Twin GEM-TPC Prototype (HGB4) Test beam at Jyväskylä – A Development for the Super-FRS at FAIR

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OUTLINE

1. Introduction and Motivation
2. Prototype Developments
3. Simuations and Rate Capability
4. Large Dynamic range – From Physics
5. The HGB4 – Twin GEM-TPC Prototype
6. Prowering Scheme of HGB4
7. Test beam - GEANT4 Simulations
8. Test beam at Jyväskylä for Protons
9. Outlook

INTRODUCTION & MOTIVATION

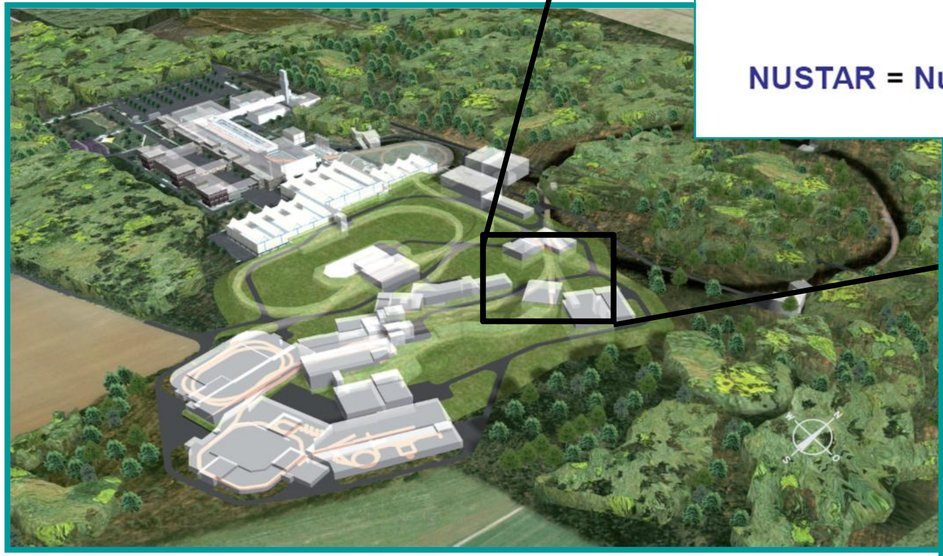
FAIR is a Facility for Antiproton and Ion Research in Darmstadt

The concept of the FAIR Facility aims for a multifaceted forefront science program, beams of stable and unstable nuclei as well as antiprotons in a wide range of intensities and energies, with optimum beam qualities

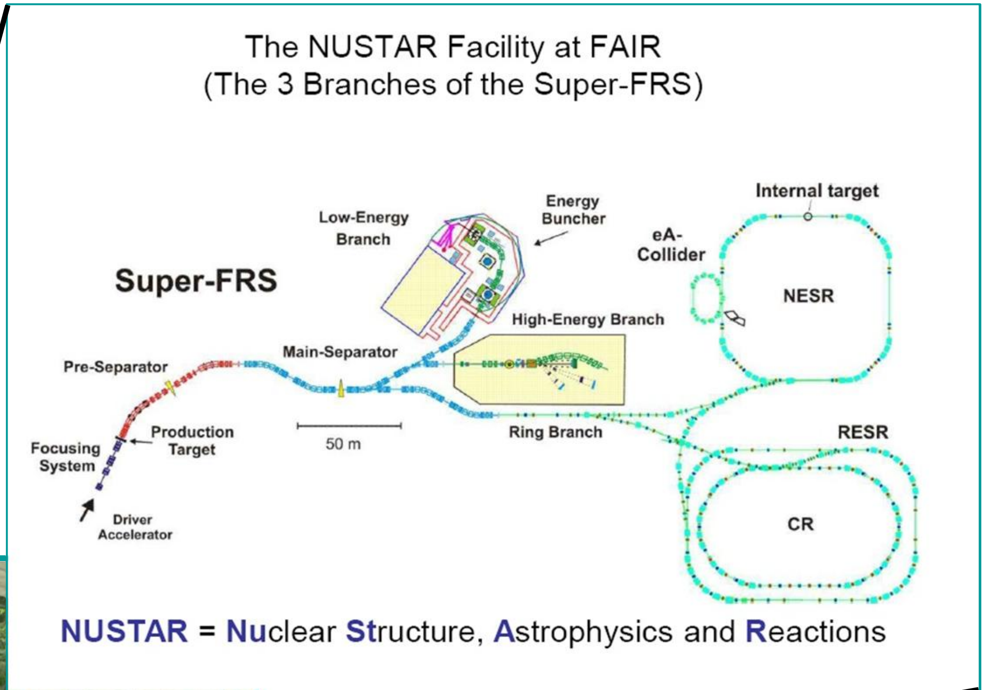
Projectile:
Elements p – U
Energy up to 1.5 GeV/u
Intensity up to 10^{12} /spill

Spot size on target:
σ_x = 1.0 mm
σ_y = 2.0 mm

Requirements:
1.- High rate capability 1 MHz
2.- Large dynamic range, from Physics
3.- Spatial Resolution ~ 500 µm
4.- Tracking efficiency close to 100%
5.- Operation in Air and Vacuum



Time Table spans till end 2025



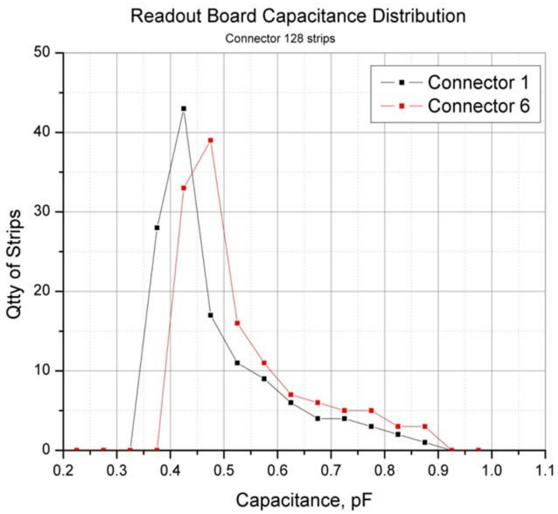
Time line:
R&D finish and Design frozen: Q3/2016

Mass production: Q2/2017 – Q4/2019

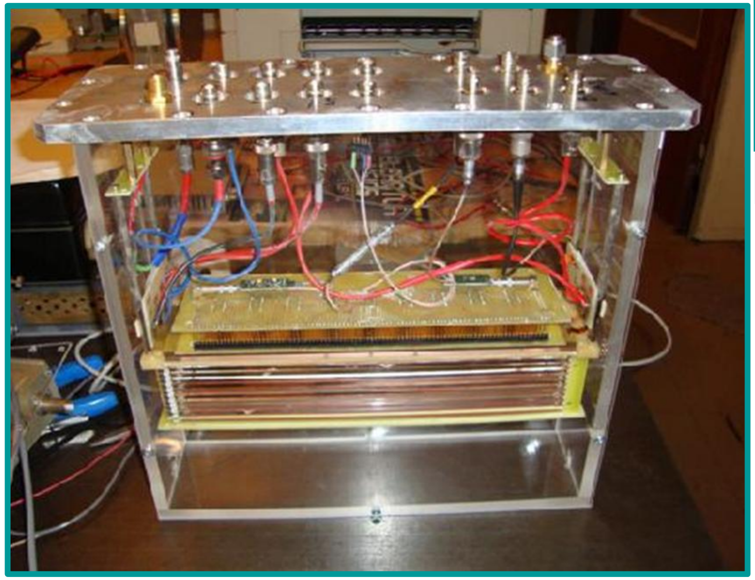
Part of the Finnish Contribution will be in Diagnostic systems, which is a work package dedicated to provide 36 GEM-TPC detectors.

PROTOTYPE DEVELOPMENTS

Capacitance measurement setup

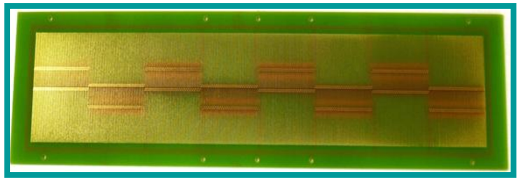


Flange of the GEM-TPC HB1, read out by delayed lines



Right: The electrodes of the board with strips of 200 µm width and 500 µm pitch

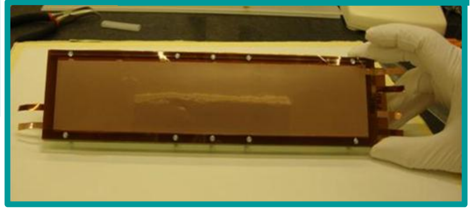
And 8 Header Panasonic connectors with 130 Pin each



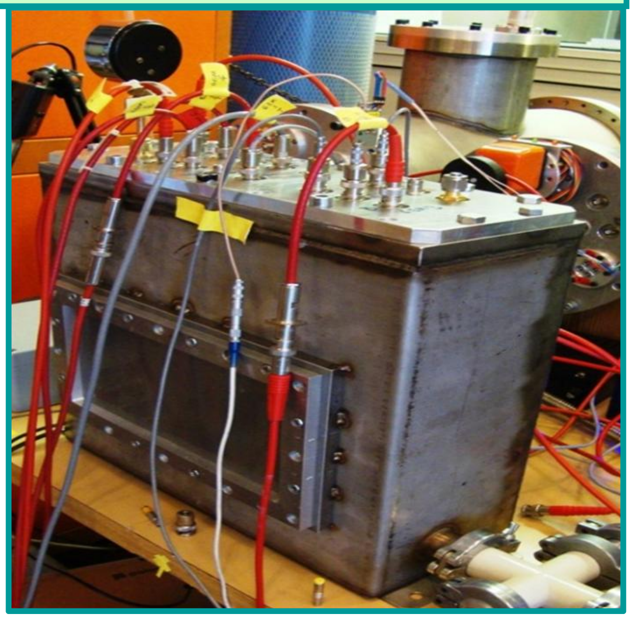
Comenius University - Bratislava

Field cage of 40 mm drift

Triple GEM stack

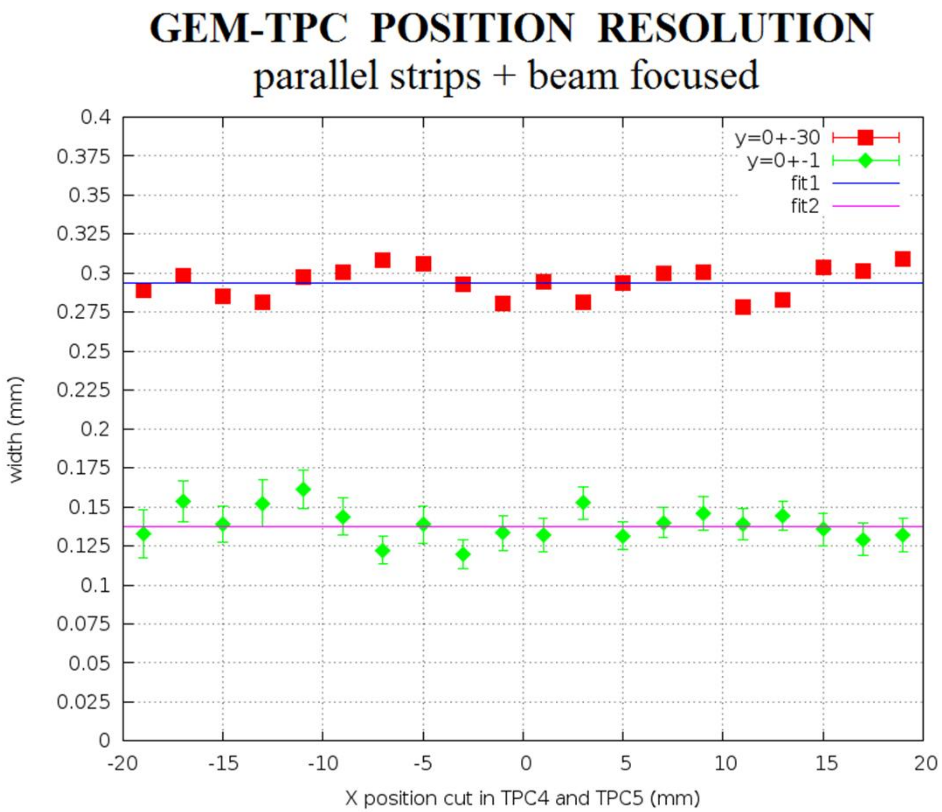


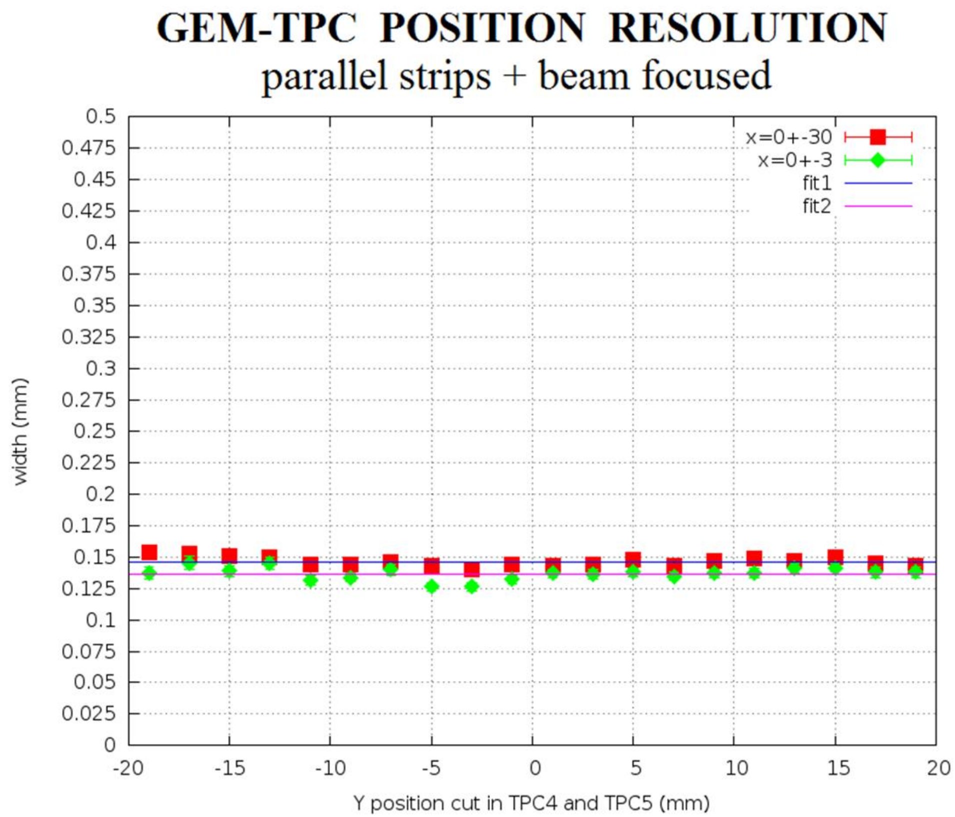
First GEM-TPC called HB1 detector (Helsinki Bratislava prototype 1)



PROTOTYPE DEVELOPMENTS (cont.)

