GEM-TPC in twin configuration (HGB4) a tracking detector for the Super-FRS - Test beam results at Jyväskylä and GSI

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OUTLINE

1. Introduction and Motivation
2. Prototype Developments
3. Indications and Mitigations
4. Test Beam at Jyväskylä
5. Test beam at GSI
6. Improvements of Timing response
7. Outlook

INTRODUCTION & MOTIVATION

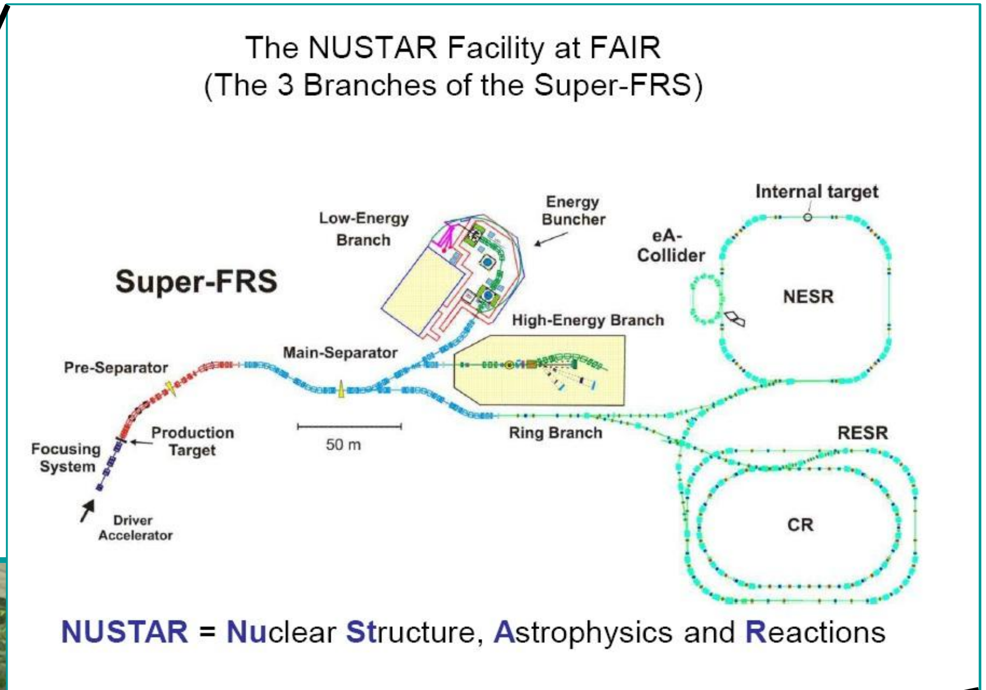
FAIR is a Facility for Antiproton and Ion Research in Darmstadt

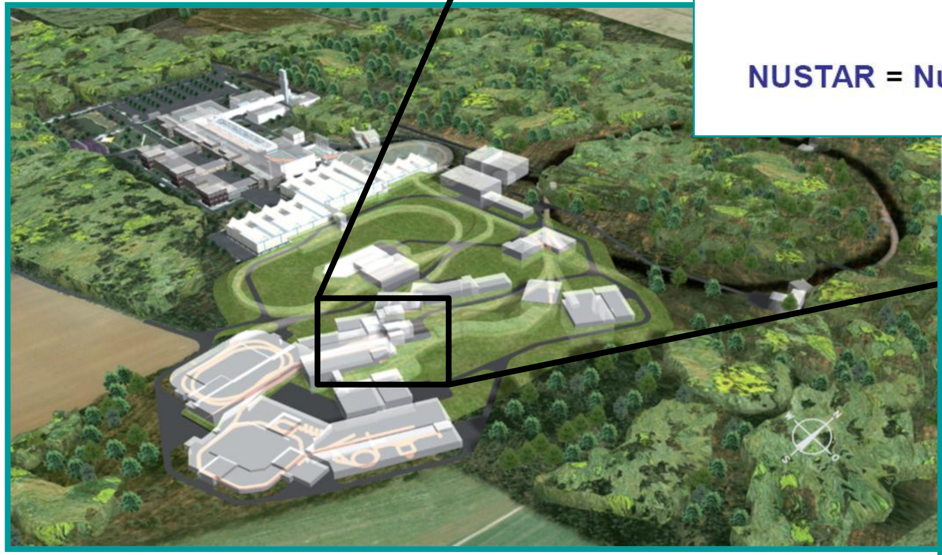
The concept of the FAIR Facility aims for a multifaceted forefront science program, beams of stable and unstable nuclei as well as antiprotons in a wide range of intensities and energies, with optimum beam qualities

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 (1 kHz/mm^2)
2.- Large dynamic range, from Physics
3.- Spatial Resolution ~ 500 μm
4.- Tracking efficiency close to 100%
5.- Operation in Air and Vacuum





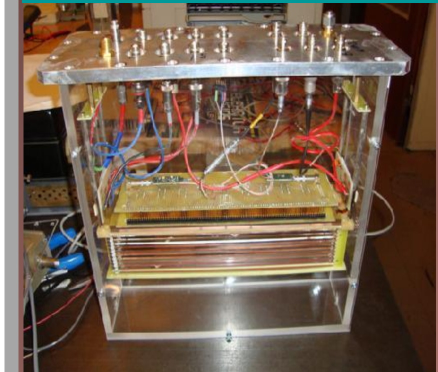
Time line:
R&D finish and Design frozen: Q4/2016

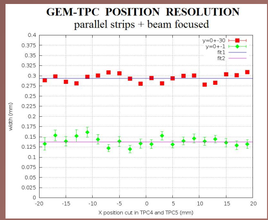
Mass production: Q1/2018 - Q2/2020

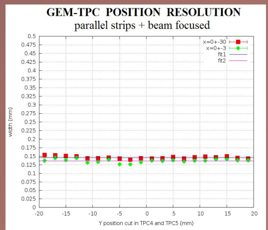
Part of the Finnish Contribution will be in Diagnostic systems, which is a work package dedicated to provide 36 GEM-TPC detectors.

