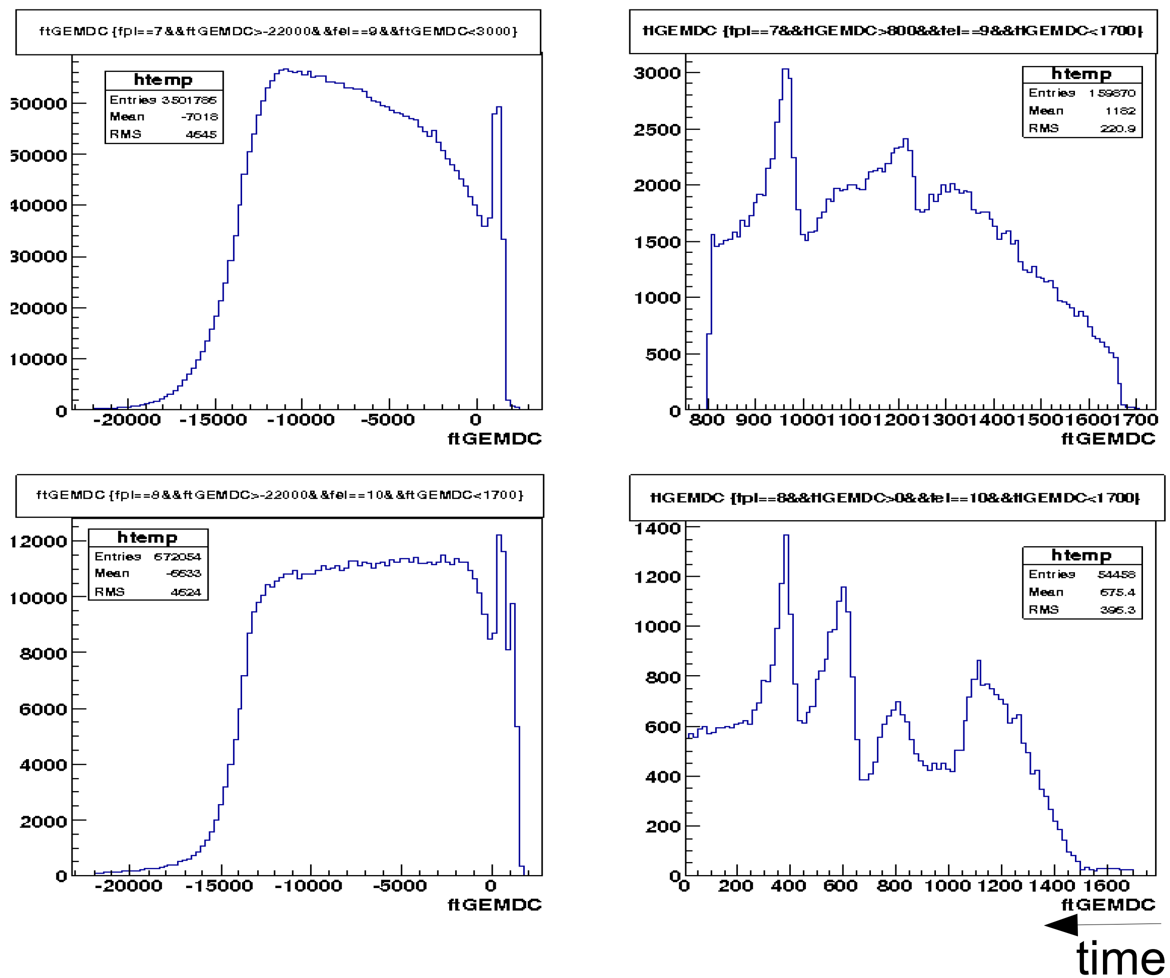


Particle Separation Power
(charge measurement + cluster counting)

- Shape of particle separation power differs
  - → maximum separation at somewhat higher momenta for cluster counting
    - more separation below, less separation above certain momentum for cluster counting



run 10185, 1.0 GeV/c, deuterons, time spectra



GEMDC0, double GEM

GEMDC2, tripple GEM

run 10185, 1.0 GeV/c, deuterons