GEM-TPC Results for a Test Beam @GSI with ^{64}Ni ions at 550 MeV/u

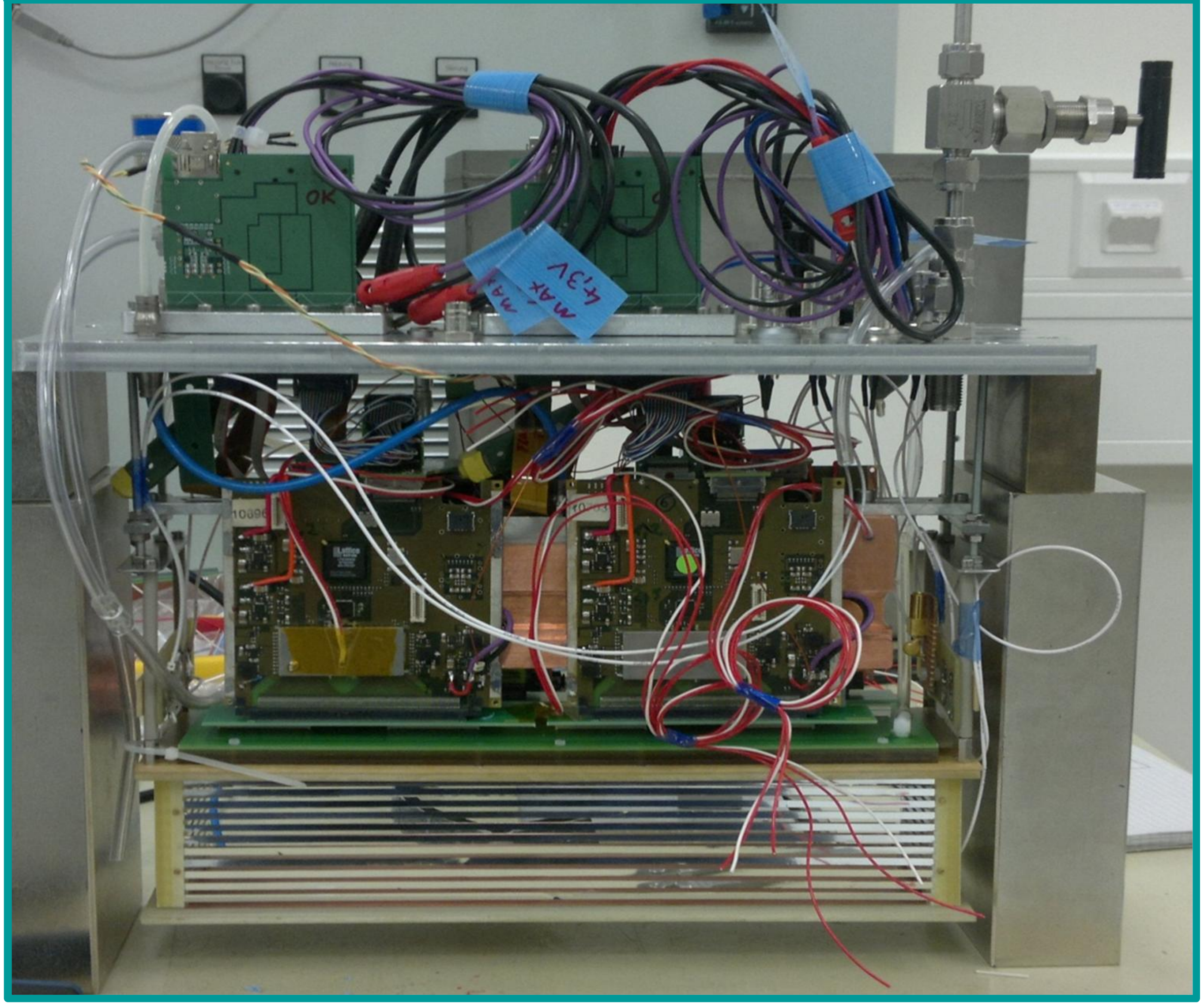




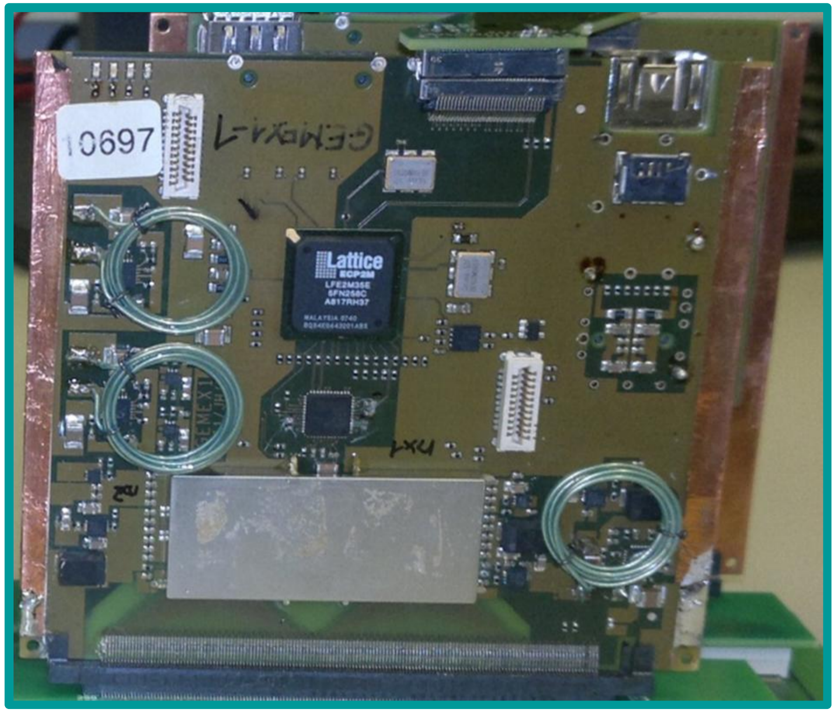
The GEM-TPC shows that the resolution in Y (Drift) reaches value around 130 μm and on X between 130 to 300μm

PROTOTYPE DEVELOPMENTS (cont.)

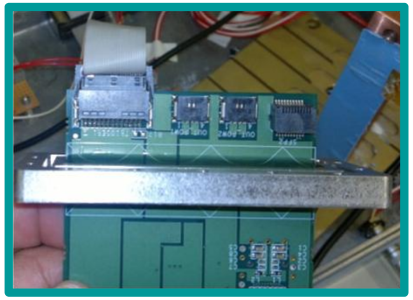
HB3 with four GEMEX cards



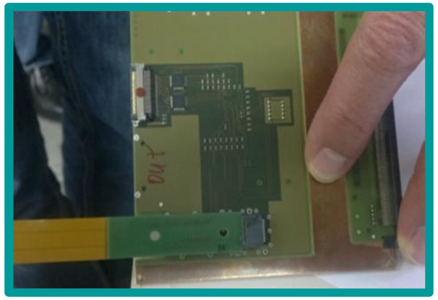
GEMEX cards provide by EE - GSI



Flange Adapter card



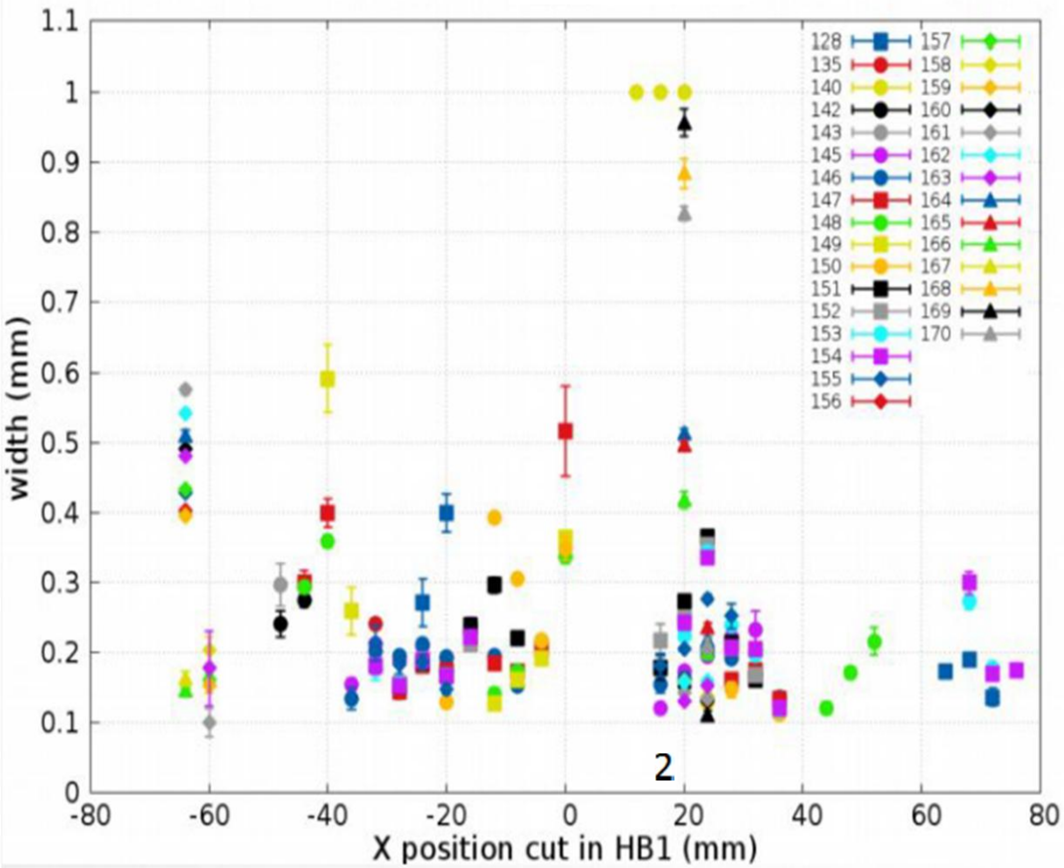
SFP to Copper inside the chamber



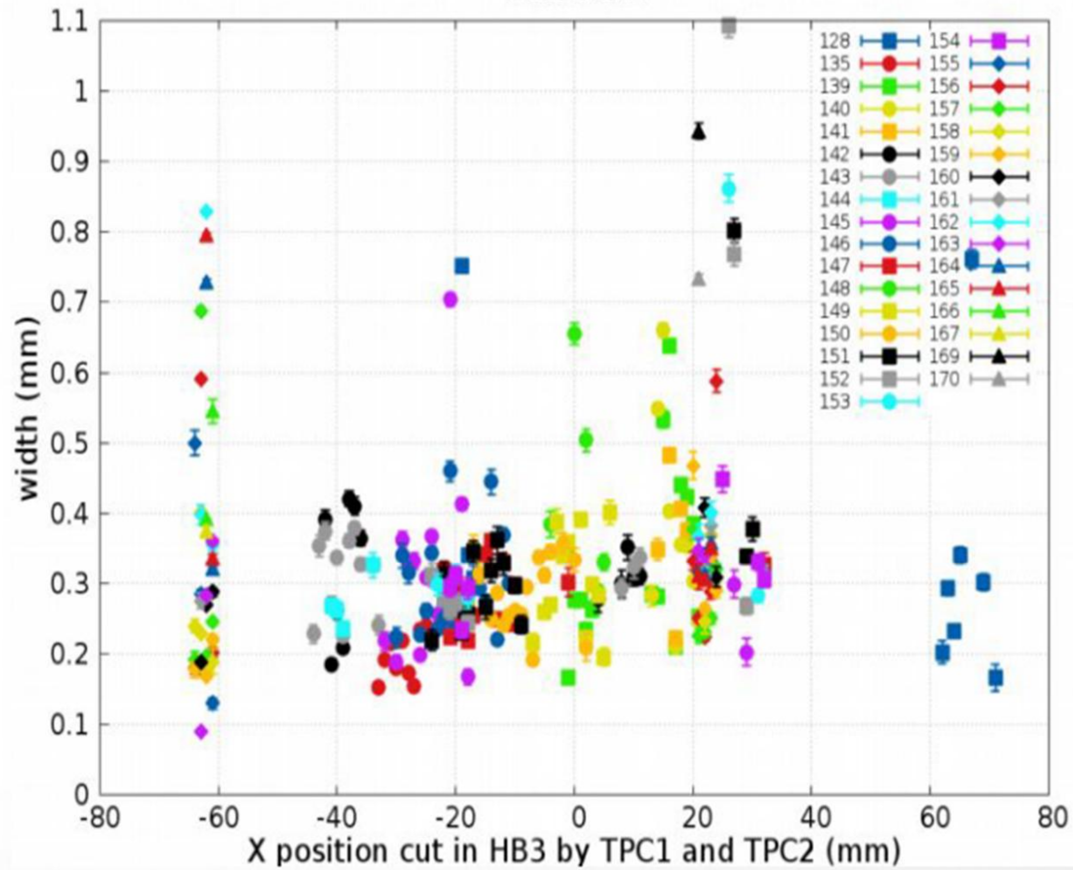
PROTOTYPE DEVELOPMENTS (cont.)