PROTOTYPE DEVELOPMENTS

GEM-TPC HB1, with delayed lines



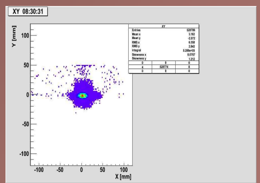


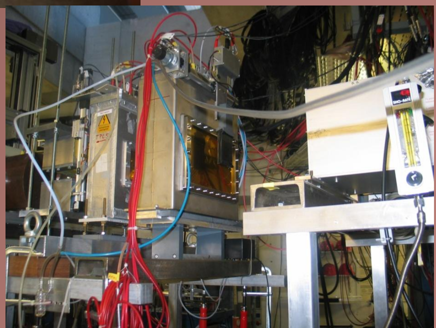


Beam profile

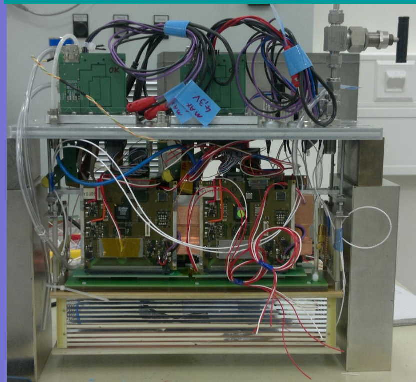
^{64}Ni ions at 550 MeV/u

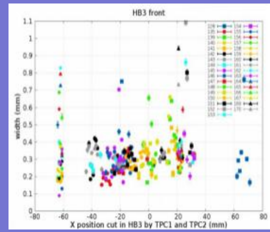
At the prespec experiment - S363

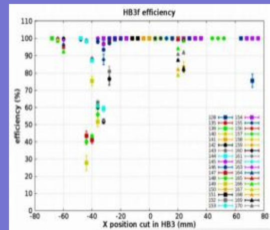




GEM-TPC HB3, with GEMEX readout

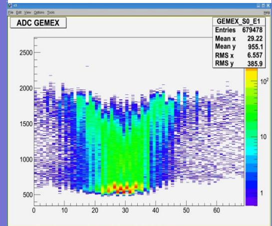




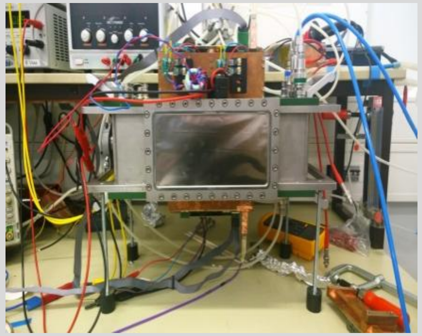


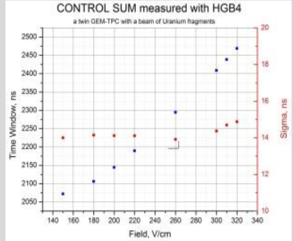
HB3 @ S2 and Beam test of ^{197}Au at 770 MeV/u

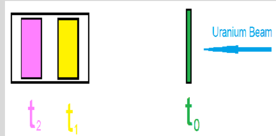
Hits Projection on X axis



Twin GEM-TPC HGB4, with GEMEX readout



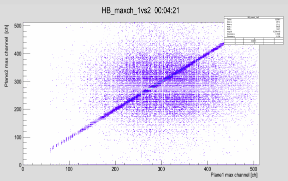




Projectiles: ^{238}U @ 330 MeV/u

Master Trigger from Sofia experiment

Hits Projection on X axis for both twin GEM-TPC



Details at:

1. NUSTAR Annual meeting 2012 at GSI → https://indico.gsi.de/conferenceOtherViews.py?view=standard&confId=1413 / https://tuhat.helsinki.fi/portal/files/72659836/NUSTARmeetingInGSI_FG.pdf
2. NUSTAR Week 2013 at HIP → https://indico.gsi.de/conferenceOtherViews.py?view=standard&confId=2391
3. IWAD and 14th RD51 Collaboration Meeting 2014 → http://indico.vecc.gov.in/indico/conferenceOtherViews.py?view=standard&confId=31
4. NUSTAR Annual meeting 2015 at GSI → https://indico.gsi.de/conferenceOtherViews.py?view=standard&confId=2716
5. Local GEM-TPC meetings at CERN Indico → http://indico.cern.ch/category/4912/ (33 events)

PROTOTYPE DEVELOPMENTS (cont.)

We end up in having:

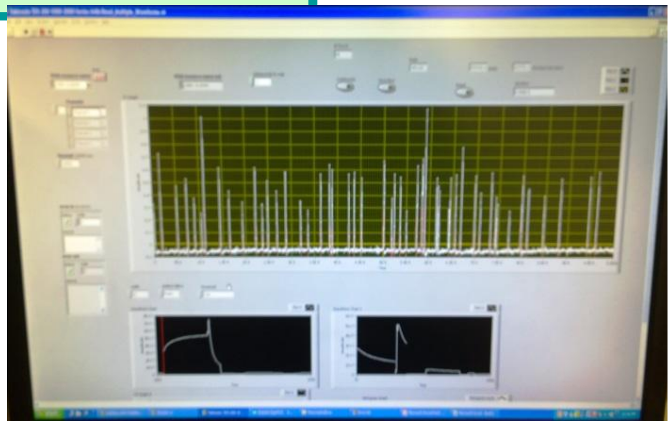
1. The GEM-TPC concept tested and performing very stable with good spatial resolution
2. Integration of high density readout electronics GEMEX to a GEM-TPC giving us a higher rate capability with good spatial resolution
3. The test of the first GEM-TPC in twin configuration was done and shows a very stable operation

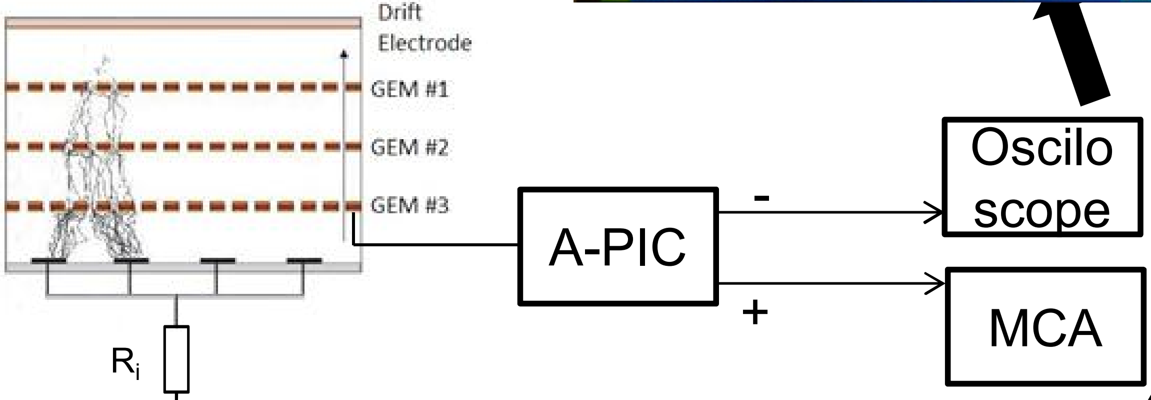
What we haven't done yet:

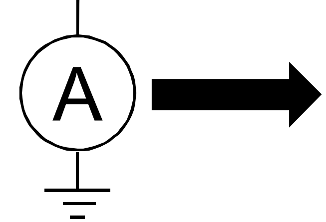
1. Operation at high rate → Measure tracking efficiency versus rate
2. Demonstrate the large dynamic range → which is coming from Physics
3. Check timing performance w.r.t. tracking efficiency
4. Full size system test → including all parameters (tracking efficiency/spatial resolution) versus rate → Usually call Precommissioning/Commissioning

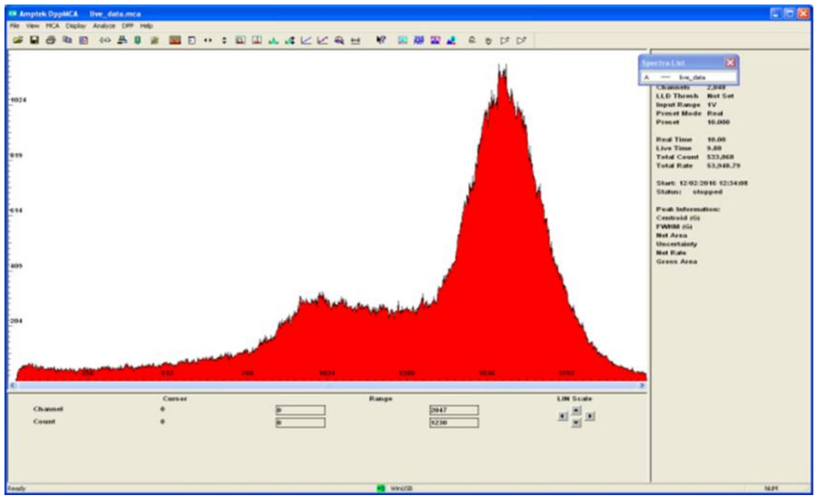
INDICATIONS AND MITIGATIONS (cont.)