HB2/HB3 @ GSI Test Beam with ^{197}Au at 770 MeV/u

HB2 – 40 cm

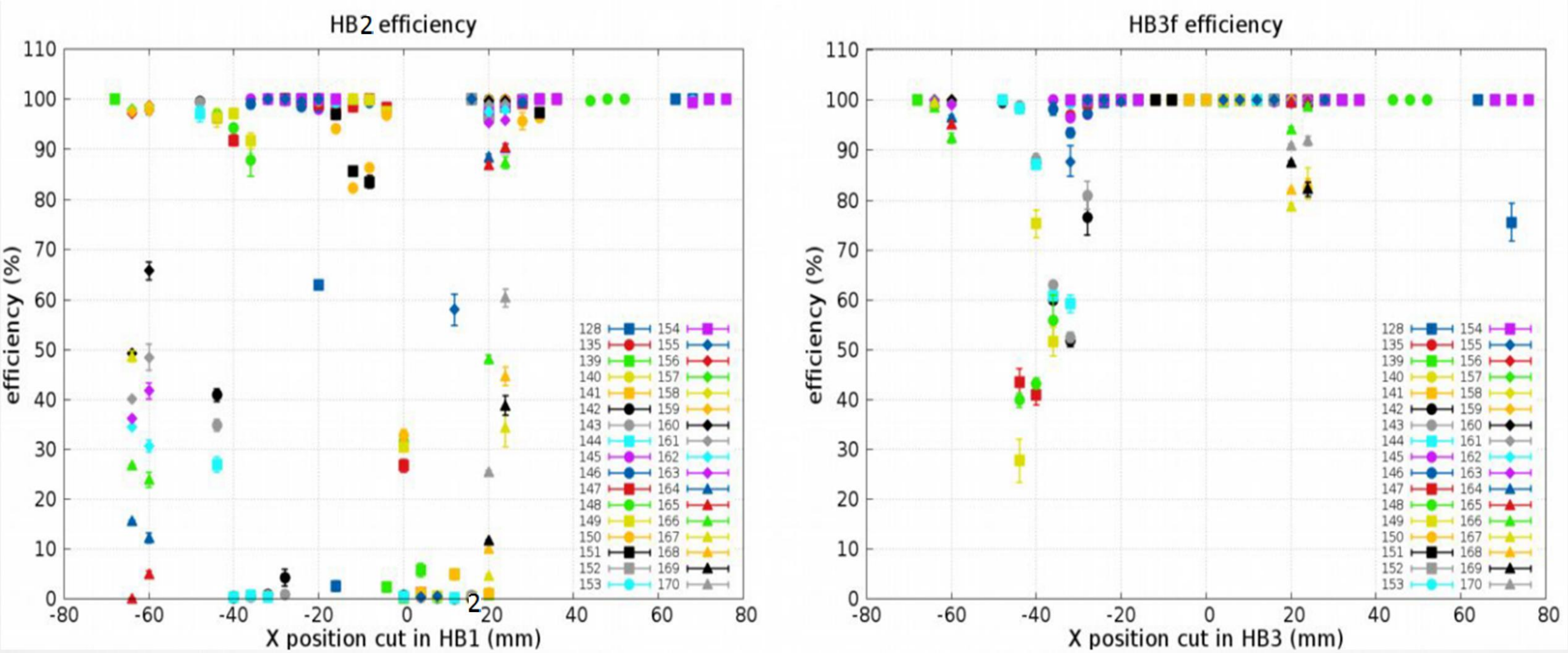


HB3 – 60 cm



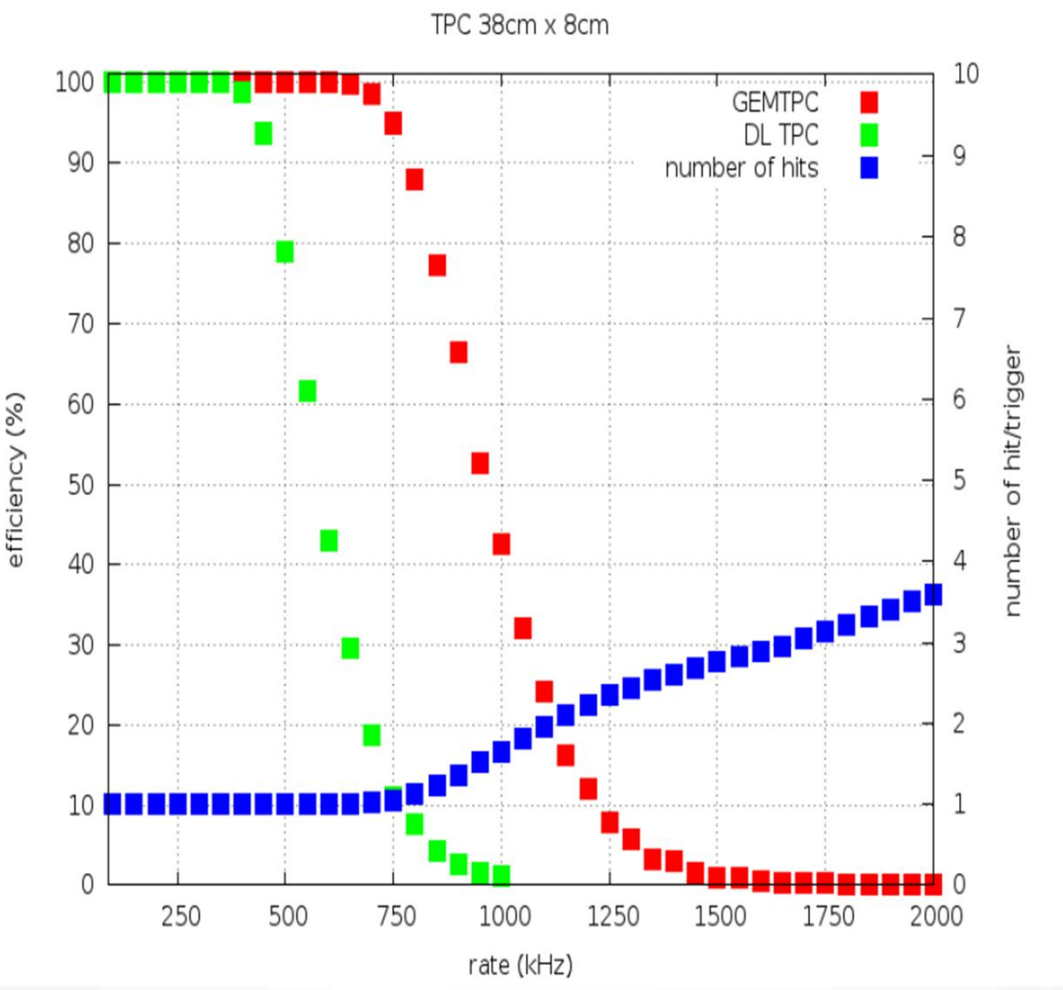
The position resolution in X coordinate for the HB2 (200 μm) and HB3 (300 μm) for most of the runs.

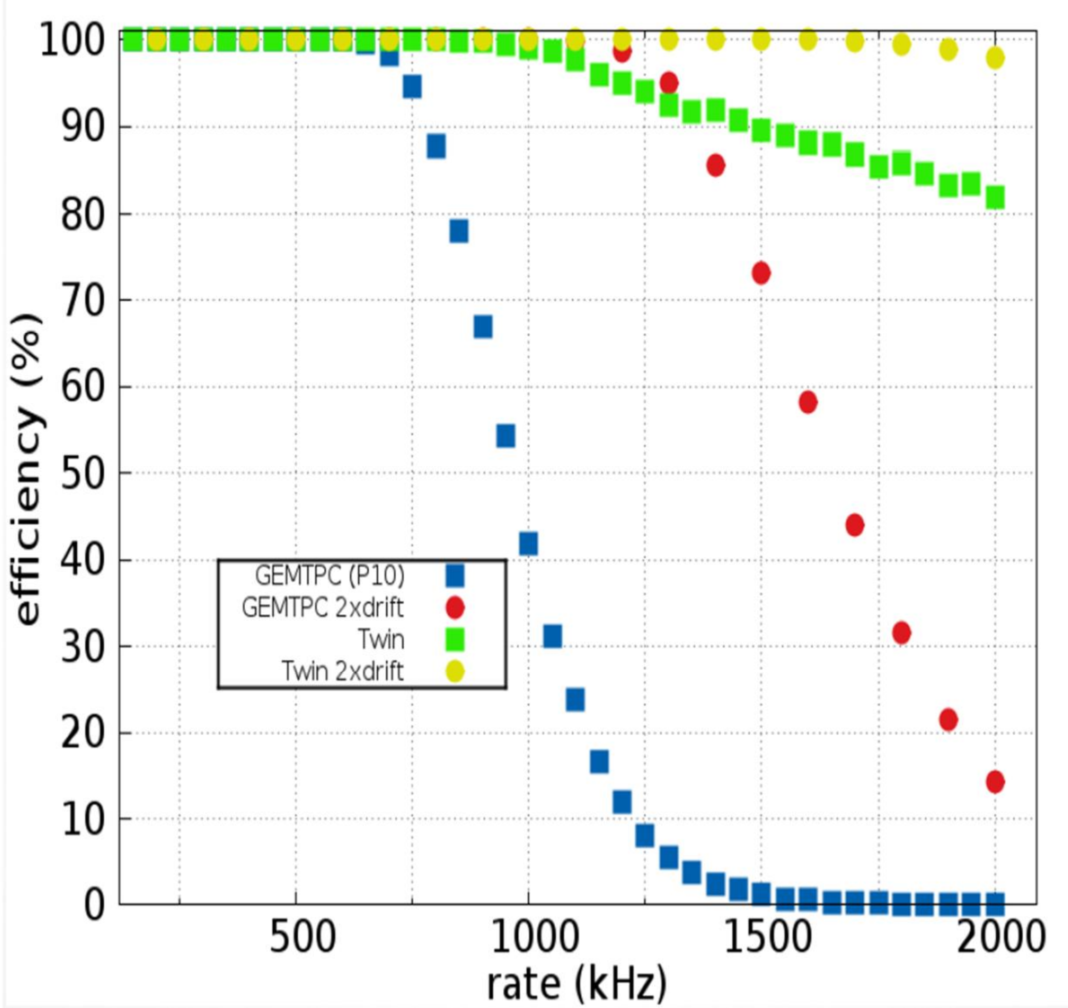
PROTOTYPE DEVELOPMENTS (cont.)



Efficiency plots for the HB2 and HB3 for all the runs close to 100%

SIMULATIONS And RATE CAPABILITY





Efficiency Plots simulations for the GEM-TPC equipped with Delayed lines and with GEMEX readout for the case of P10 and a faster gas. The twin GEM-TPC using a 1.6 μs time window and a 21 ns check sum can reach 1.75 MHz

LARGE DYNAMIC RANGE – FROM PHYSICS

Educated guess:

From Physics; the run with largest Dynamic range requires:

The Sensitivty from: Ni: 56 fC up to U: 614 fC (in $ArCH_4$, Gain=1 and 3 cm thick gas)

U → 614 fC → 122 fC/strip [cluster:10 strips] (20%) → 153 fC (25%)

Ni → 56 fC → 11.2 fC/strip [cluster:10 strips] (20%) → 14.3 fC (25%)

All in all, in order to have some gain to steer the space chage/avalanche

A Gain of the order of = 10 is desired, which arrives to 1.5 pC/strip

Keeping this in mind one can find a solution! → see next slide

LARGE DYNAMIC RANGE – FROM PHYSICS (cont.)

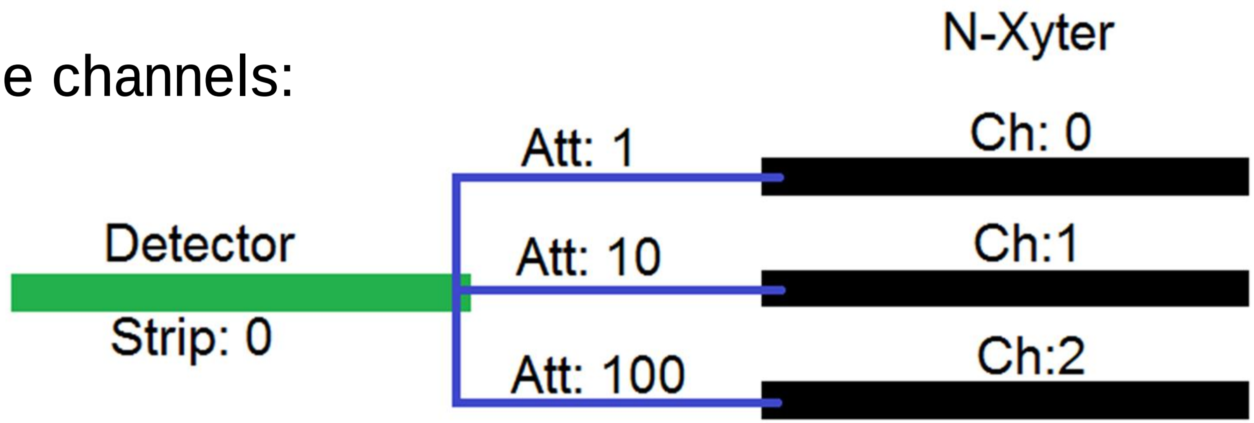
One solution for large dynamic range is shwon below....

Split the incoming charge into three channels:

1 channel with attenuation of 1

1 channel with attenuation of 10

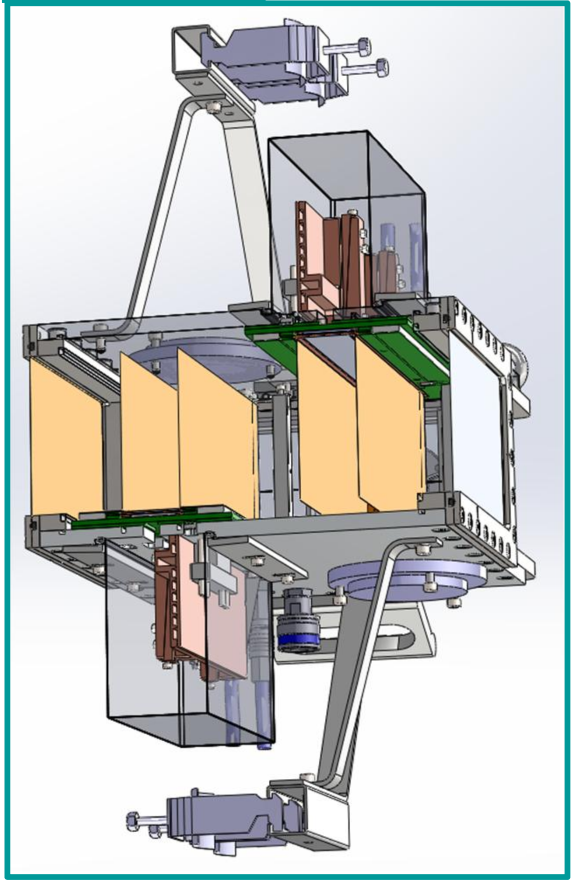
1 channel wth attenuation of 100

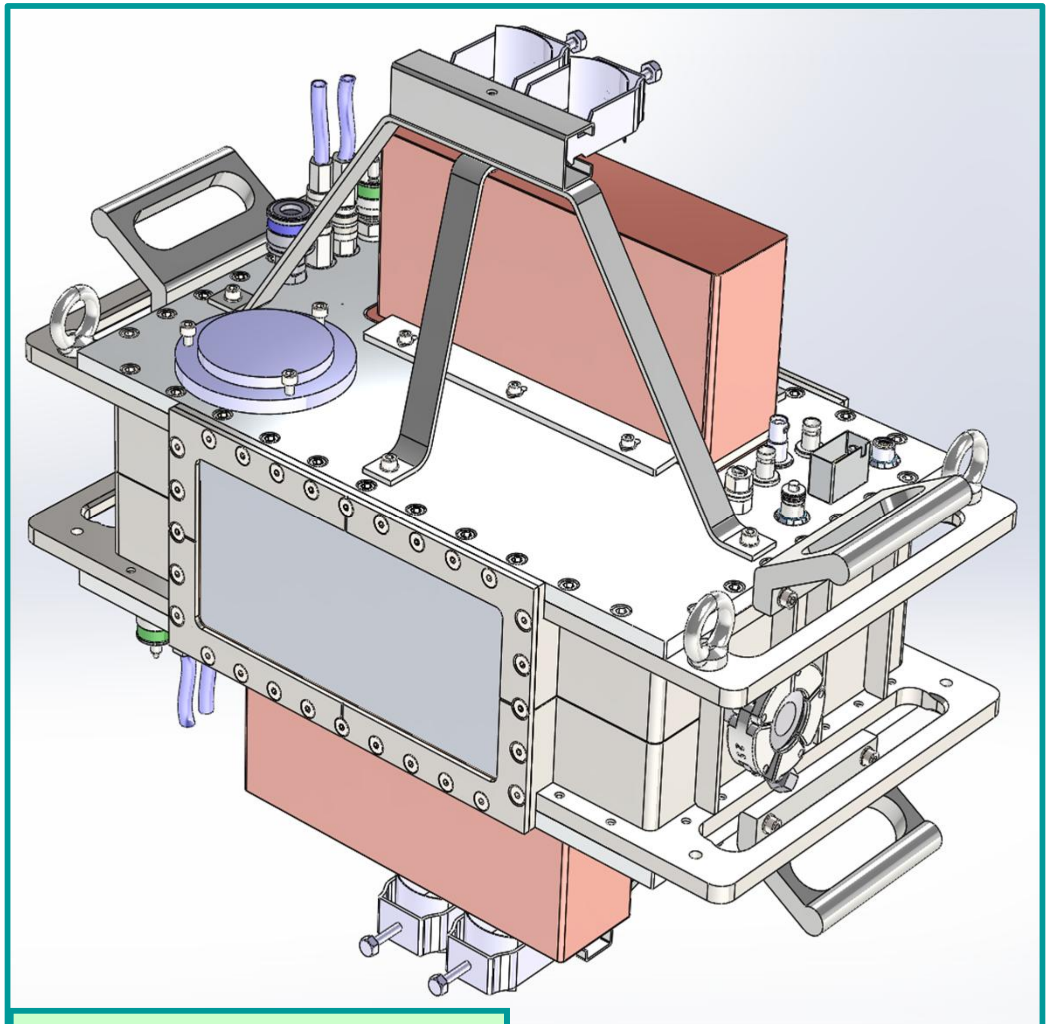


As a result one can have up to 1.5 pC per strip dyamic range → based on the assuption of the current n-Xyter v.2.0 with a dynamic range of 15 fC per channel.

The HGB4 – Twin GEM-TPC Prototype

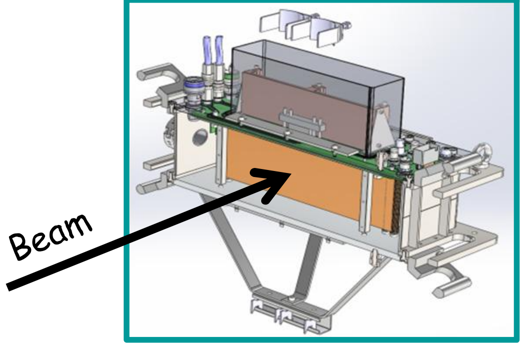
Lateral view



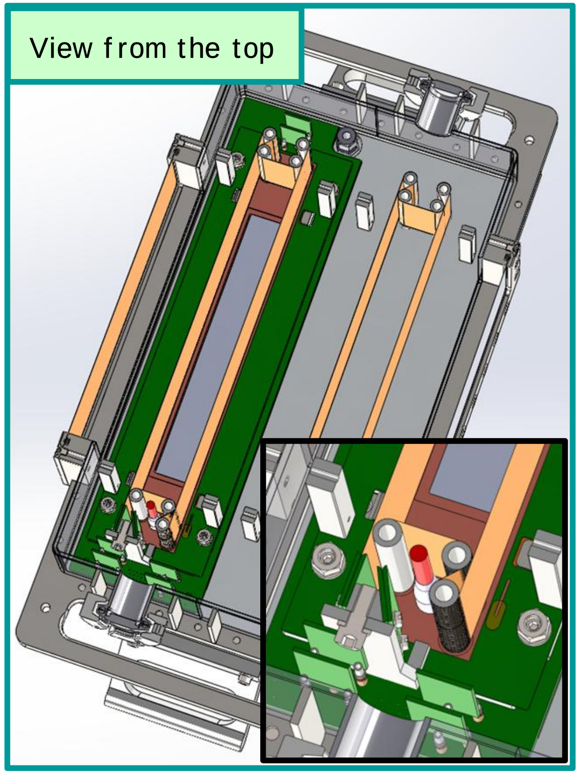


This GEM-TPC has a twin configuration, which means that two GEM-TPC are positioned back to back.

View beam downstream

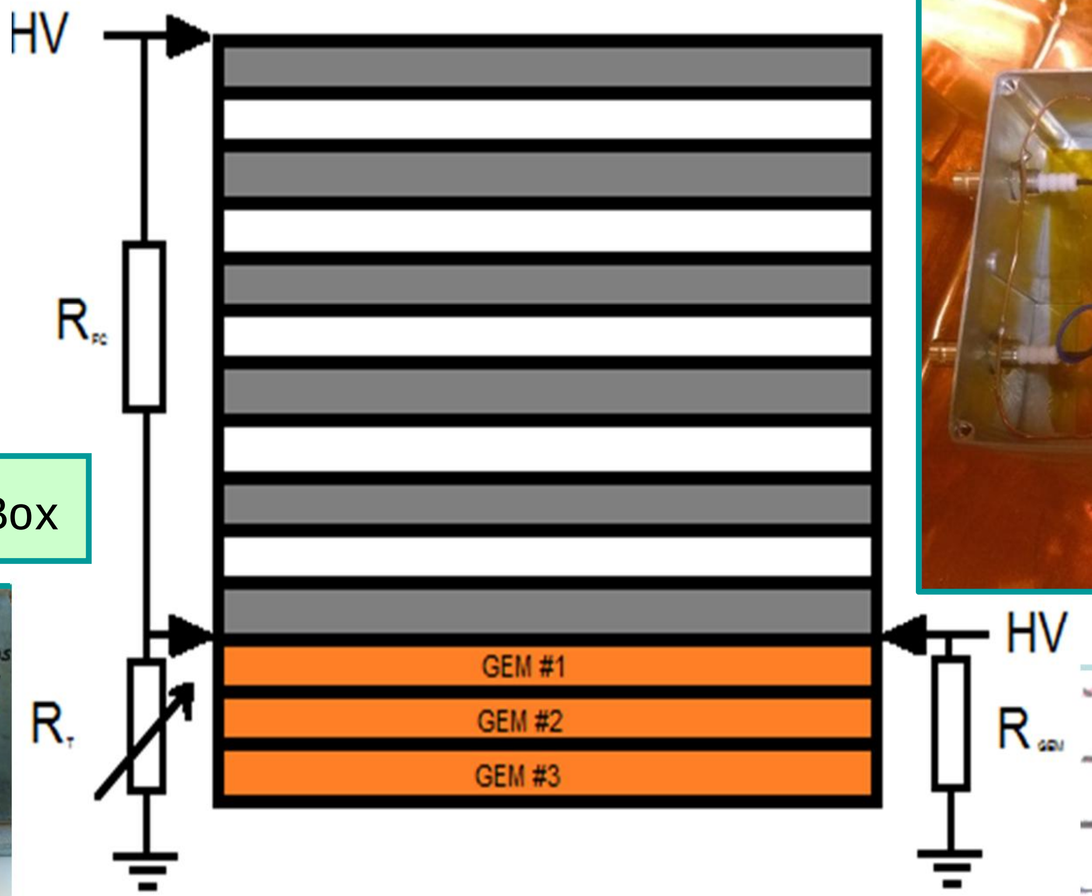


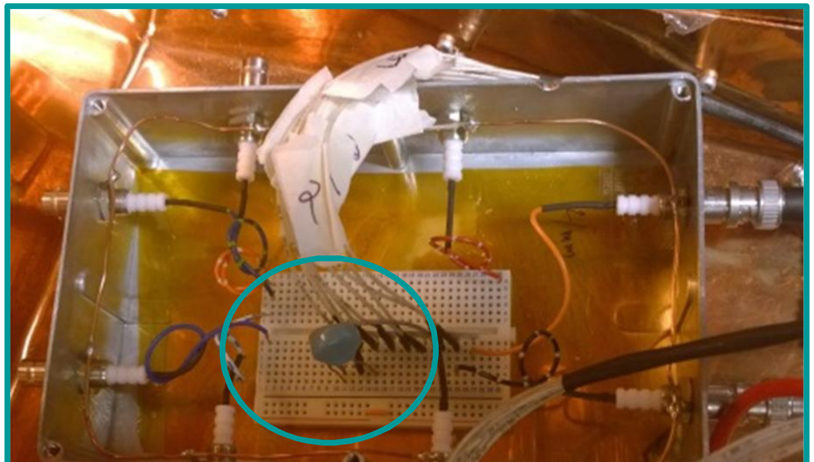
View from the top

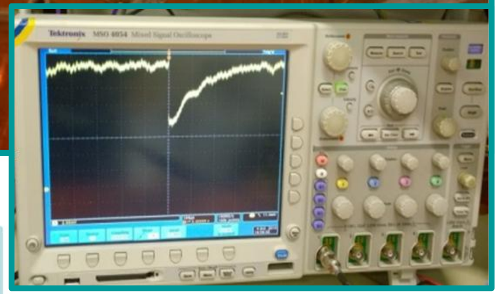


POWERING SCHEME of HGB4

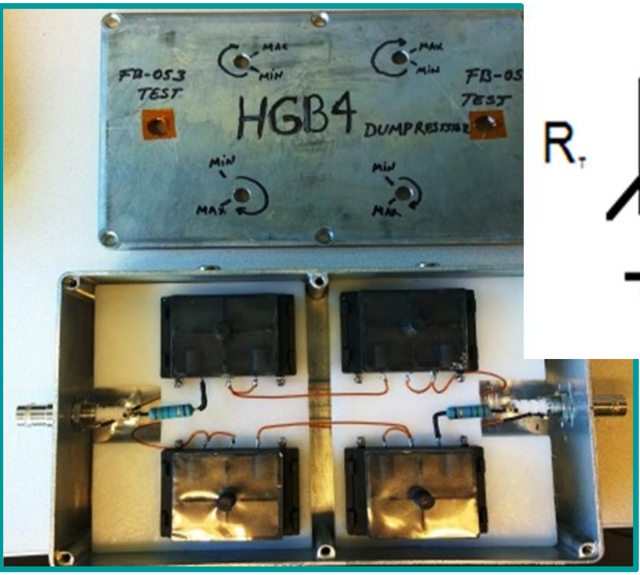
The Twin GEM-TPC called HGB4 needs two HV power suppliers to operate







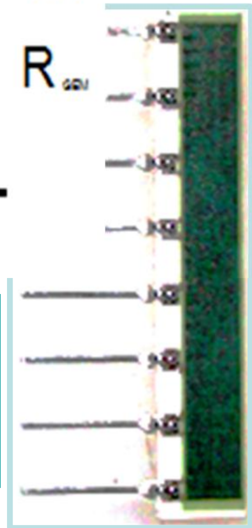
Resistor Termination Box



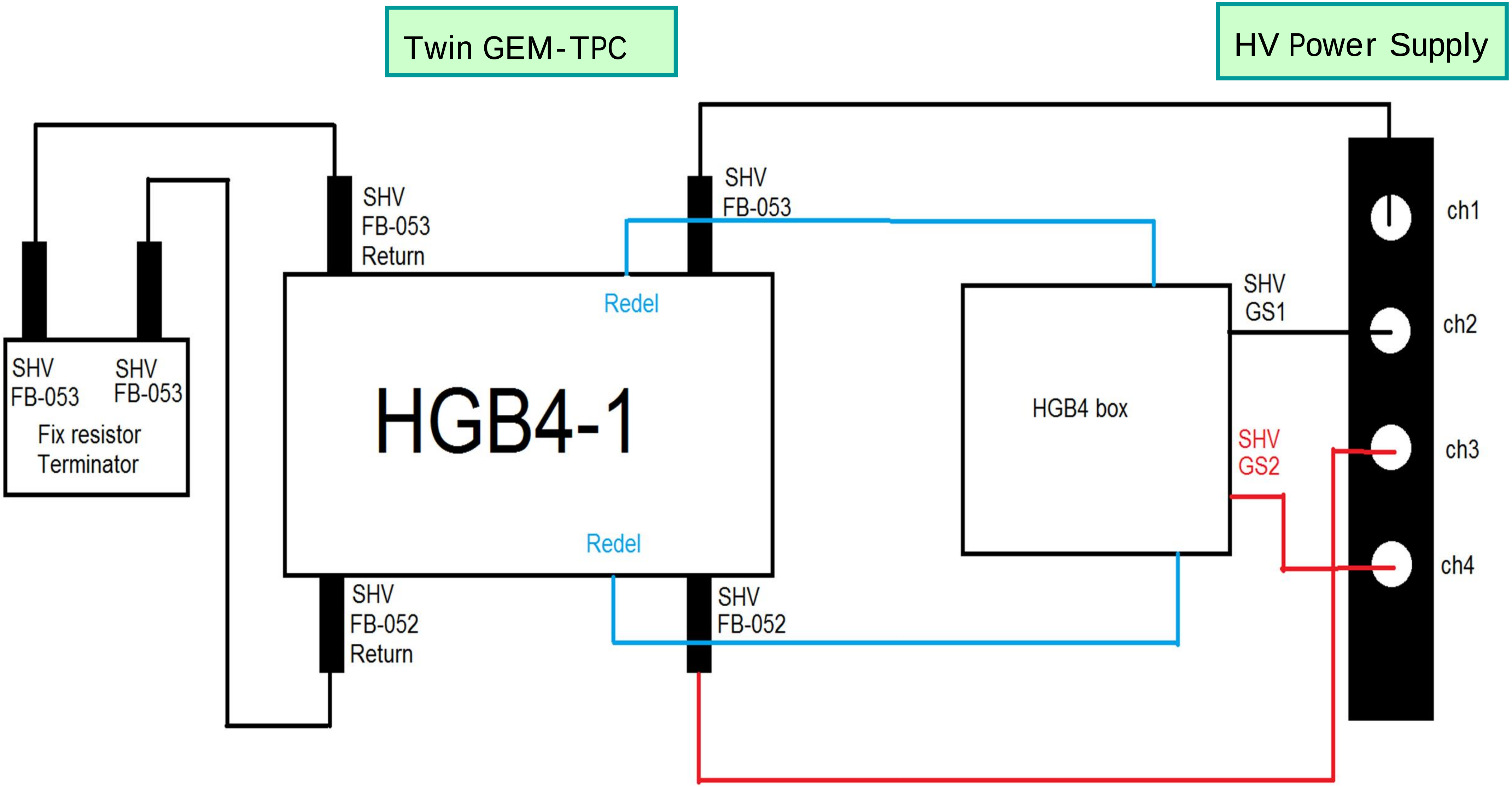
R_{total} = 5.45 MΩ

Rui et al

Pick-up signal taken from the Pin (GEM #3 Bottom) of the divider



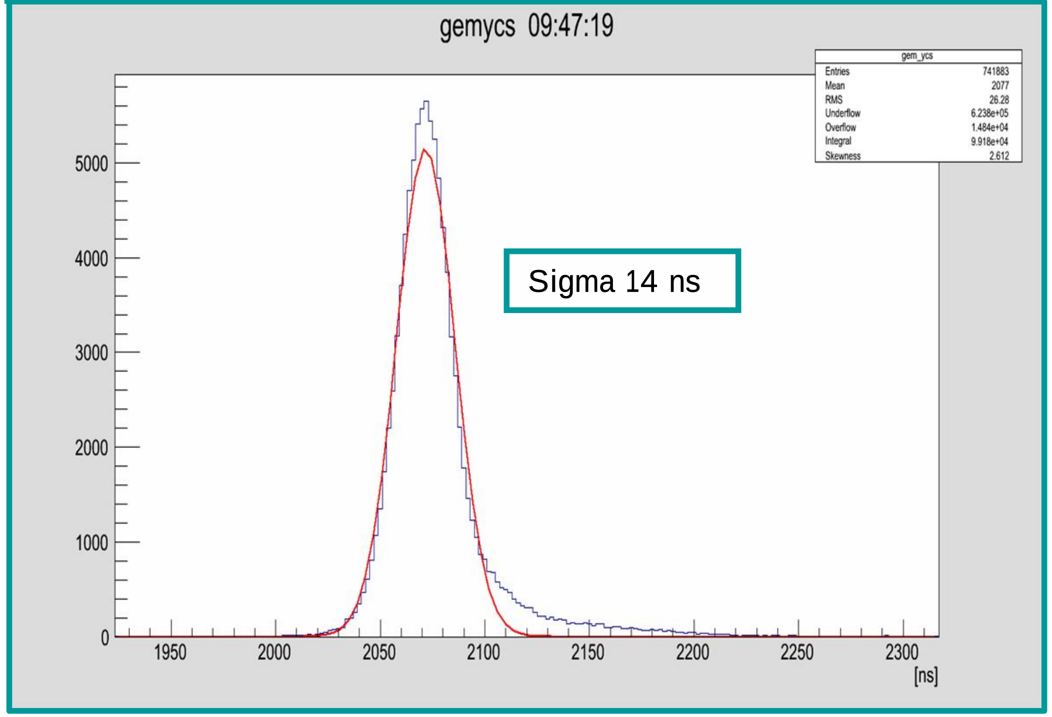
POWERING SCHEME of HGB4 (cont.)