Let's address **High Rate operation:**





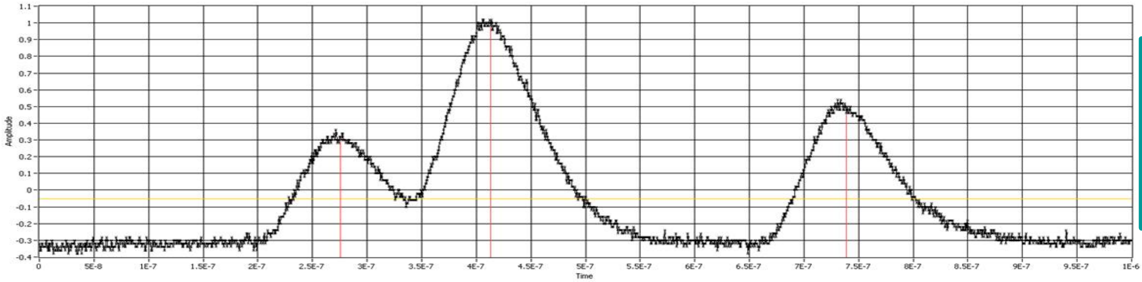




INDICATIONS AND MITIGATIONS (cont.)

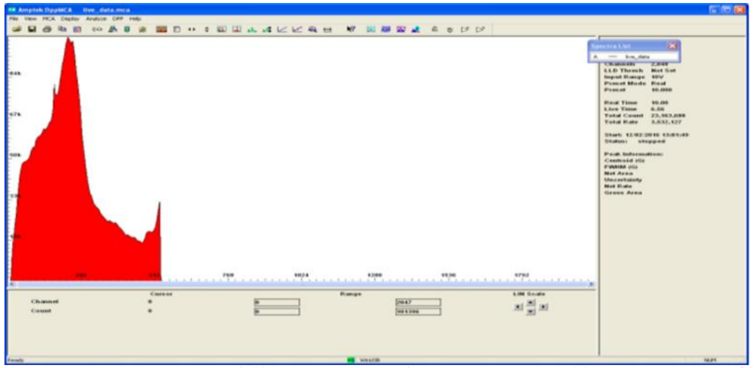
INTENSITY SCAN from 50 kHz/mm^2 - 3MHz/mm^2

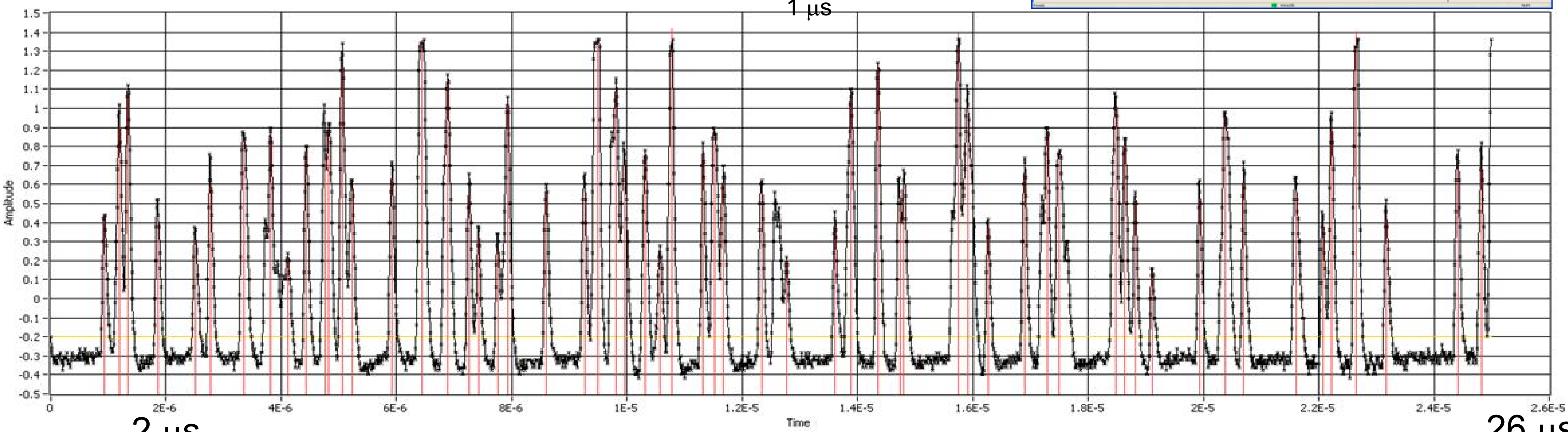
Fluence: 2 10^6 γ/mm^2



A-PIC:

Tpeak: 30 ns
Full Width: 150 ns
Gain: 2mV/fC





Details at:

RD51 Mini-Week (Dec. 2016) at CERN → https://indico.cern.ch/event/588409/

INDICATIONS AND MITIGATIONS (cont.)

Let's address **Large Dynamic range**:

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 desirable, which arrives to 1.5 pC/strip

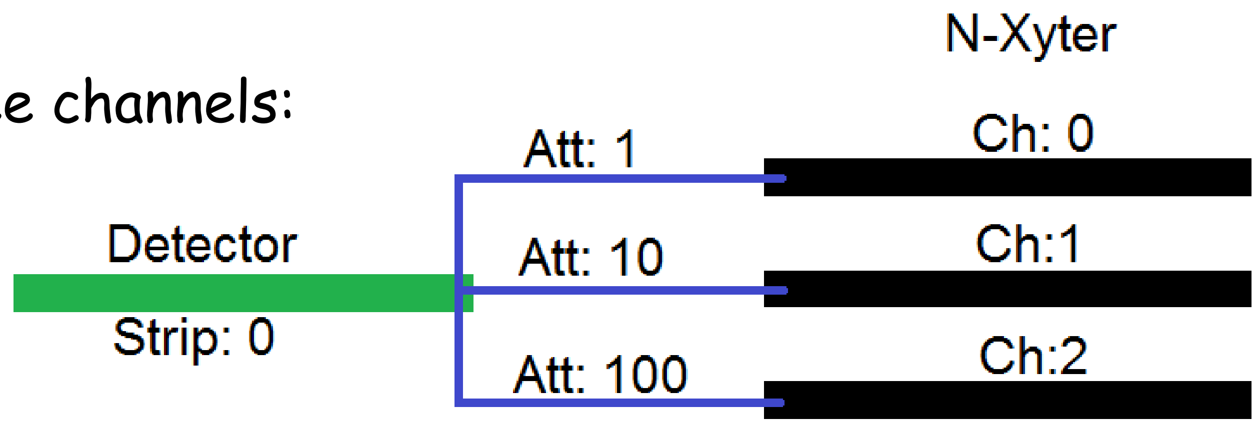
Keeping this in mind one can find a solution! → see next slide

INDICATIONS AND MITIGATIONS (cont.)