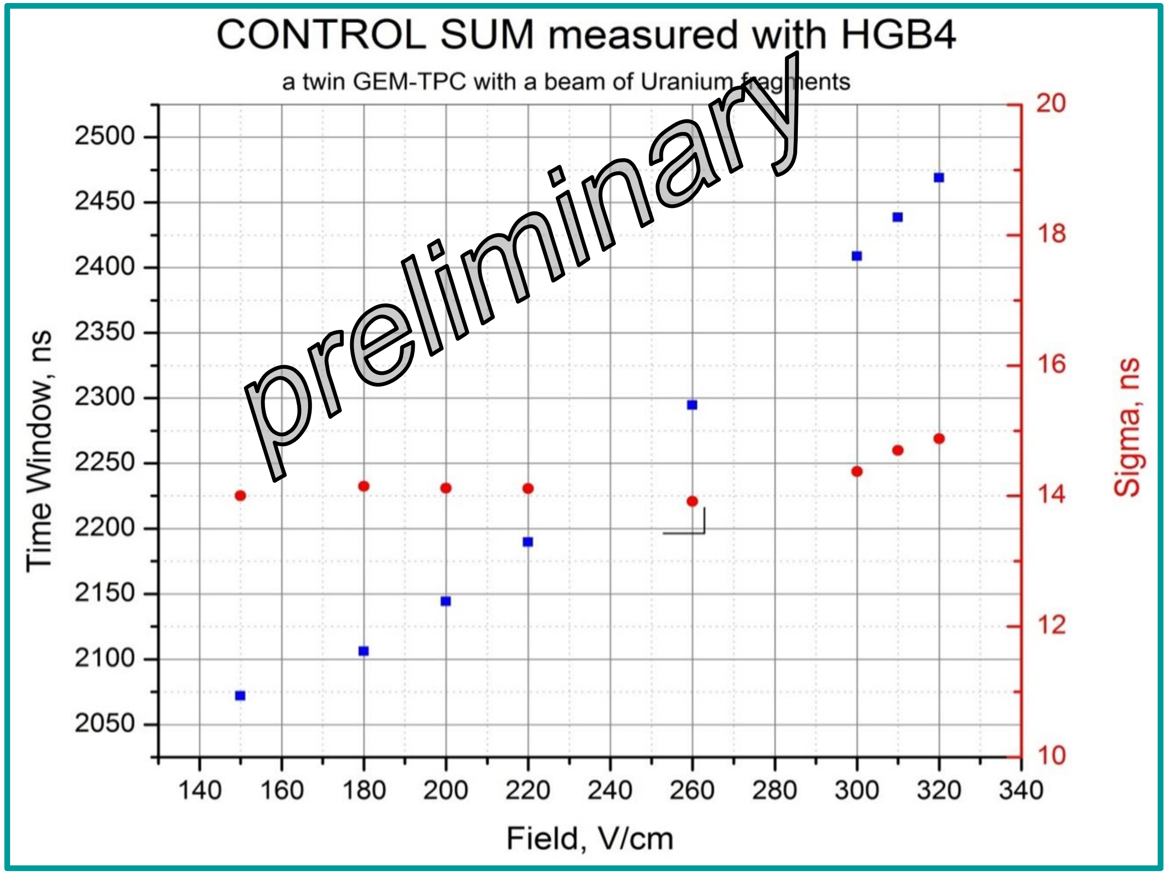


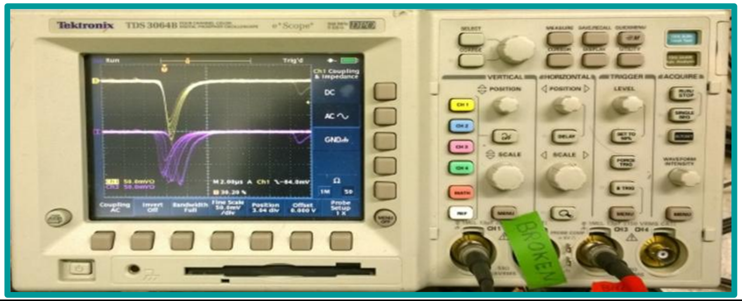
HGB4 CONTROL SUM

Projectiles: ^{238}U @ 330 MeV/u

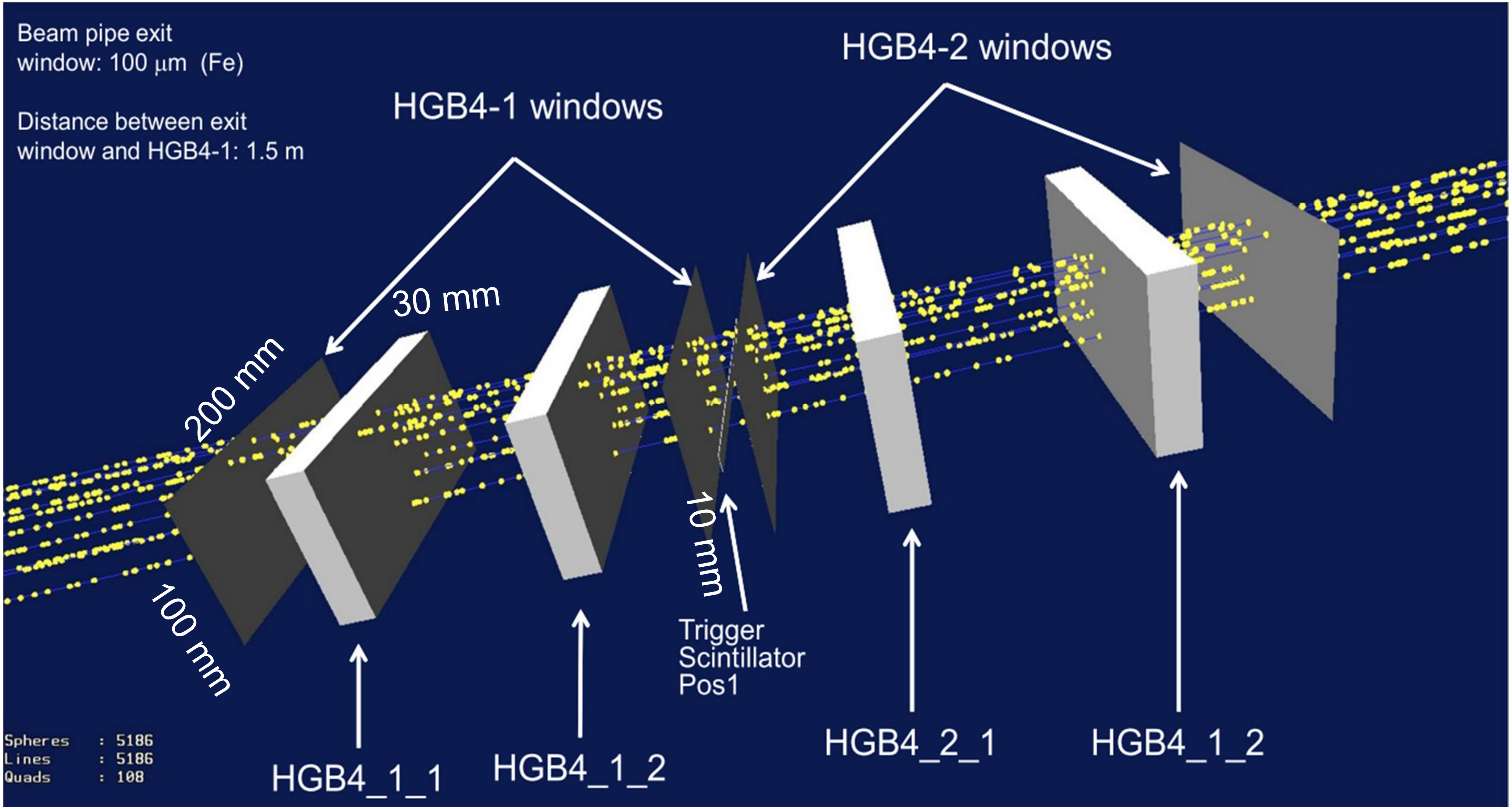
Hits distribution for a field of 150 V/cm



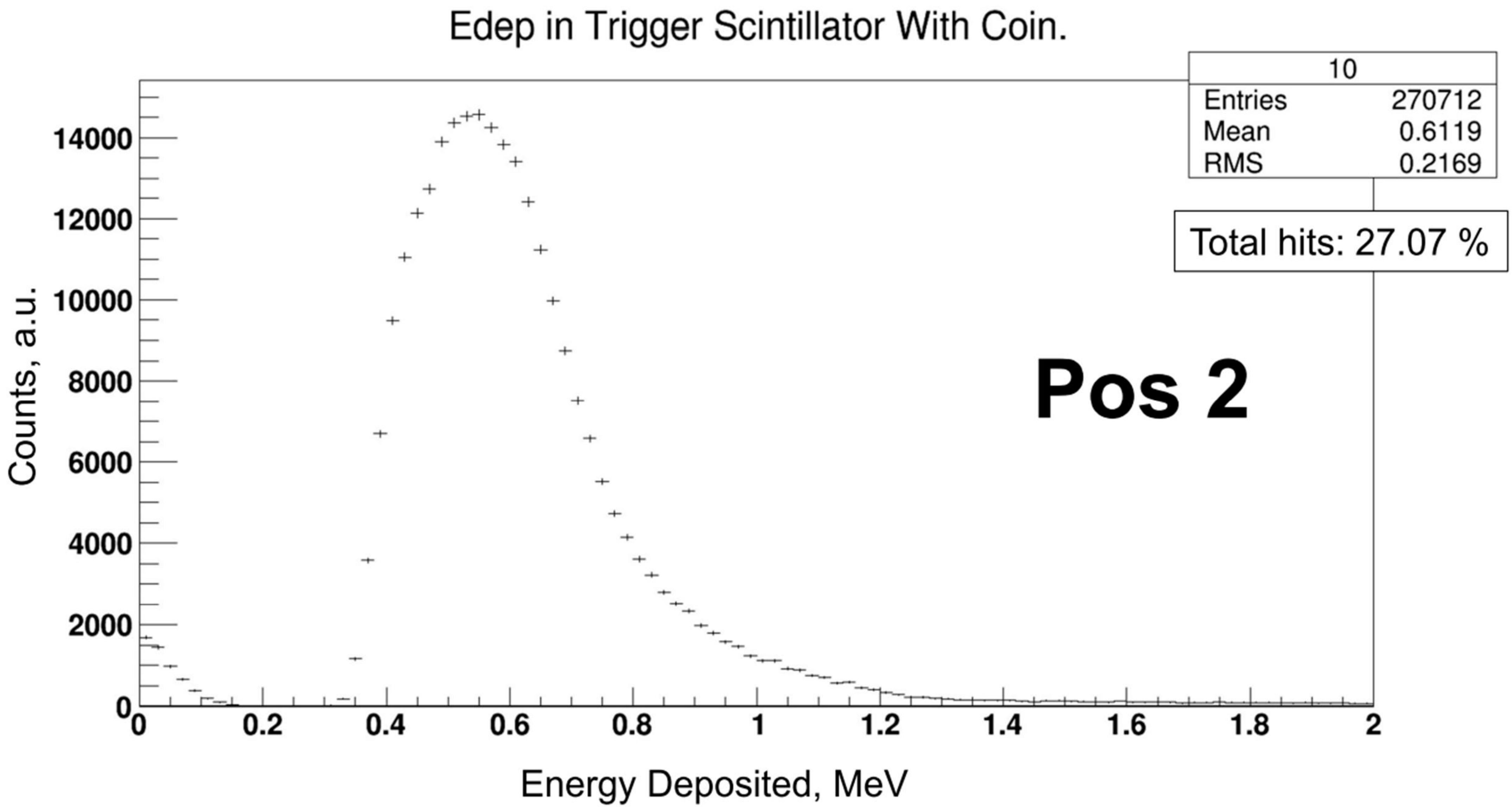




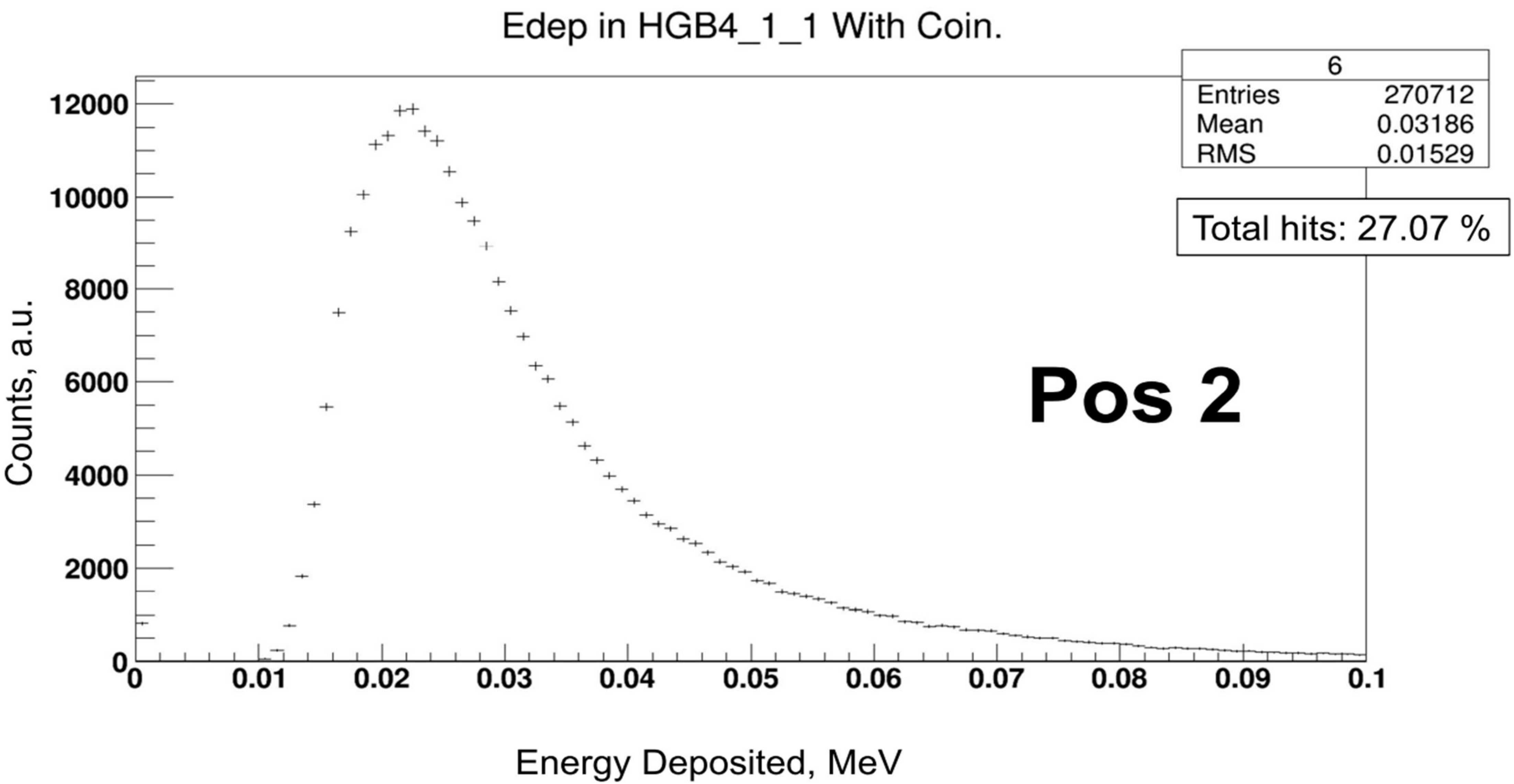
TEST BEAM - GEANT4 SIMULATIONS



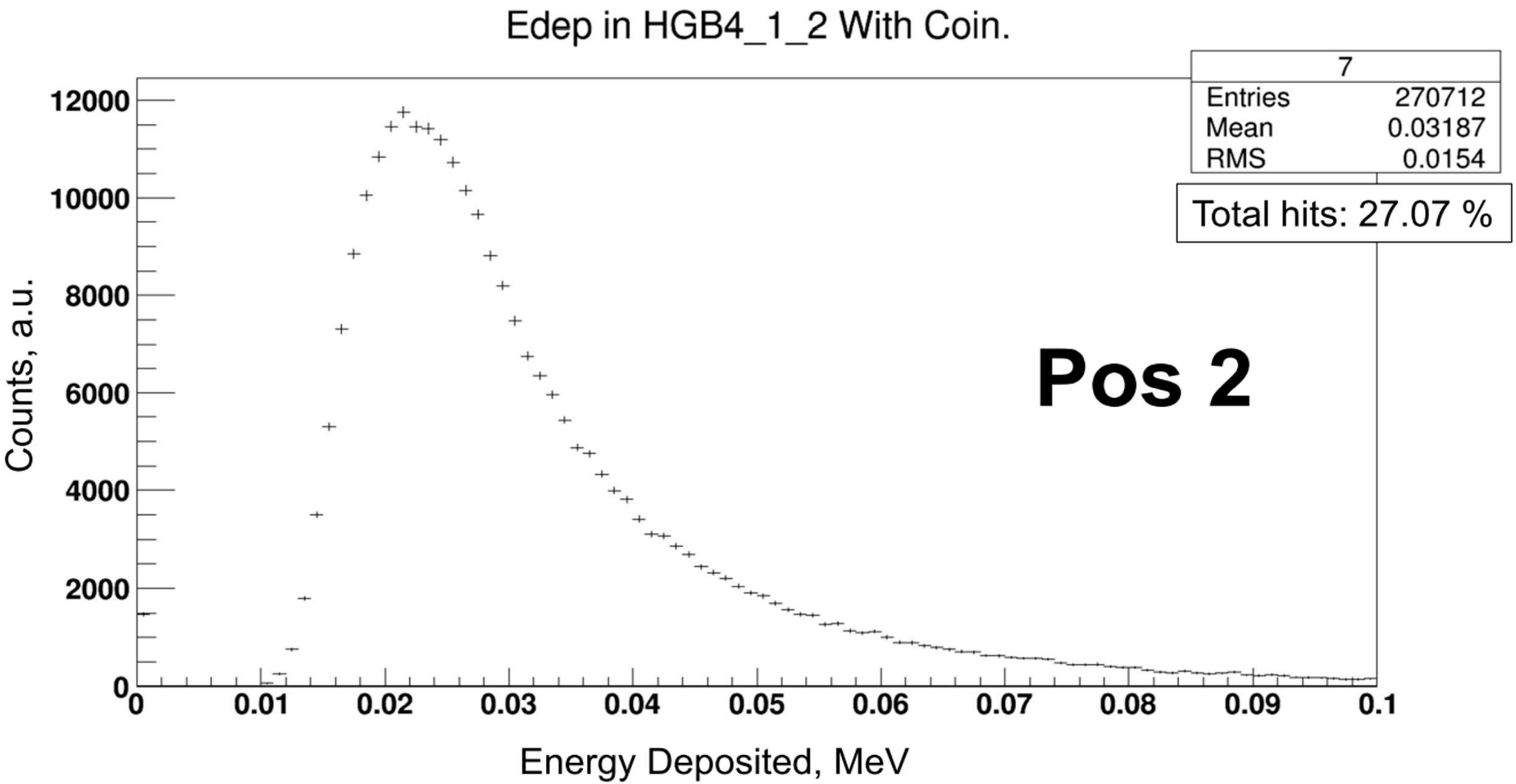
TEST BEAM - GEANT4 SIMULATIONS (cont.)



TEST BEAM - GEANT4 SIMULATIONS (cont.)

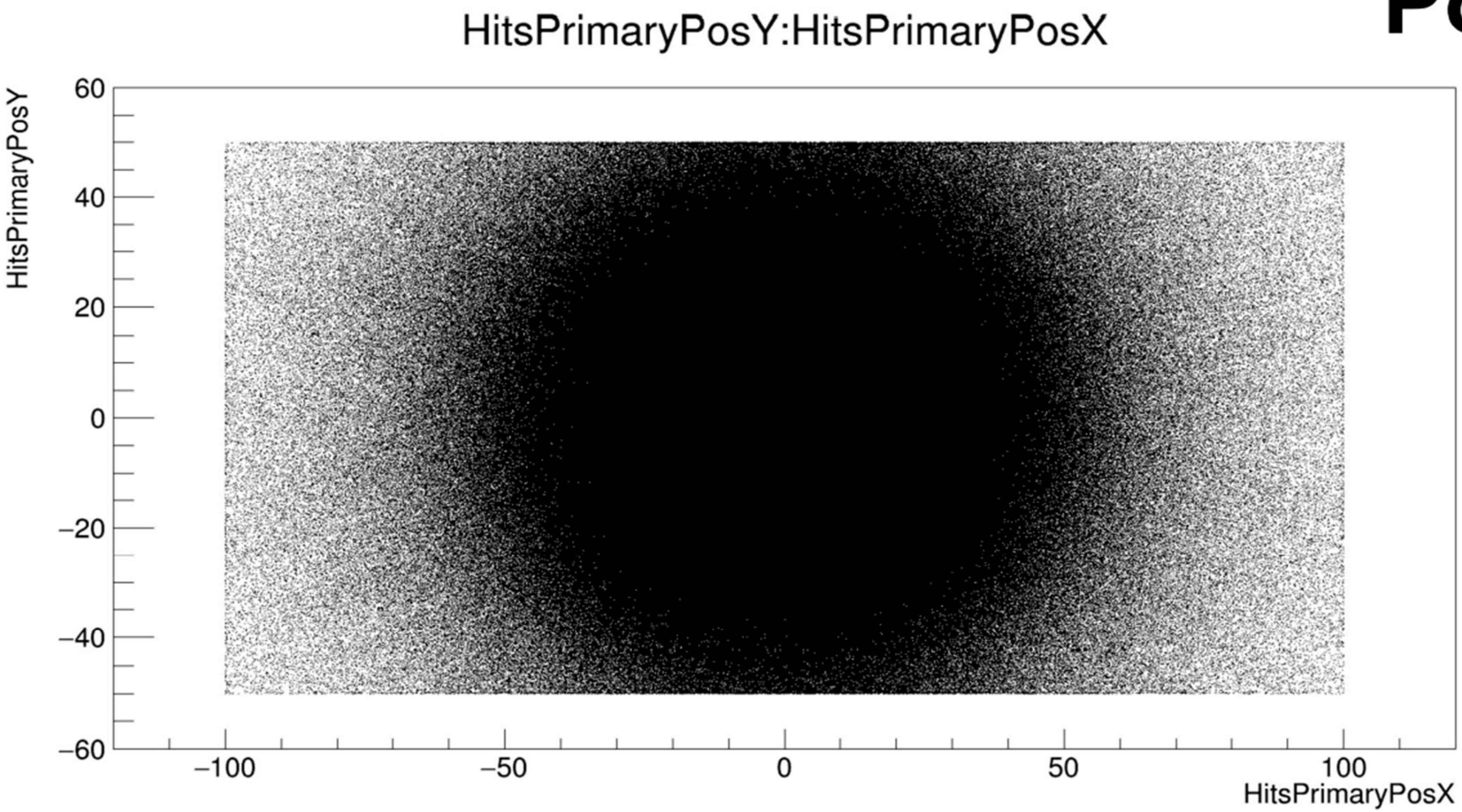


TEST BEAM - GEANT4 SIMULATIONS (cont.)



TEST BEAM - GEANT4 SIMULATIONS (cont.)

Pos 2



TEST BEAM - GEANT4 SIMULATIONS (cont.)

Educated guess:

From Simulations:

$\Delta E \approx 20$ KeV (Landau distr.)

$N_{e\text{-}i\ pair} = 678$ e-

From Electronics:

G = 2 mV/fC

$\tau_{rise} = 120$ ns

From Oscilloscope:

$\Delta V = 40$ mV → 20 fC

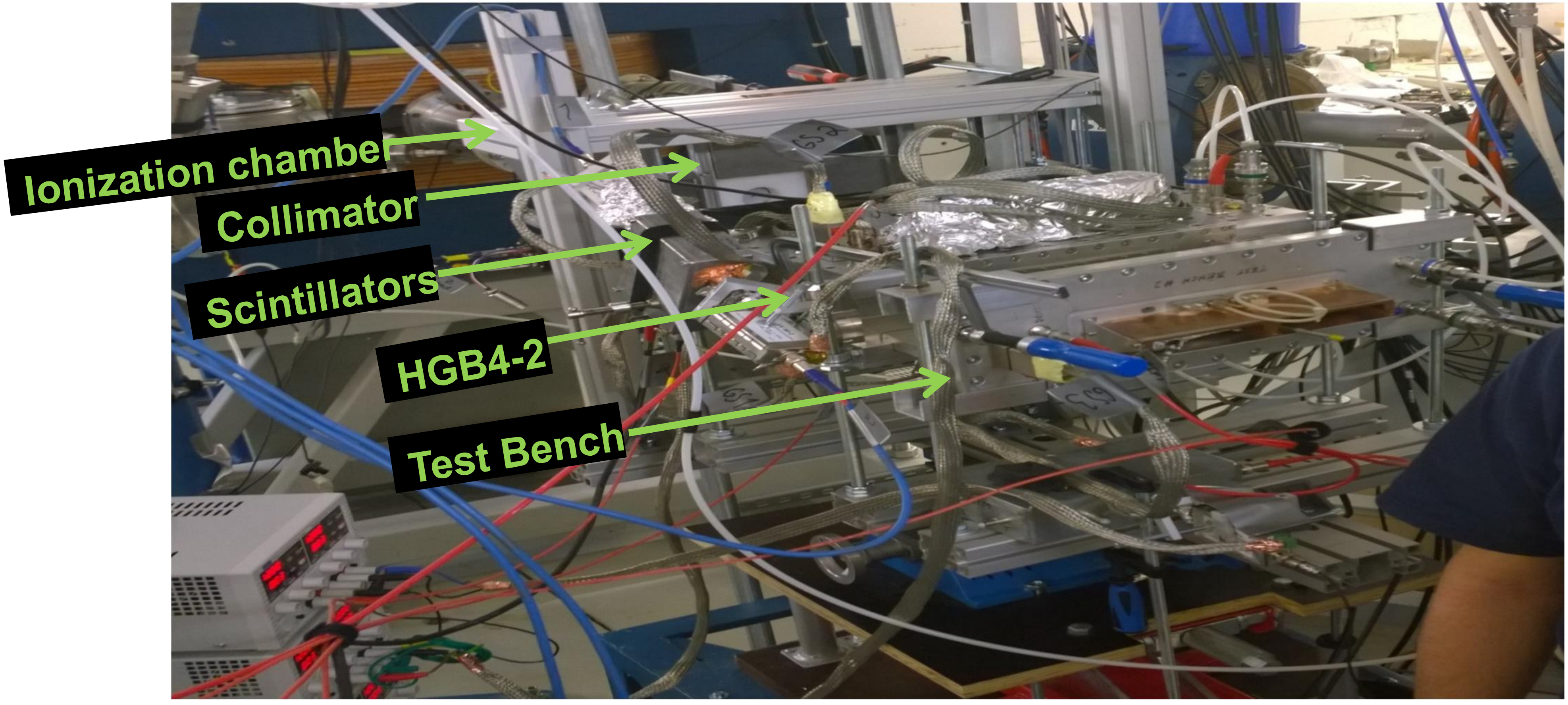
20 fC = 125000 e-

$Gain_{eff} = 184$ (per GEM-TPC)

The other one was several times higher.

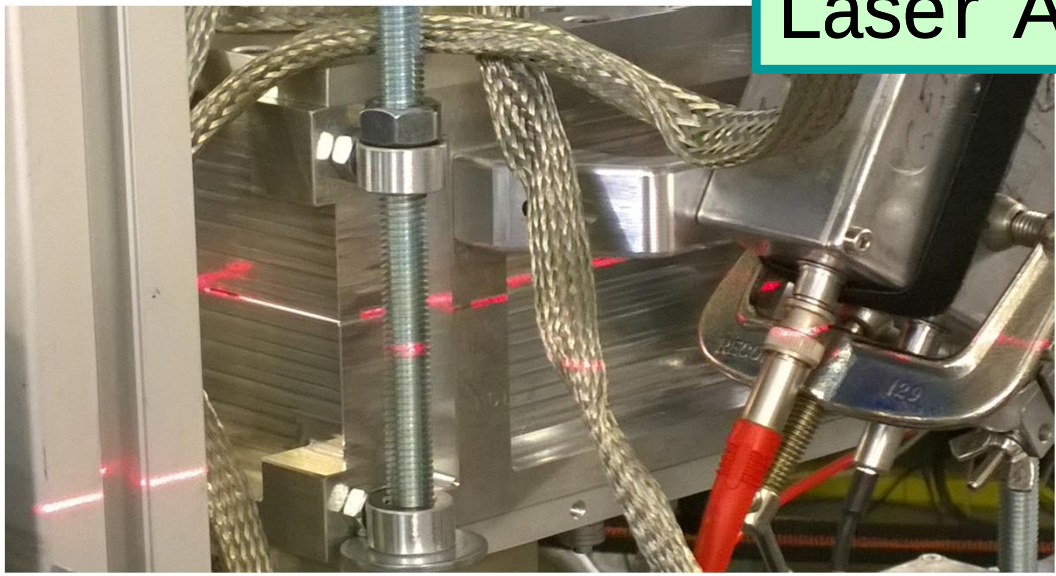
TEST BEAM at JYVÄSKYLÄ for PROTONS

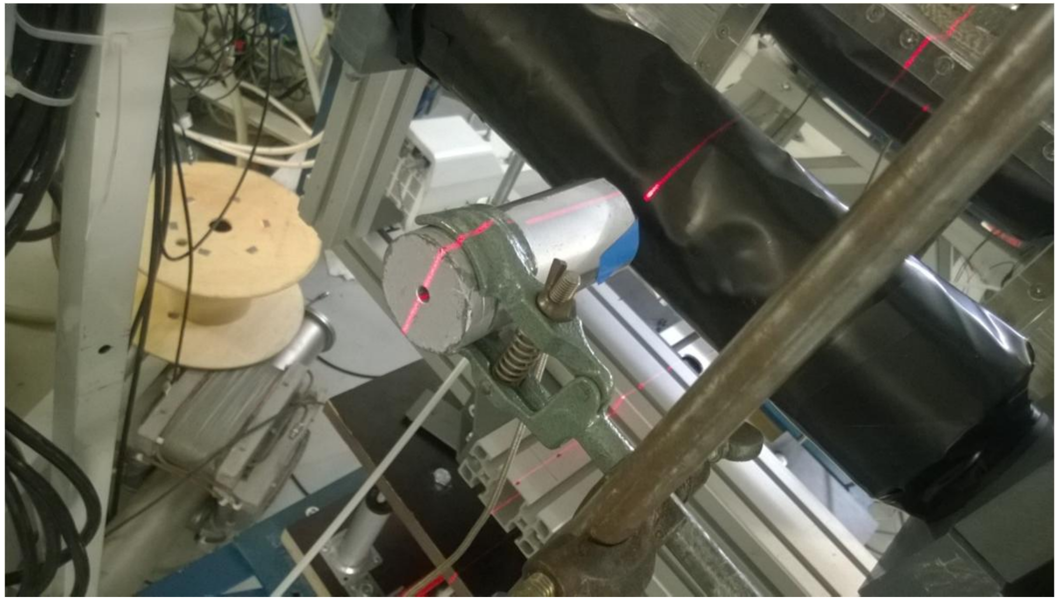
Geometry of the Setup

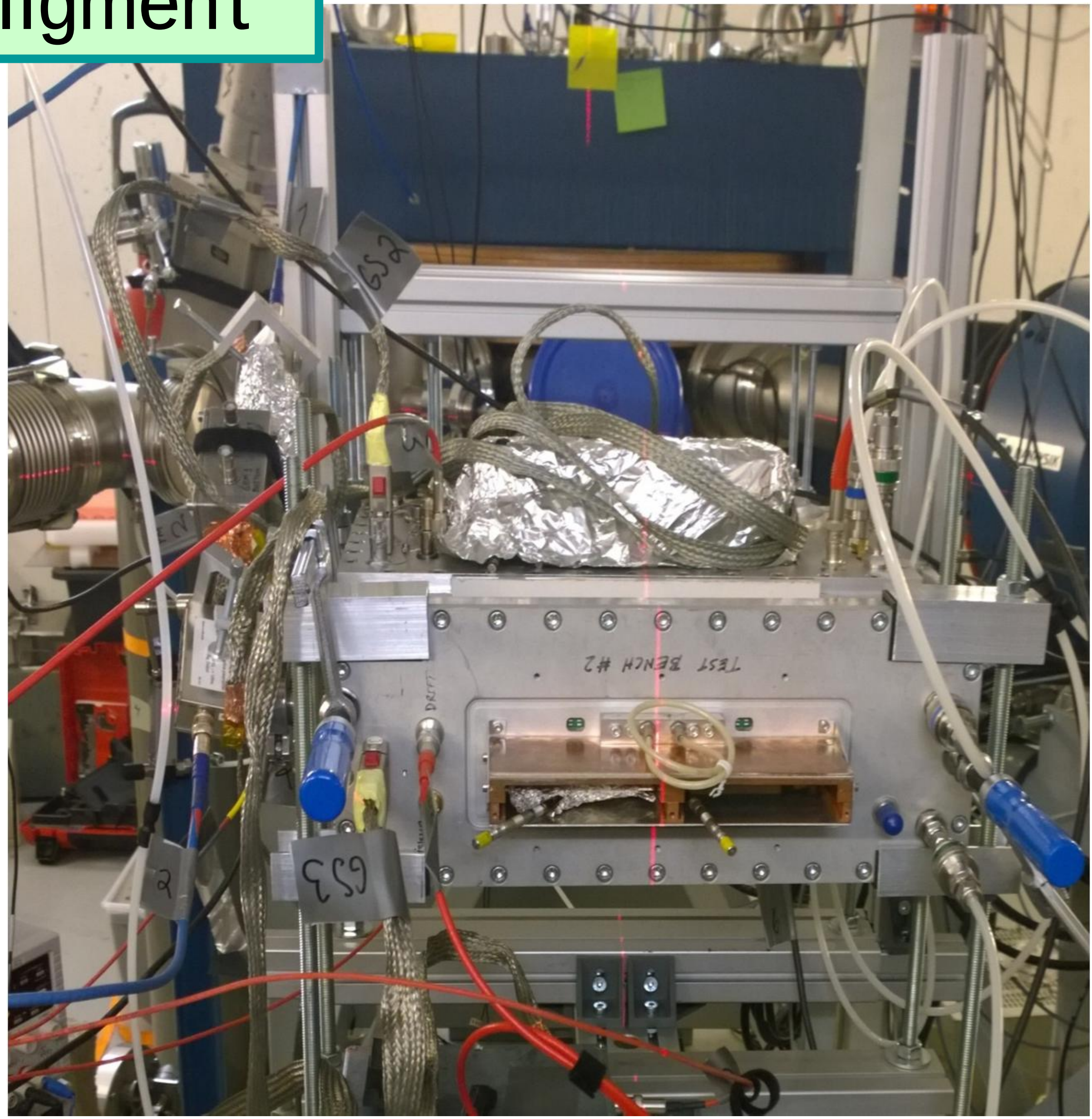


TEST BEAM at JYVÄSKYLÄ for PROTONS (cont.)