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

Split the incoming charge into three channels:

1 channel with attenuation of **1**
1 channel with attenuation of **10**
1 channel with attenuation of **100**



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

Another solution at this very moment is a fast ASIC called VMM3 (RadHard) which has 1 pC per channel dynamic range and can run up to a 1 MHz rate per channel.

Another possibility is to use an ASIC from the family of STS-XYTER (RadHard) chip for gas detectors (with spark protection)

Details at:

GDD lab meeting at CERN (May 2016) →
https://tuhat.helsinki.fi/portal/files/79092164/GDD_internalMeeting_04_05.pdf

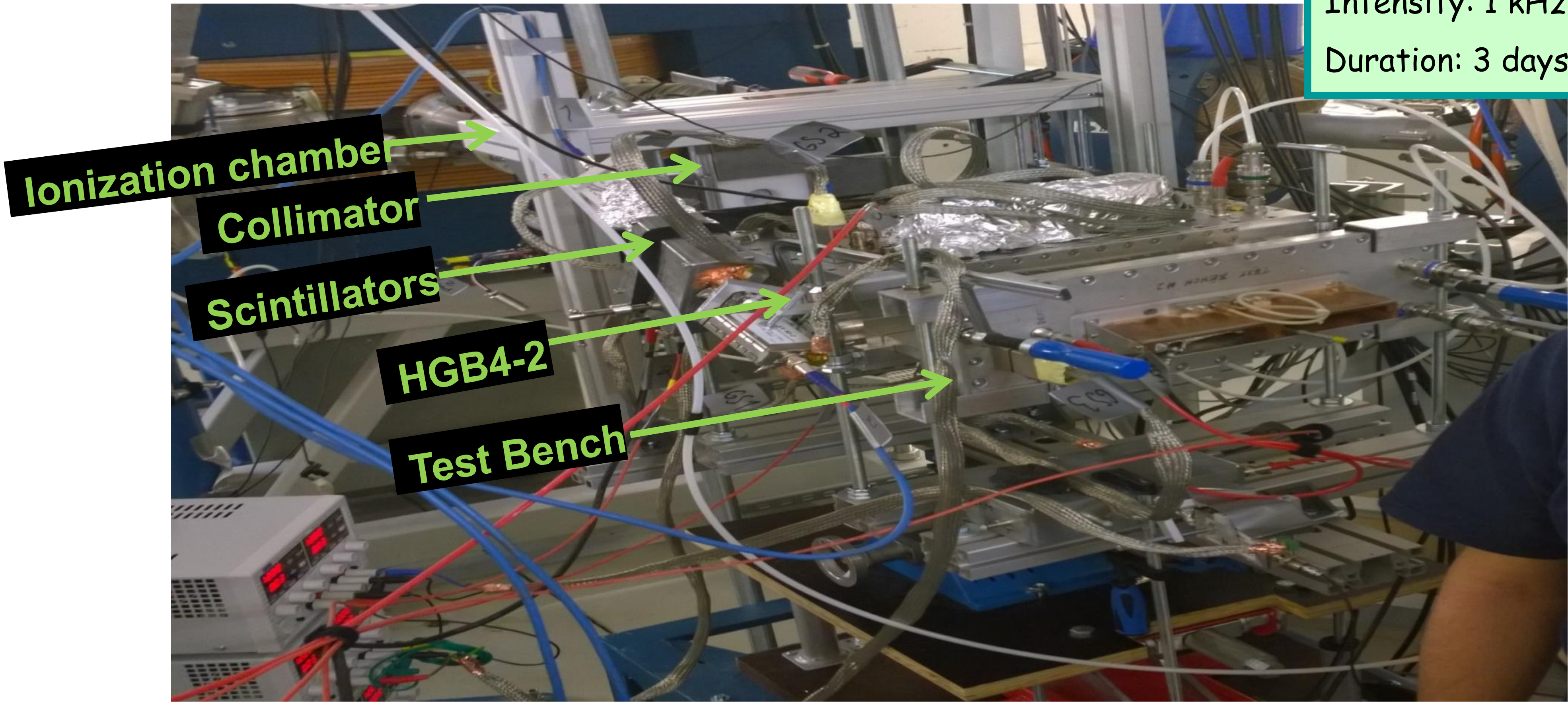
TEST BEAM at JYVÄSKYLÄ

Geometry of the Setup

Projectile: Proton

Intensity: 1 kHz – 7 MHz

Duration: 3 days

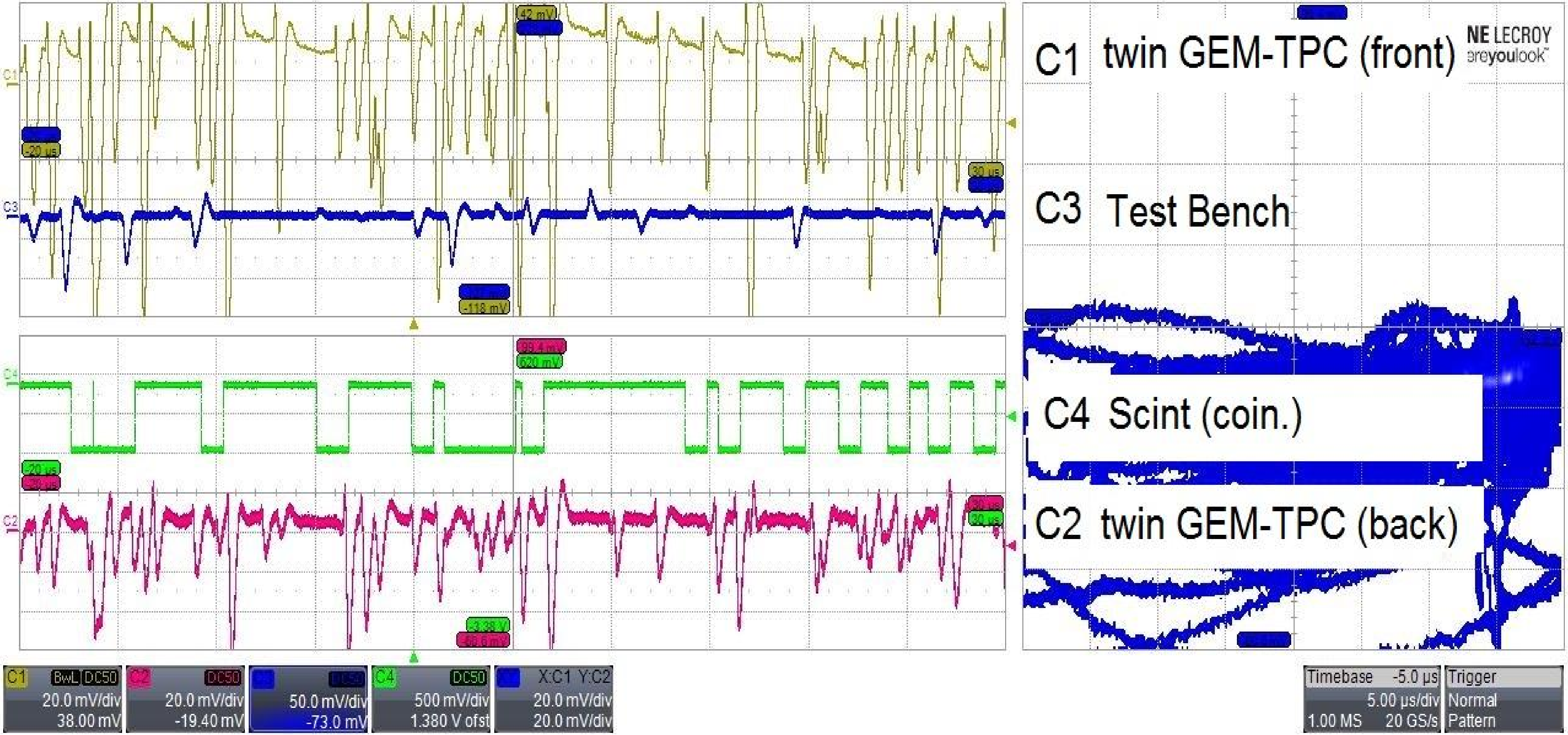


Details at:

MPGD Applications Beyond Fundamental Science and 18th RD51 Collaboration Meeting (2016) → https://indico.cern.ch/event/525268/timetable/#20160913.detailed

TEST BEAM at JYVÄSKYLÄ (cont.)

No Collimator, rate: 2.20 MHz



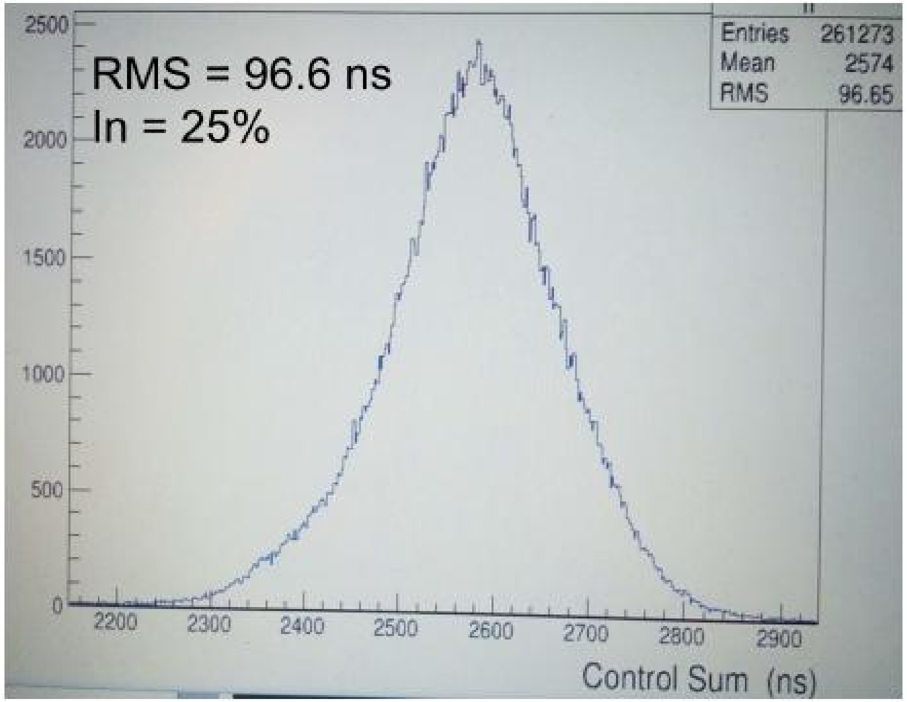
TEST BEAM at JYVÄSKYLÄ (cont.)

CS with and without collimator

CS = Control Sum

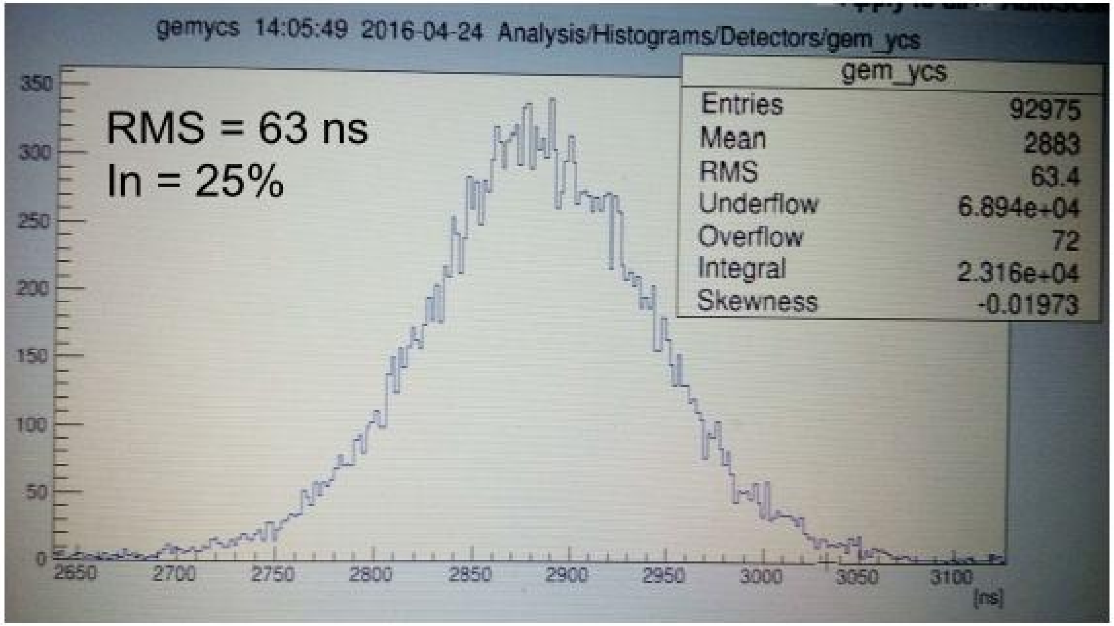
With collimator

Fieldcage: 250 V/cm

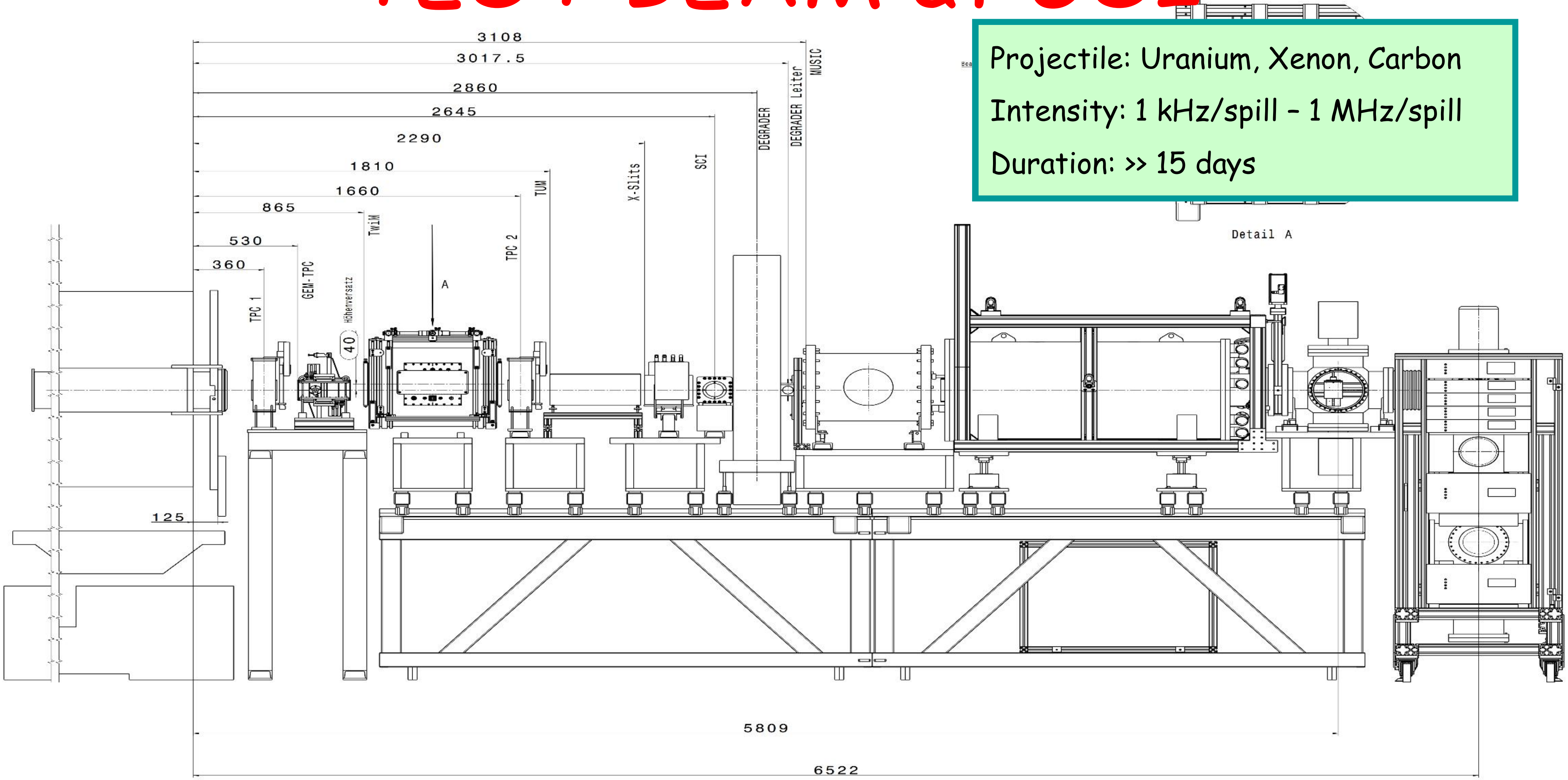


Without collimator

Fieldcage: 290 V/cm



TEST BEAM at GSI



Projectile: Uranium, Xenon, Carbon

Intensity: 1 kHz/spill – 1 MHz/spill

Duration: >> 15 days

Details at:

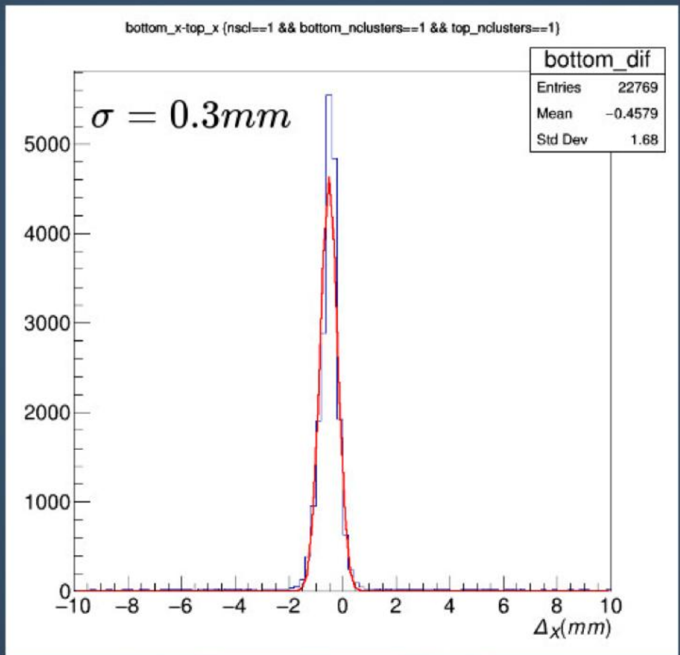
Local Super-FRS meeting at GSI →
file:///C:/Users/fgarcia/AppData/Local/Microsoft/Windows/Temporary%20Internet%20Files/Content.Outlook/WVVFINK9/ap_gemtpc_meeting_10_2_2017.html#/

TEST BEAM at GSI (cont.)

Position resolution in X-axis

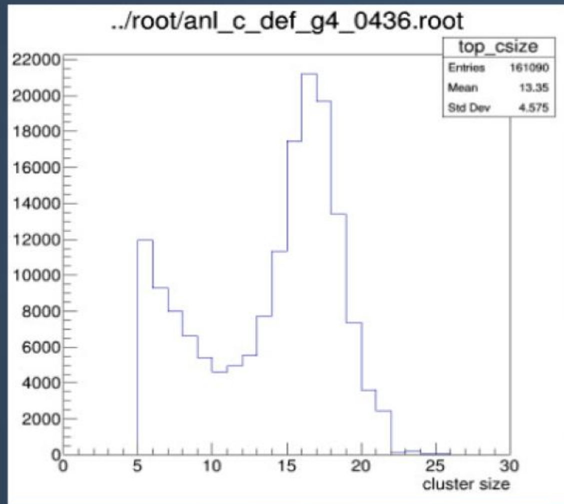
C beam

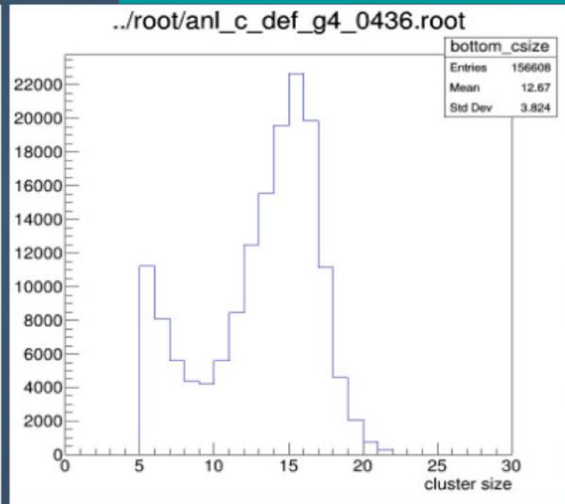
Top vs Bottom X position



C, defocused beam

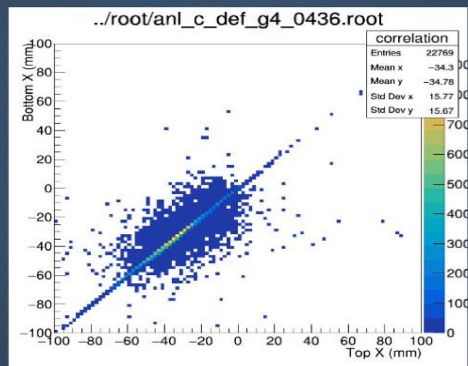
Trigger multiplicity





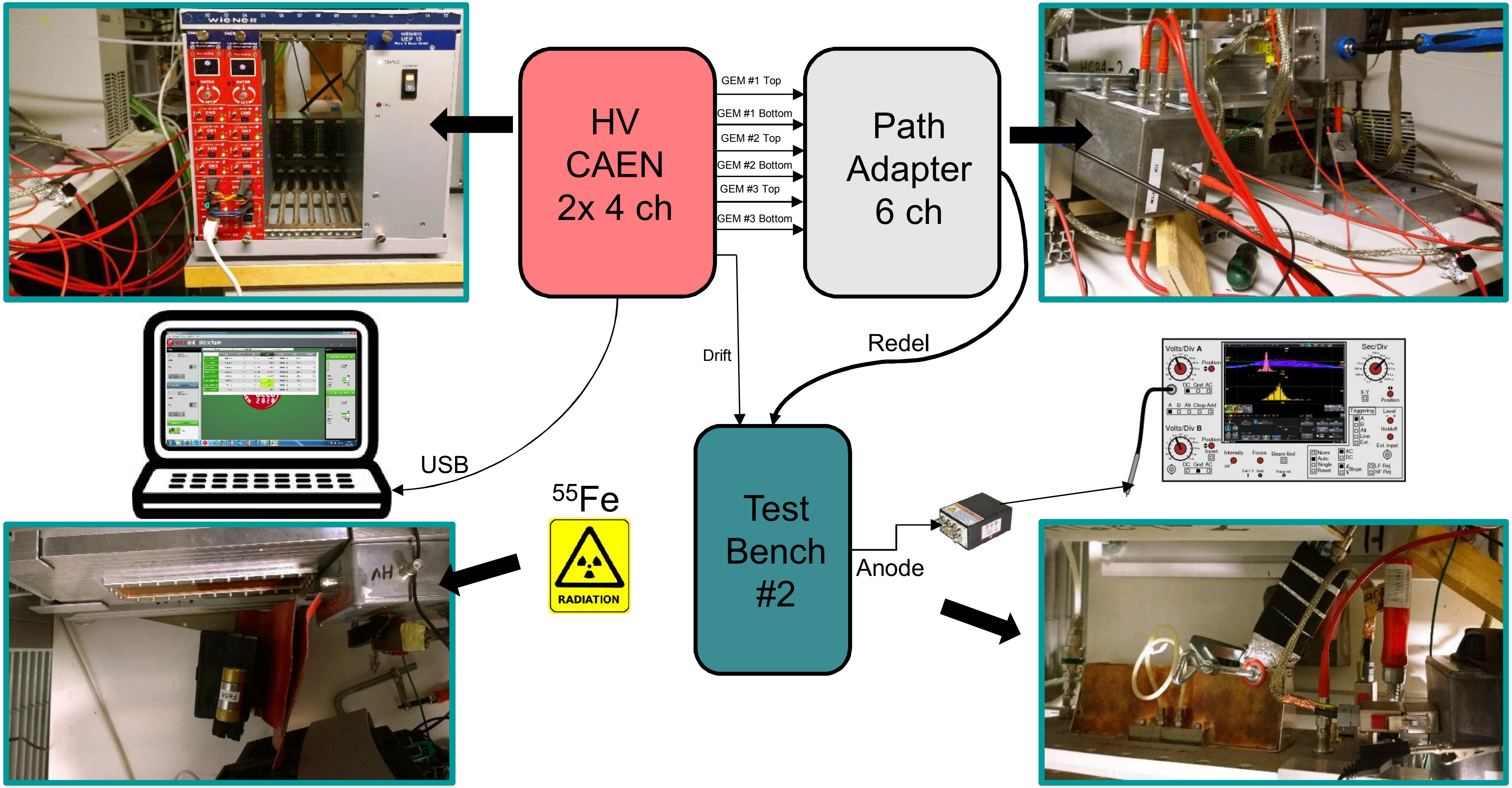
C beam

Top vs Bottom X position

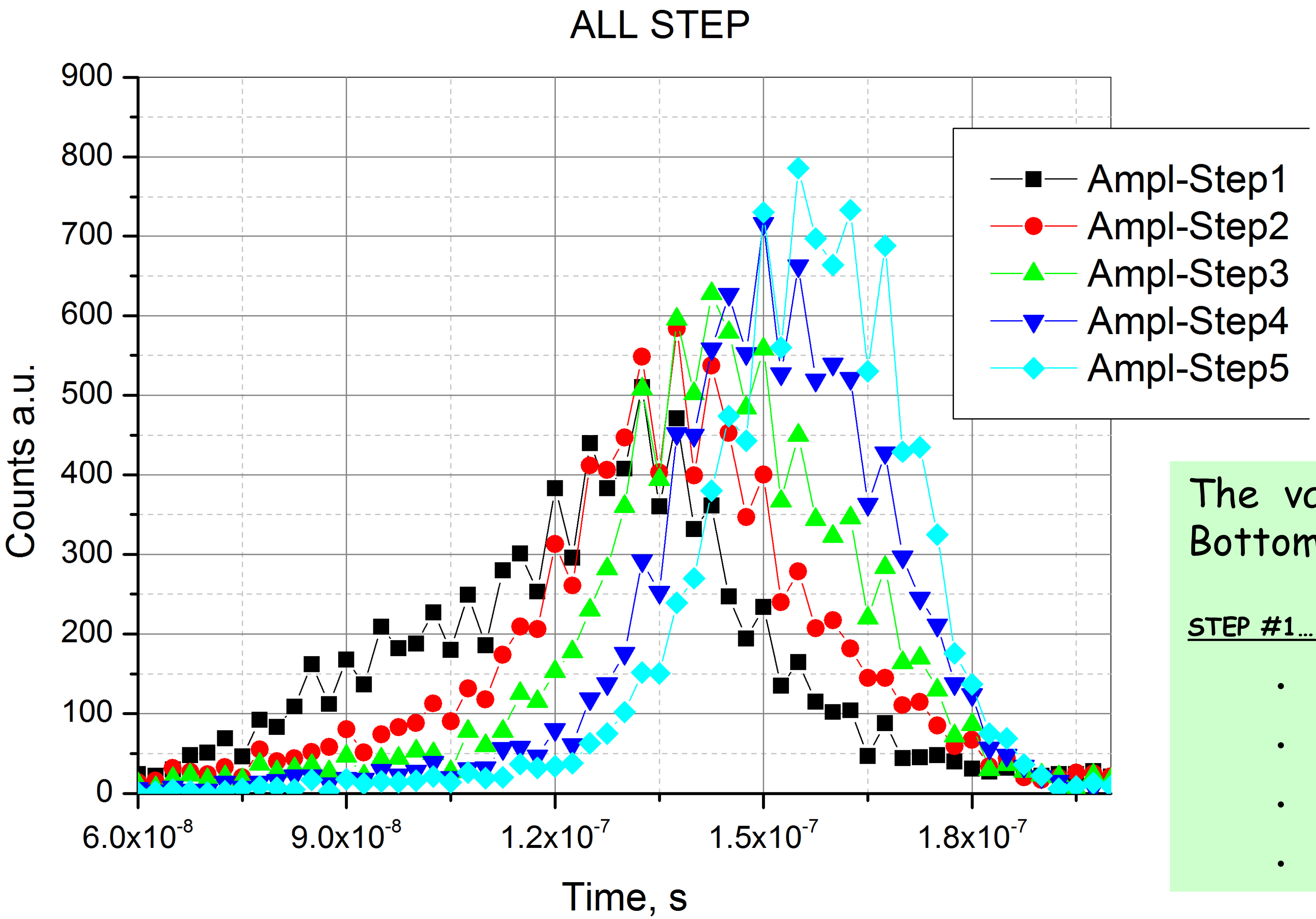


Position correlation per trigger between Top and Bottom GEM-TPCs of HGB4-2

IMPROVEMENTS of TIMING RESPONSE



IMPROVEMENTS of TIMING RESPONSE (cont.)



One can see that the rising time move to the right and the standard deviation (rms) get smaller, **which is very good**

The values of GEM #3 Top and Bottom were scanned

STEP #1….#5

- **Drift:** 3250 V
- **GEM #3 Top:** 839 V
- **GEM #3 Bottom:** 576 V

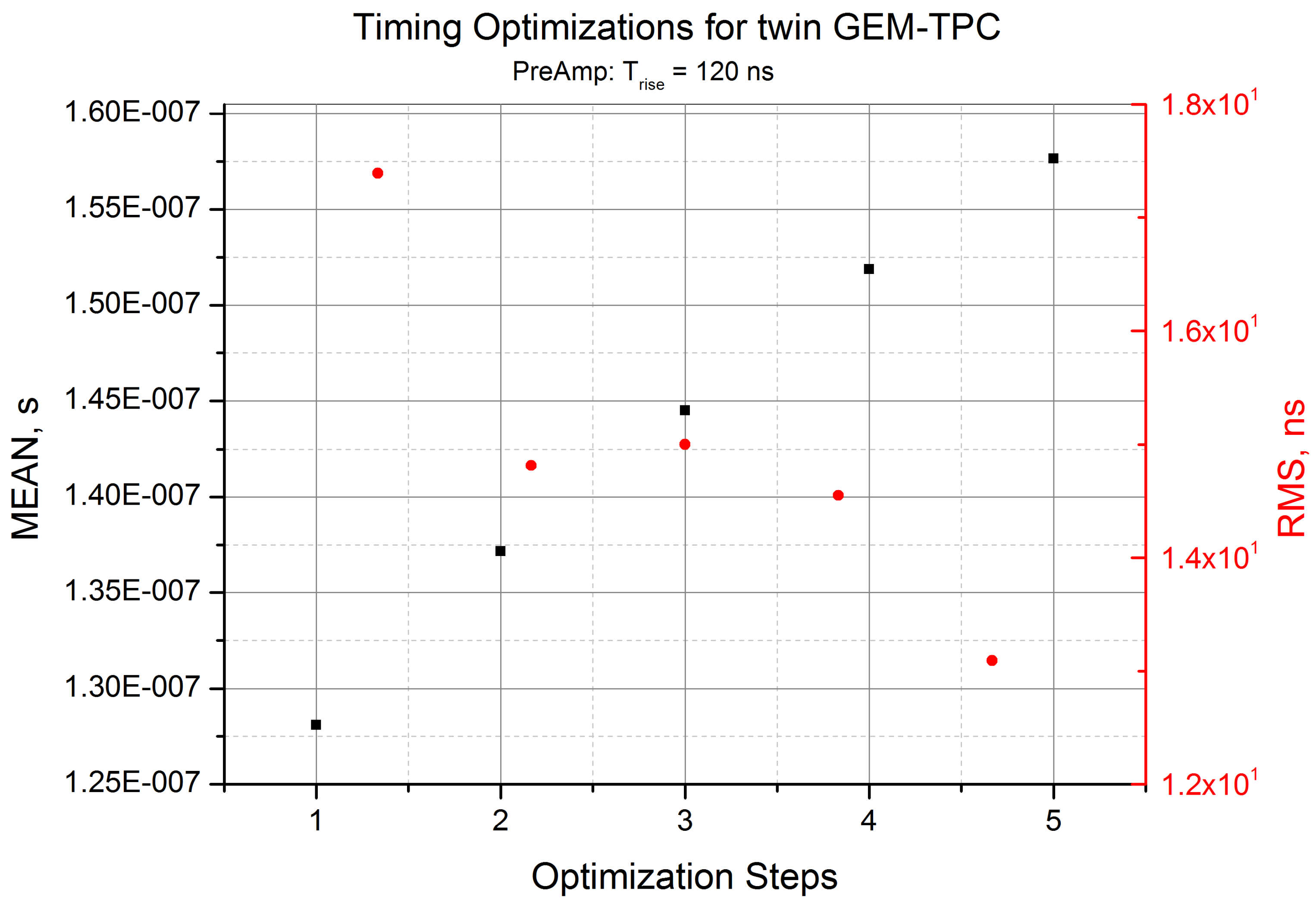
ΔV: 263V

- **Indution Field:** 2.88 kV/cm

Details at:

Local Super-FRS meeting at GSI → https://tuhat.helsinki.fi/portal/fi/activities/gemtpc-timing-optim(5d82a61d-bb85-467a-b72b-95ce459da09d).html

IMPROVEMENTS of TIMING RESPONSE (cont.)



OUTLOOK

1. Find the optimal operation parameters, in terms of Timing response, keeping discharge probability very low
2. Procurement of fast preamplifiers, targeting 25 ns rising time, to be comparable with a similar discretization of VMM3
3. Participation in a test beam at Jyväskylä equipped with the fast preamplifiers, TAMEX and DNF-NYXOR cards, in order to study timing and tracking capabilities versus rate for protons (high gain)
4. Analysis of the vast data collected from 2016 campaigns
5. Get the Factory acceptance and prepare tools for mass-production

COLLABORATORS

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Thank you for your Attention