Laser Aligment

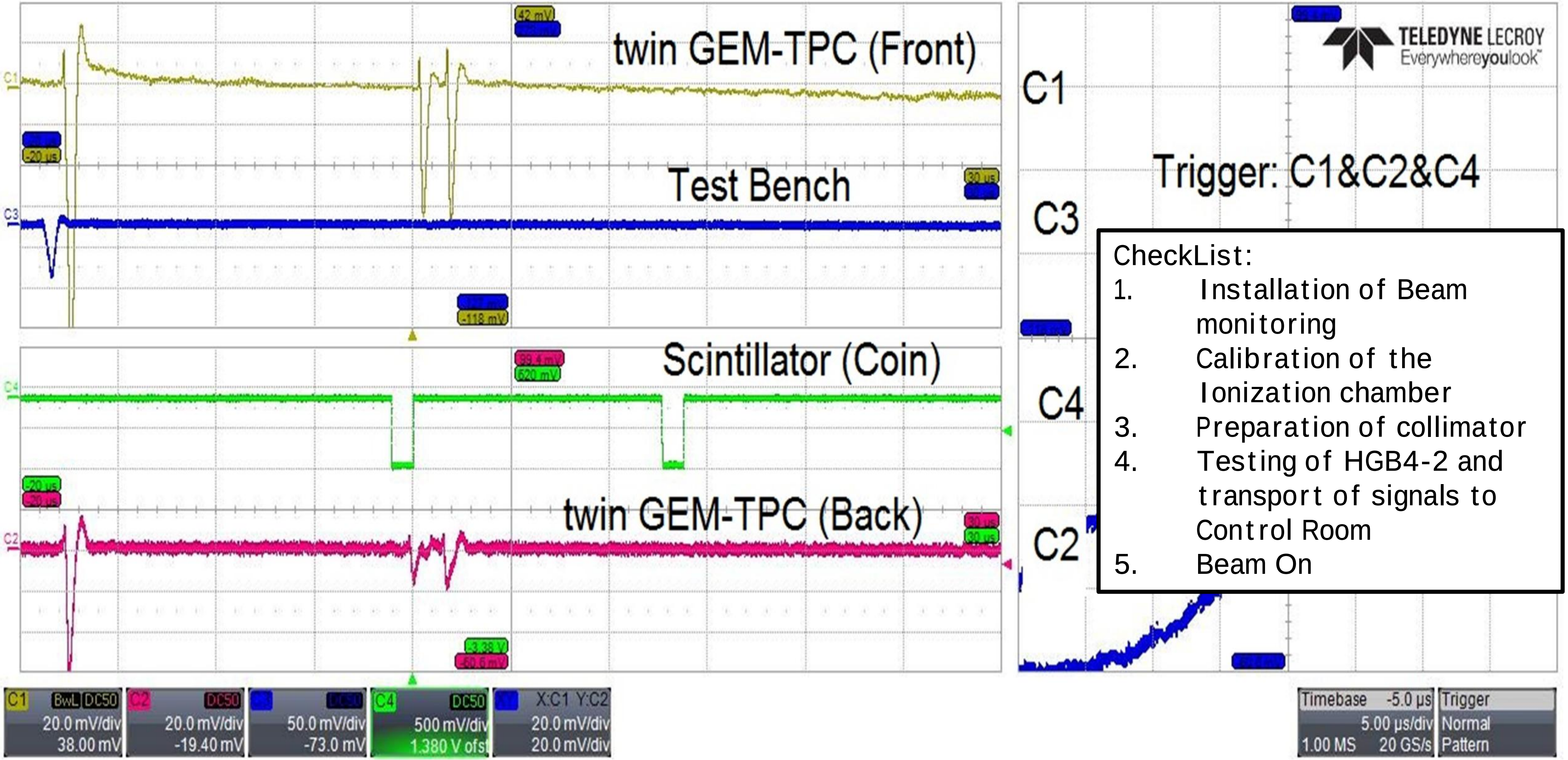






TEST BEAM at JYVÄSKYLÄ for PROTONS (cont.)

Collimator, rate: 65 kHz

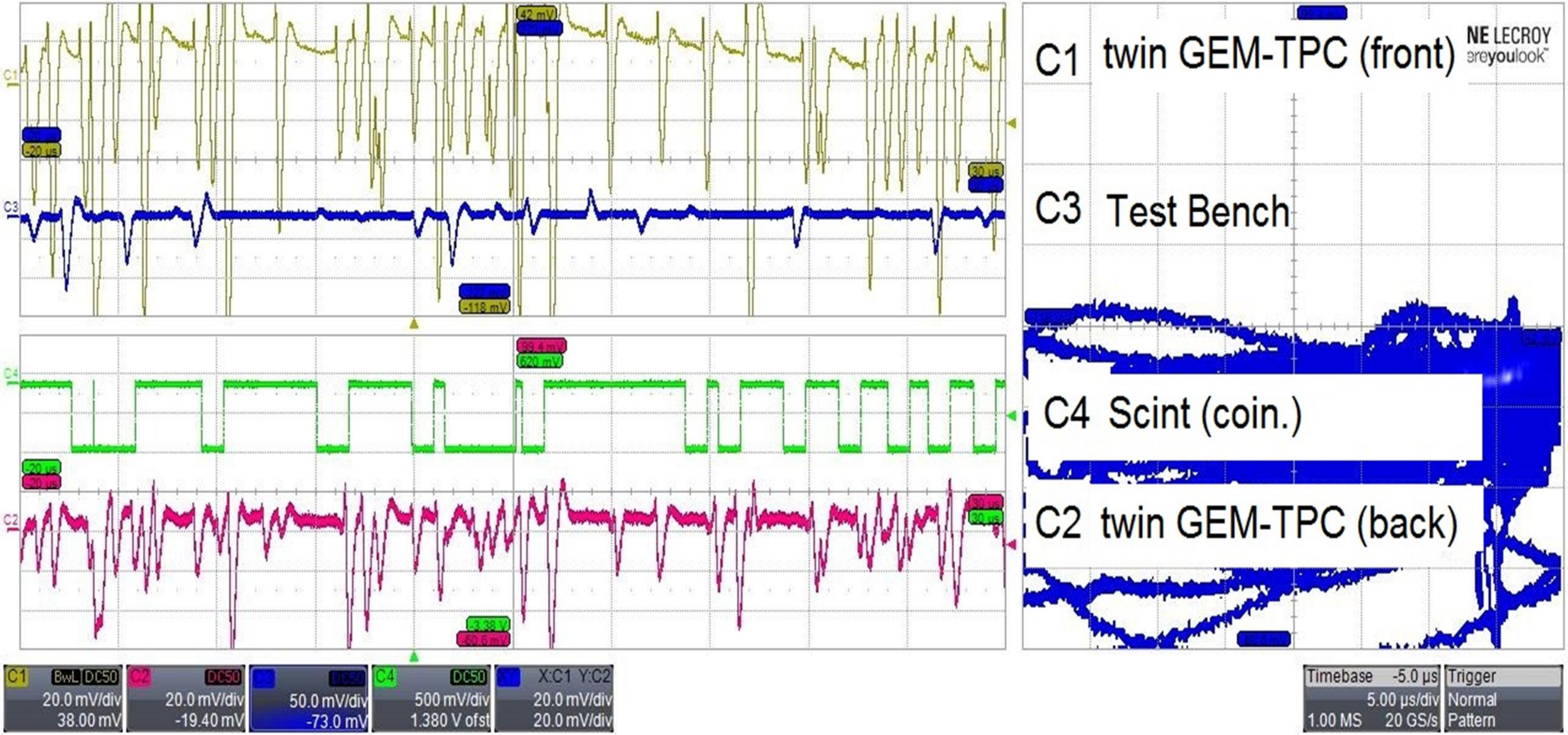


CheckList:

1. Installation of Beam monitoring
2. Calibration of the Ionization chamber
3. Preparation of collimator
4. Testing of HGB4-2 and transport of signals to Control Room
5. Beam On

TEST BEAM at JYVÄSKYLÄ for PROTONS (cont.)

No Collimator, rate: 2.20 MHz



TEST BEAM at JYVÄSKYLÄ for PROTONS (cont.)

Power supply at 2.20 MHz

iseg OPC Control Version 1.0

File System Module Channel Help

Connected Modules: can0.ma00 800004

Connected to N06C2 sn. 800004 at can0.ma00

	Vset (V)	Vmeas (V)	Vnominal (V)	Iset (mA)	Imeas (mA)	Inominal (mA)	Status
Channel 0	5 402.0	-5 402.0	-6 000.0	0.118	-0.117	1.000	Constant Voltage
Channel 1	3 132.0	-3 132.0	-6 000.0	0.630	-0.622	1.000	Constant Voltage
Channel 2	5 500.0	-5 500.0	-6 000.0	0.109	-0.107	1.000	Constant Voltage
Channel 3	3 181.0	-3 181.0	-6 000.0	0.590	-0.581	1.000	Constant Voltage
Channel 4	3 377.0	-3 377.0	-6 000.0	0.620	-0.615	1.000	Constant Voltage
Channel 5	1 000.0	-0.3	-6 000.0	0.571	0.000	1.000	Off

Power supply at 7.80 MHz

iseg OPC Control Version 1.0

File System Module Channel Help

Connected Modules: can0.ma00 800004

Connected to N06C2 sn. 800004 at can0.ma00

	Vset (V)	Vmeas (V)	Vnominal (V)	Iset (mA)	Imeas (mA)	Inominal (mA)	Status
Channel 0	5 402.0	-5 402.0	-6 000.0	0.119	-0.117	1.000	Constant Voltage
Channel 1	3 132.0	-3 132.0	-6 000.0	0.629	-0.627	1.000	Constant Voltage
Channel 2	5 500.0	-5 500.0	-6 000.0	0.109	-0.107	1.000	Constant Voltage
Channel 3	3 181.0	-3 181.0	-6 000.0	0.584	-0.582	1.000	Constant Voltage
Channel 4	3 377.0	-3 377.0	-6 000.0	0.620	-0.616	1.000	Constant Voltage
Channel 5	1 000.0	-0.3	-6 000.0	0.571	0.000	1.000	Off

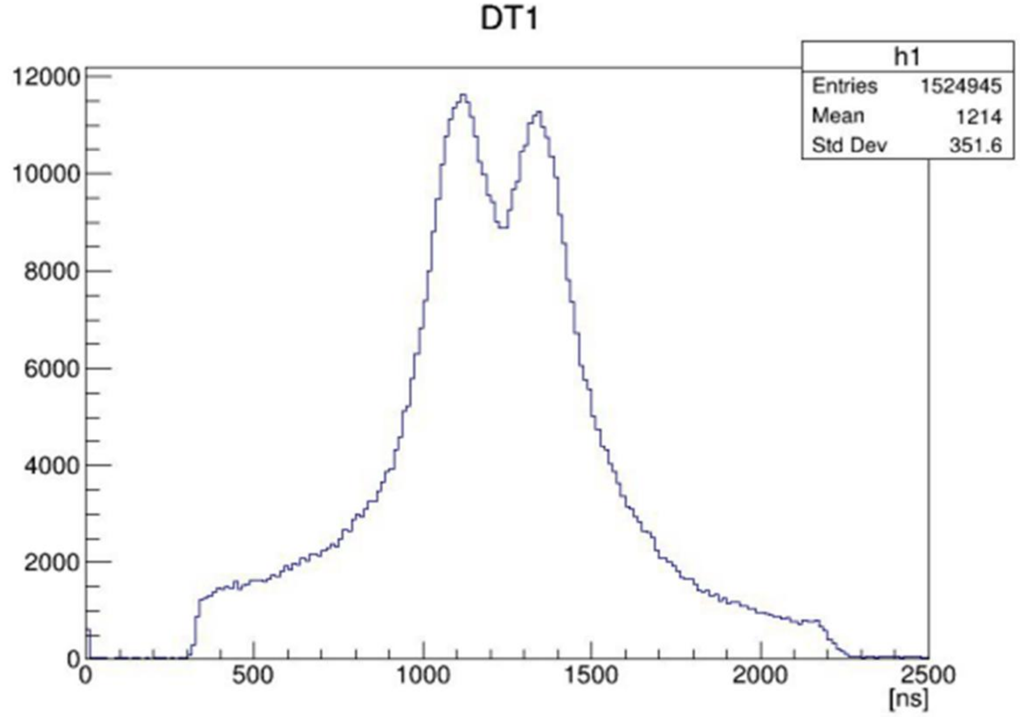
Leyend:
Channel 0 = Cathode of Field cage (Front)
Channel 1 = GEM stack (Front)
Channel 2 = Cathode of Field cage (Back)
Channel 3 = GEM stack (Back)
Channel 4 = Test Bench

TEST BEAM at JYVÄSKYLÄ for PROTONS (cont.)

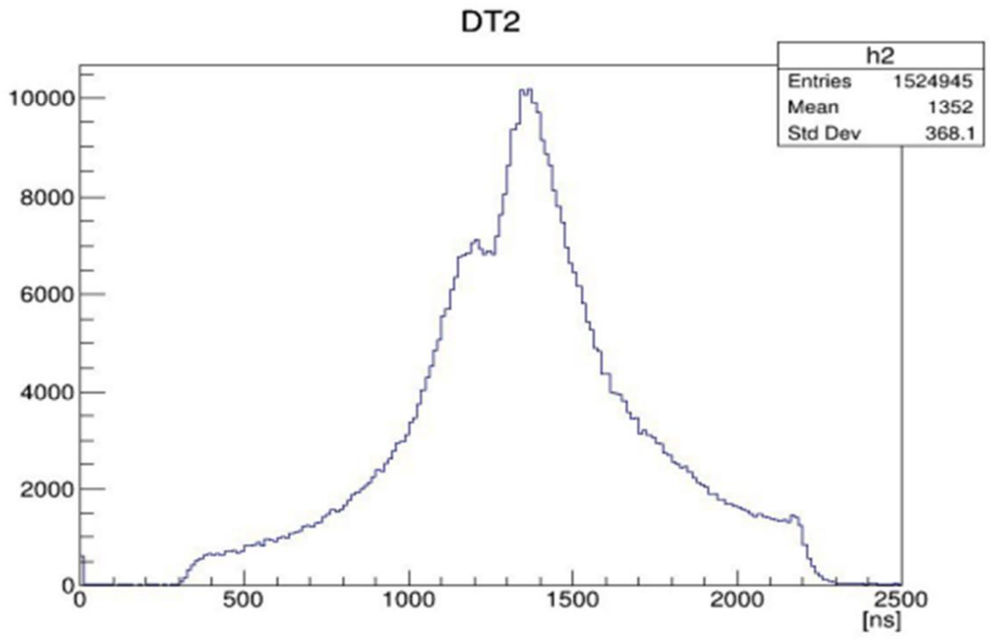
Online Drift Time Spectra, 5kHz rate, with collimator

File #21

Drift Time 1



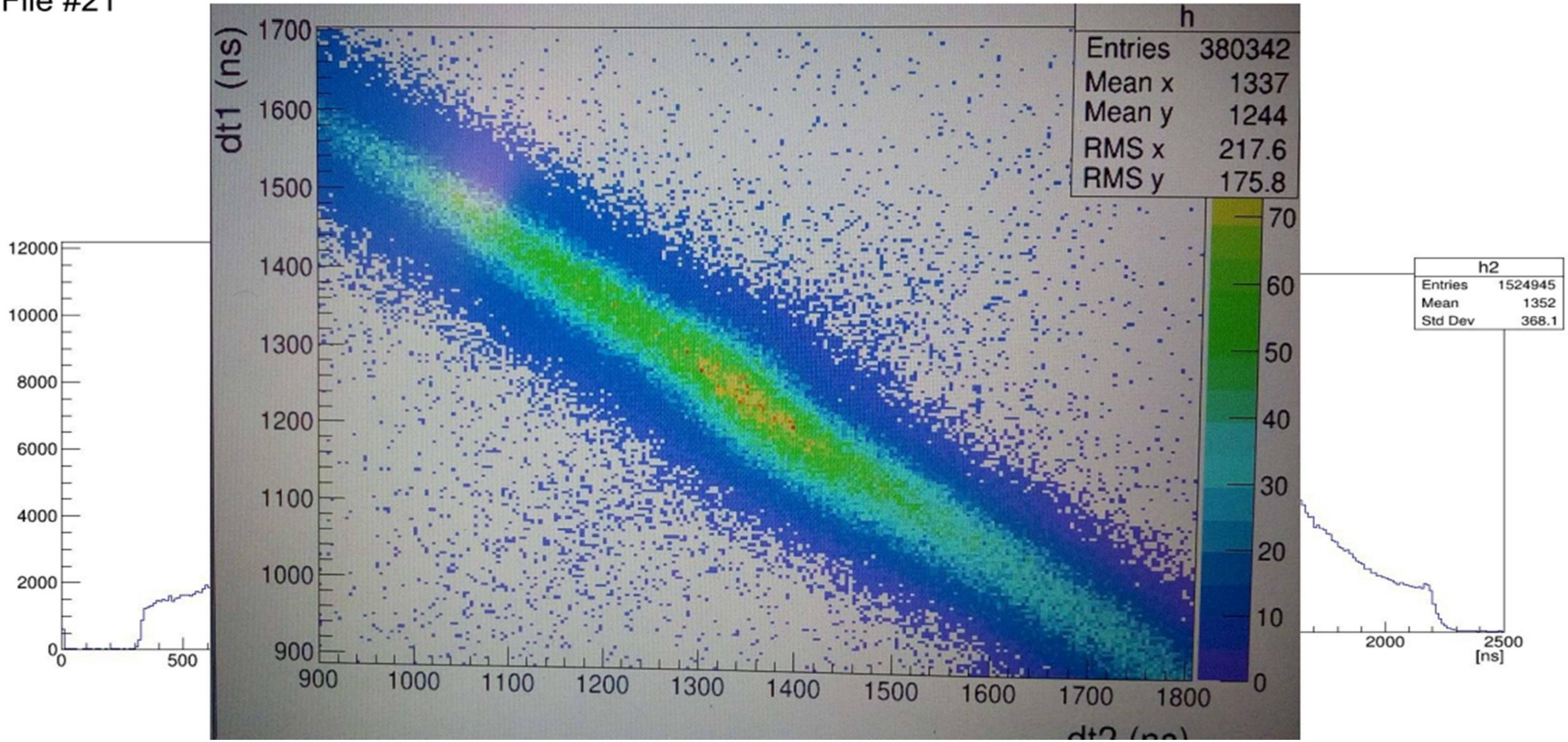
Drift Time 2



TEST BEAM at JYVÄSKYLÄ for PROTONS (cont.)

Online Drift Time Spectra, 5kHz rate, with collimator

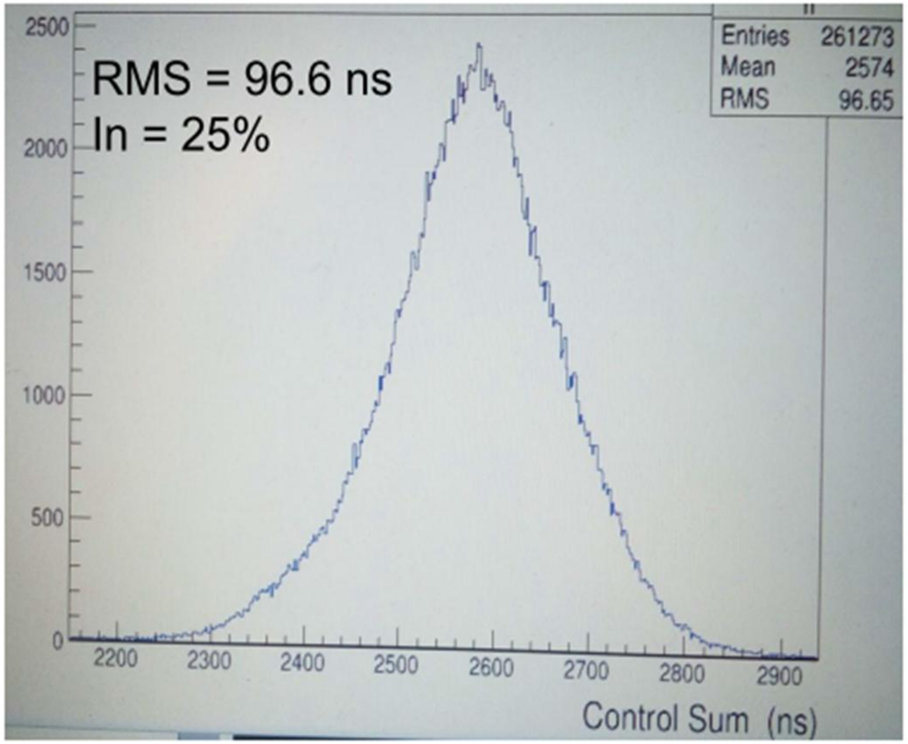
File #21



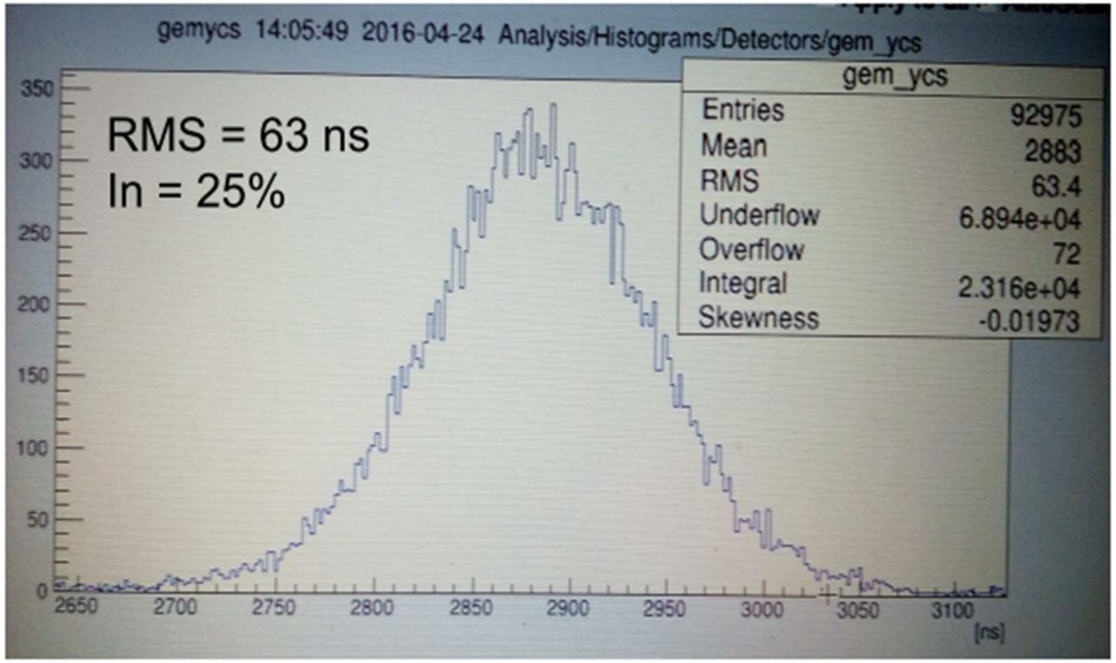
TEST BEAM at JYVÄSKYLÄ for PROTONS (cont.)

CS with and without collimator

With collimator



Without collimator



OUTLOOK

1. Continuing with the optimization of the operational parameters, in terms of time performance keeping same stability

2. Procurement of fast preamplifiers, targeting 10, 15 and 50 ns full signal width, to be able to compare with VMM2/3 discretization of 25 ns

3. Try to get the CPE connectors implemented on the FB-057 (Bottom flange)

4. Prepare a campaign for long terms operation stability and radiation damged studies

5. Detection of Protons has becomed possible.....

COLLABORATORS

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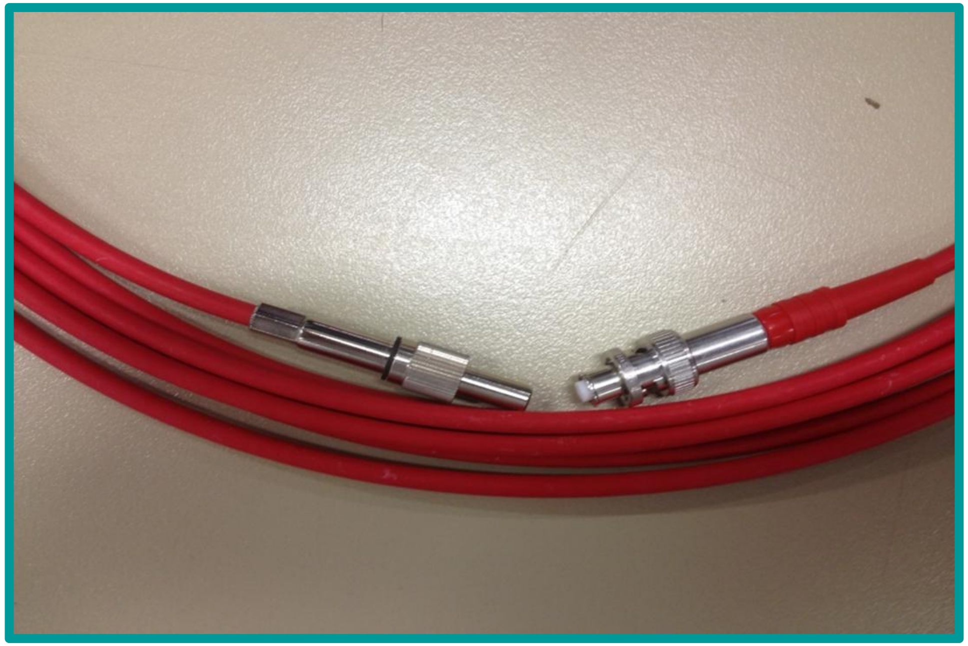
Detector Laboratory – GSI – Darmstadt - Germany

J. Hoffmann, N. Kurz, I. Rusanov, P. Skott, M. Shizu
EE - GSI – Darmstadt - Germany

Thank you for your Attention

BACKUP SLIDES

CPE Connectors



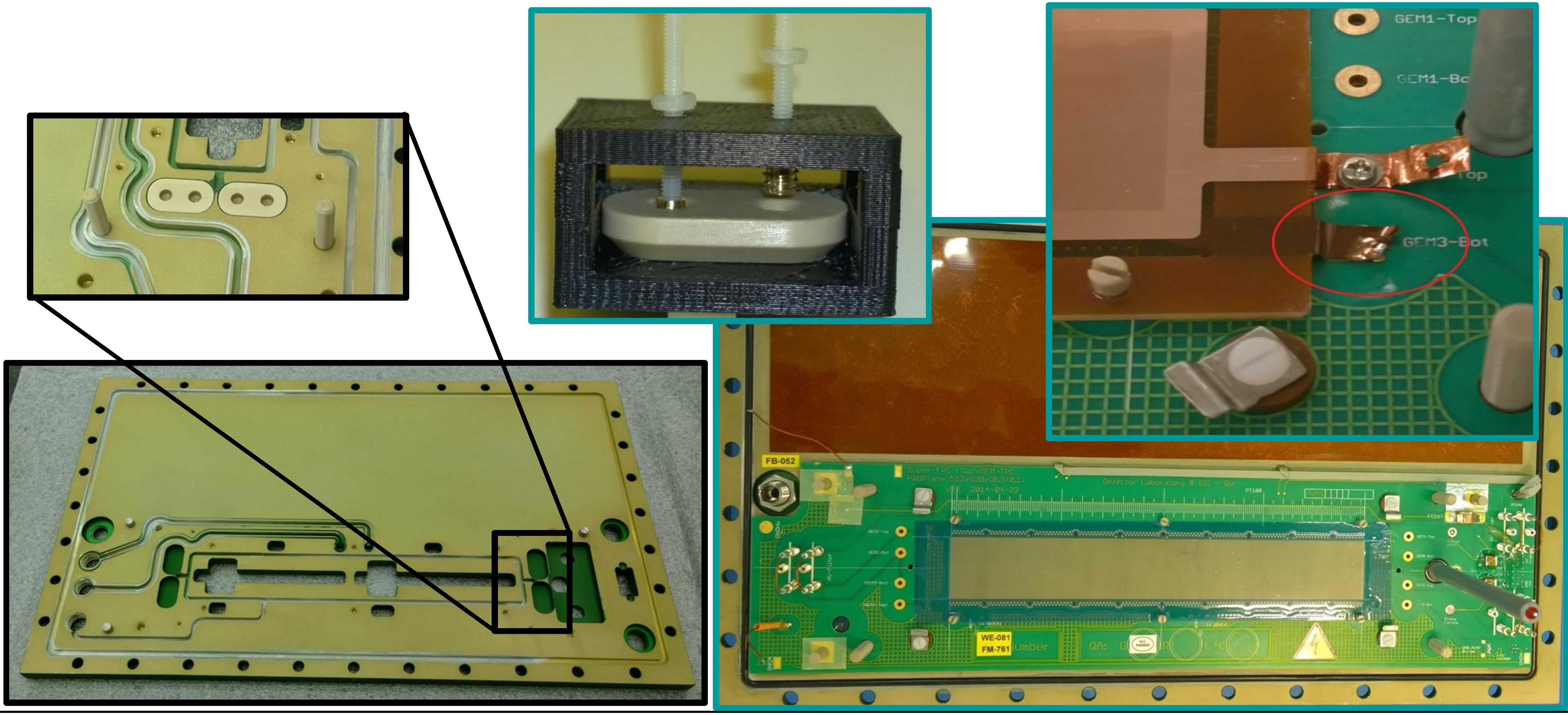
CPE to SHV cable

CPE female flange

http://www.cpeitalia.it/high_voltage_connectors.html#

BACKUP SLIDES

GEM-TPC none Equalization cause

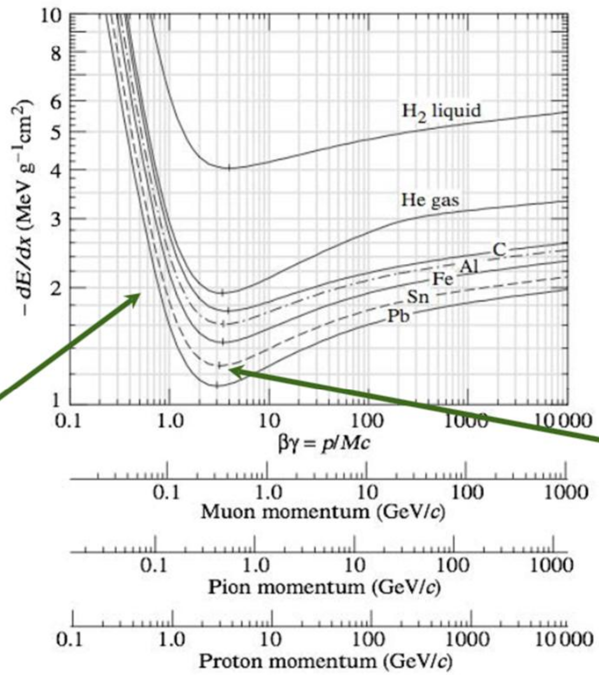


BACKUP SLIDES

From Theory:

- Minimum for $\beta\gamma \approx 3.5$
  energy loss in the mimimum:

$$\left.\frac{dE}{dx}\right|_{min} \approx 1.5\frac{MeV \cdot cm^2}{g}$$



$1/\beta^2$

Bethe-Bloch formula:

$$-\frac{dE}{dx} = Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln f(\beta) - \beta^2 - \frac{\delta(\beta\gamma)}{2}\right]$$

Except in hydrogen, particles of the same velocity have similar energy loss in different materials.

The minimum in ionisation occurs at $\beta\gamma$ = 3.5 to 3.0, as Z goes from 7 to 100

Figure 27.3: Mean energy loss rate in liquid (bubble chamber) hydrogen, gaseous helium, carbon, aluminum, iron, tin, and lead. Radiative effects, relevant for muons and pions, are not included. These become significant for muons in iron for $\beta\gamma \gtrsim 1000$, and at lower momenta for muons in higher-Z absorbers. See Fig. 27.21.

PDG 2008

From GEANT4: