AWAGS: a single ASIC to detect from protons up to uranium ions

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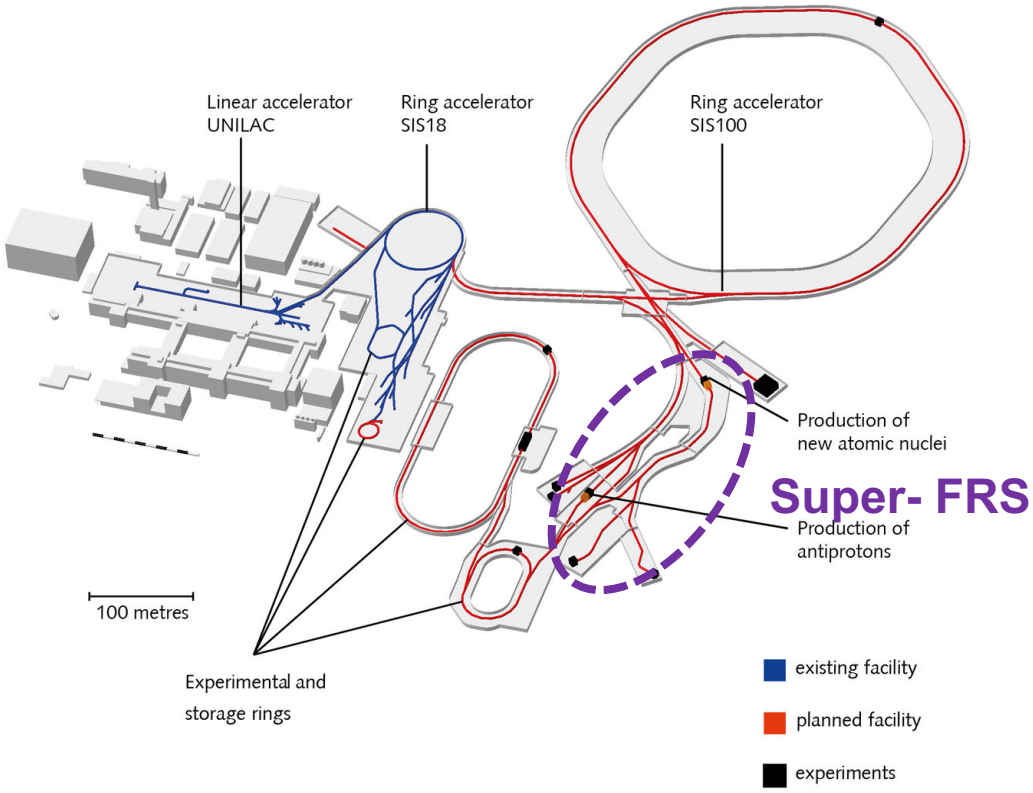
Outline:

- Motivations
- AWAGS-1 @ test beam
- AWAGS-3 characterisation
- Outlook & conclusions

Towards FAIR era

New accelerator facility at the GSI: **F**acility for **A**ntiproton and **I**on **R**esearch

https://www.gsi.de/en/researchaccelerators/fair



Primary beams

- 5 x 10^{11} $^{238}U^{28+}$ (pulse)
- 3,5 x 10^{11} $^{238}U^{28+}$/s (DC) @1,5 GeV/u
- factor 10^2 in intensity over present

Super-Fragment Separator

https://www.gsi.de/en/work/gesamtprojektleitung_fair/super_frs

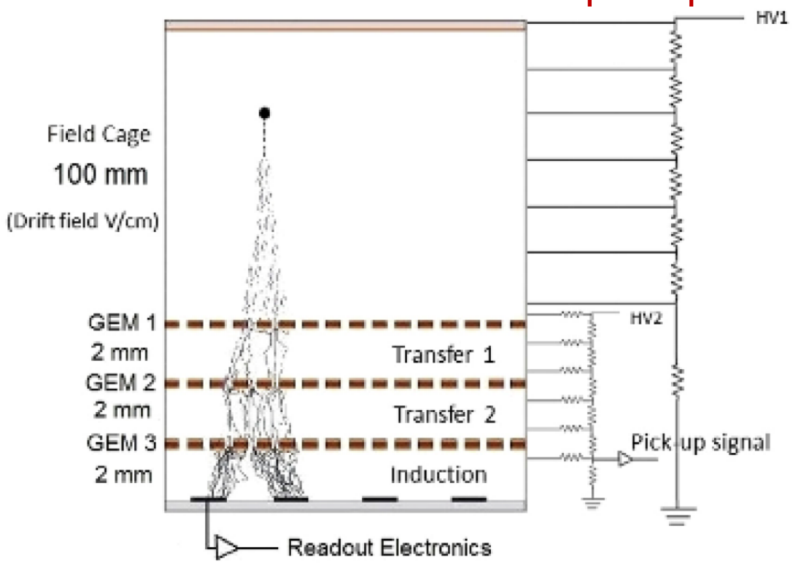
Secondary beams:

- broad range of rare isotope beams up to 1-2 GeV/u
- up to a factor 10^4 in intensity over present

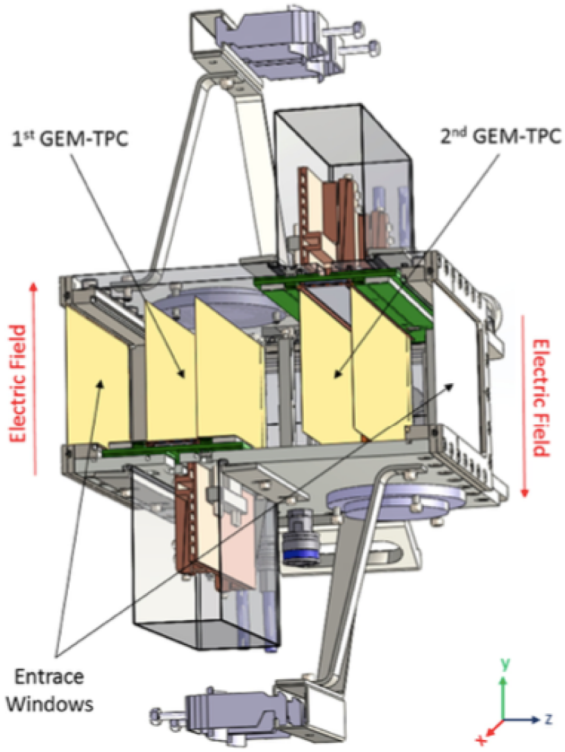
@ Super-FRS to properly monitor the beam and as experiments detector support need of **beam diagnostic detectors** -> stringent detector requirements

GEM TPC

*GEM TPC architecture and principle



CAD drawing of the GEM TPC in twin configuration



Physics detector requirements:

- < 1mm position resolution
- time precision < 3 ns
- max rate capability 2 kHz/mm^2

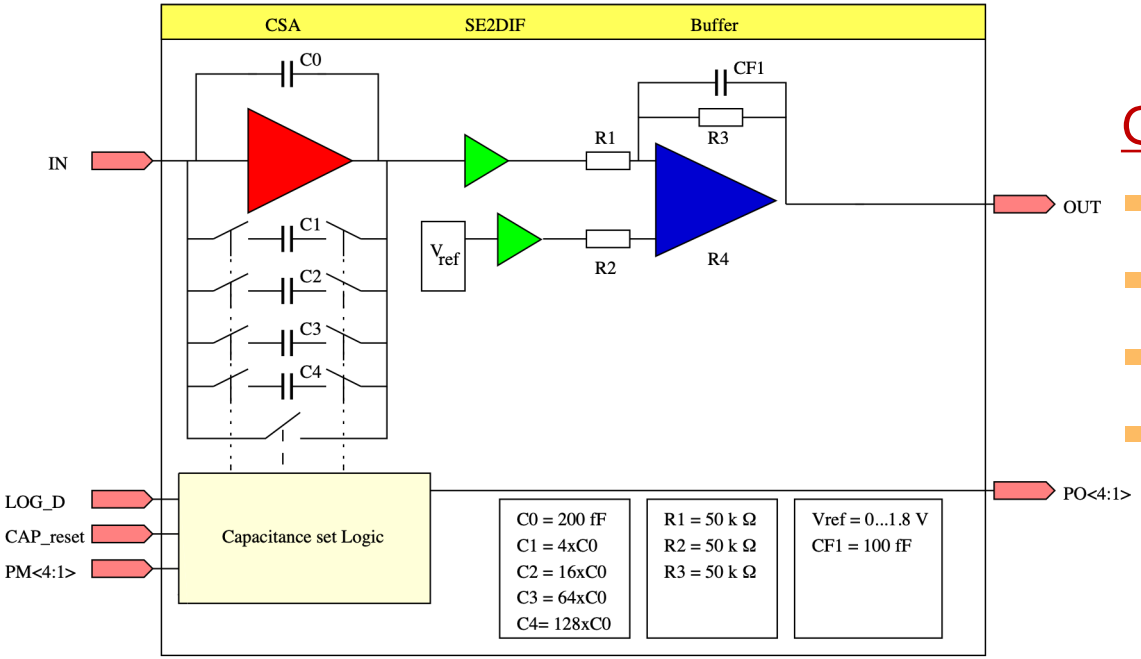
The GEM TPC in twin configuration allows a higher rate capability exploiting the control sum constraint

Challenges for the electronics:

- dynamic range (from proton to uranium beam species ~ 10^4)
- rate capability (up to 1 MHz)

*F. Garcia et al., Nucl. Instr. and Meth. **A** 884 (2018) 18-24

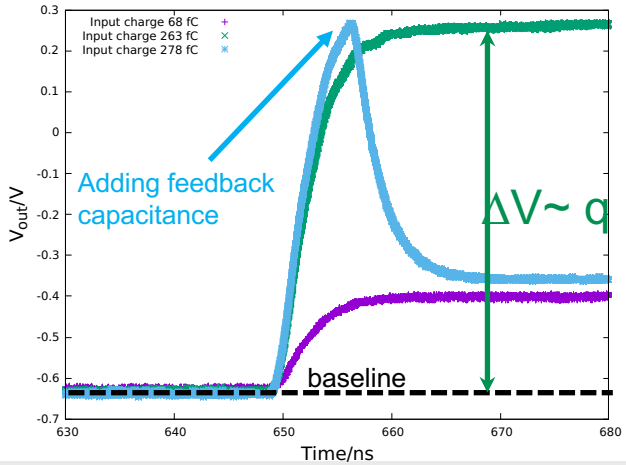
Amplifier With Adaptive Gain Setting AWAGS-1



General features:

- 4 channels per ASIC
- charge sensitive input stage
- single ended output buffer
- 2 operation modes: manual and automatic

*Signal transient

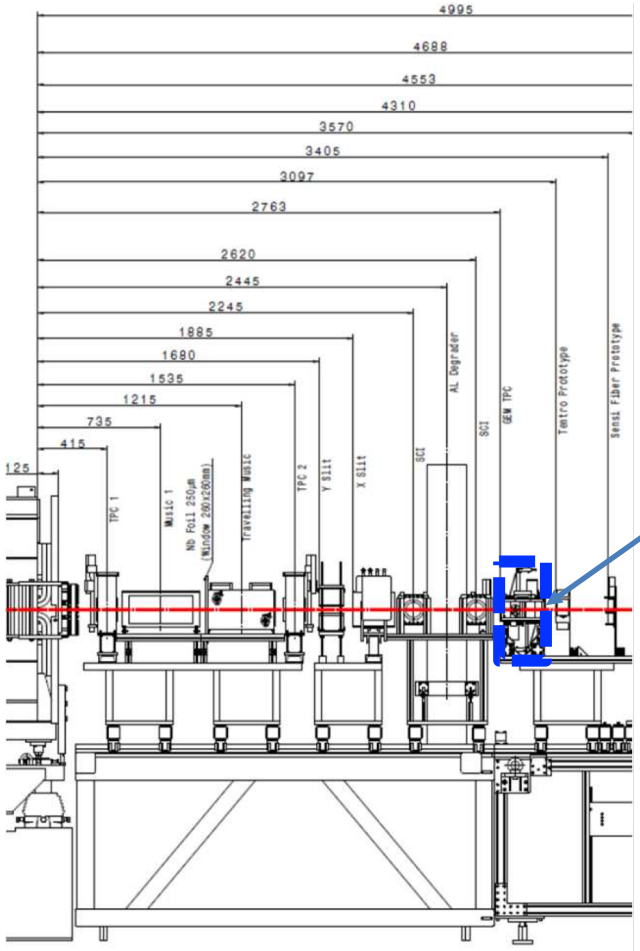


Output signal:

- the preamplifier output is proportional to the voltage difference after the transient peak
- the transient peak occurs when switching the feedback capacitance according to the incoming input charge

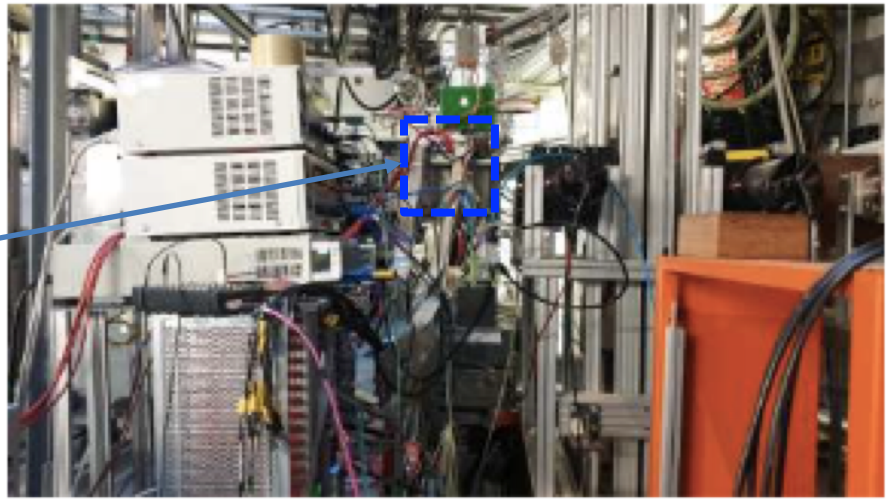
*Low Noise Amplifier With Adaptive Gain Setting (AWAGS) ASIC, P.Wieczorek, H. Flemming, H.Deppe TWEPP 2021 Topical Workshop on Electronics for Particle Physics

GEM TPC test beam 2019 - Setup



Beam line drawing: for GEM TPC characterisation other position detectors were required

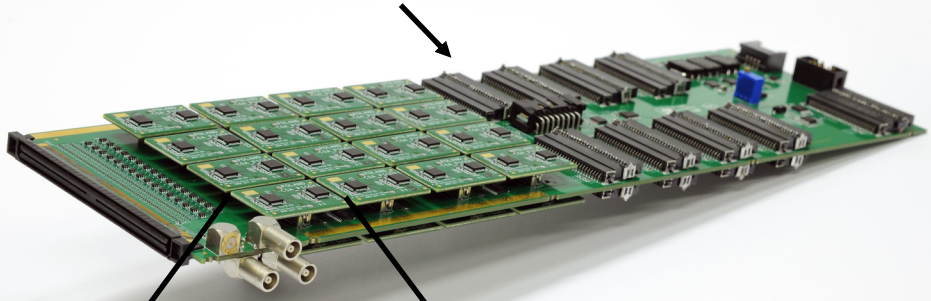
GEM TPC equipped with FEE



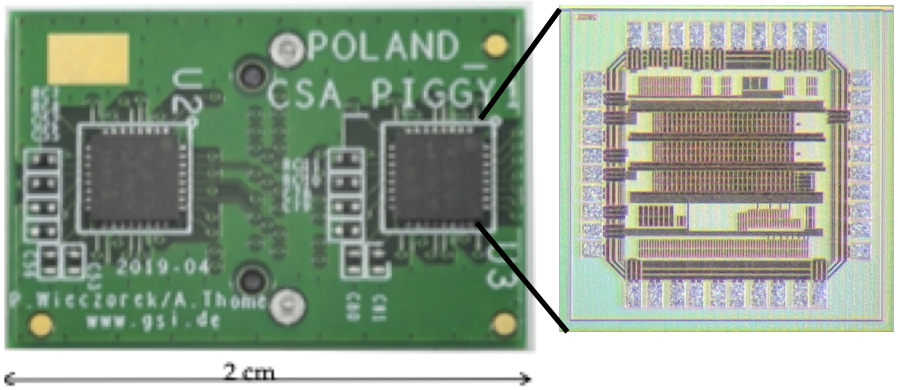
- test beam in 2019 at Fragment Separator (FRS) at GSI
- goals:
  - FEE characterisation
  - detector characterisation (not reported here)
- beam ion: Uranium, 835 MeV/u

Front End Electronics

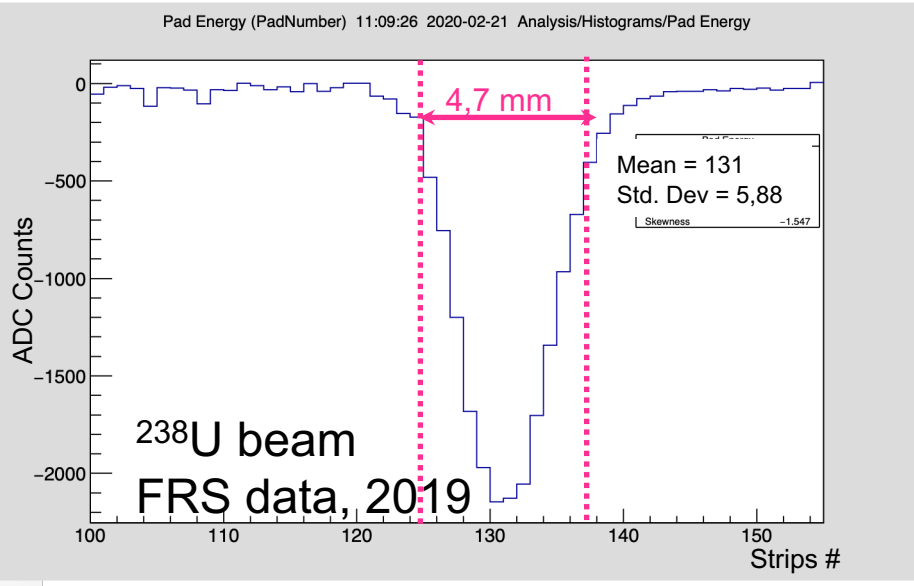
GEM TPC | FEE | DAQ



FEBEX board (signal digitisation)



AWAGS



Online analysis: event (1 ion) display

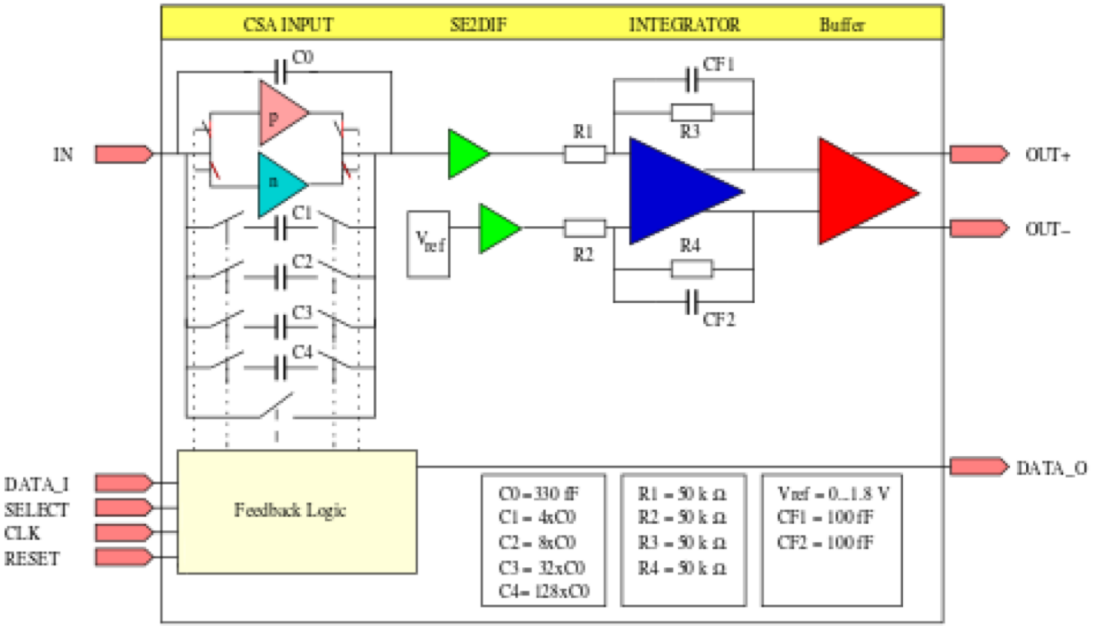
- 32 plug-in boards with AWAGS-1 ASIC
- 2 ASICs per plug-in board
- Digitiser board: 16 FEBEX cards
- 16 channels per FEBEX (14bit, 50MS/s)
- In total 256 channels read out (see Figure)

From the beam time results to the Next AWAGS development

- the ASIC behaved as expected: linearity, gain, noise level, dynamic range, time signal formation were confirmed
- the measurements showed a baseline drift as a consequence of the leakage current on the chip → possible reduction through a re-design of the feedback structure and ESD protection diodes at the input
- optimisation of the amplifier stage → differential output
- implementation of the logic interface

Next step: AWAGS-3

AWAGS-2* as intermediate development (leakage current test) →
AWAGS-3 contains the modifications for all 4 channels



Major differences to the AWAGS-1/3:

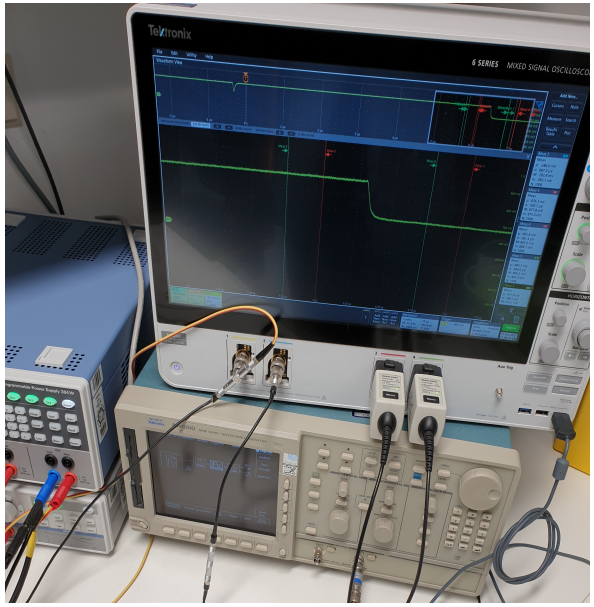
- chip interface to read/write feedback capacitances and DAC values
- differential stage output with buffers
- 4 channels in total with switching polarity

The ASIC has been fully characterised in the lab for all the 4 channels in:

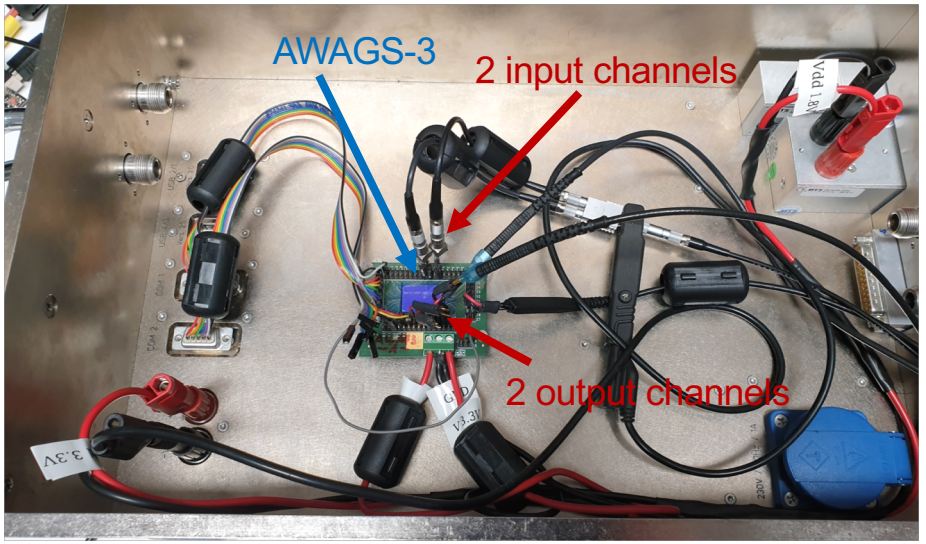
- different mode operation (manual and automatic)
- the focus will be on the nMOS polarity (negative signals)

*Low Noise Amplifier With Adaptive Gain Setting (AWAGS) ASIC, P.Wieczorek, H. Flemming, H.Deppe TWEPP 2021 Topical Workshop on Electronics for Particle Physics

AWAGS-3 Characterisation - Setup



Scope and signal generator (Tektronix AWG510)



AWAGS setup measurement in a full metal box as Faraday cage

- 2 channels measured at the same time
- AWAGS is programmed via ARDUINO
- 2 capacitance values (~15pF/160pF) used to span the full charge range (>1 fC to 80 pC)
- manual and automatised (finer step size) measurements

AWAGS-3 characterisation: Power consumption and Noise

Power Consumption Summary

	Current at 1.8 V (mA)	Current at 3.3V (mA)
Sim. Power	36.9	0.44
AWAGS PCB -1-	34.3 ± 0.1	0.33 ± 0.1

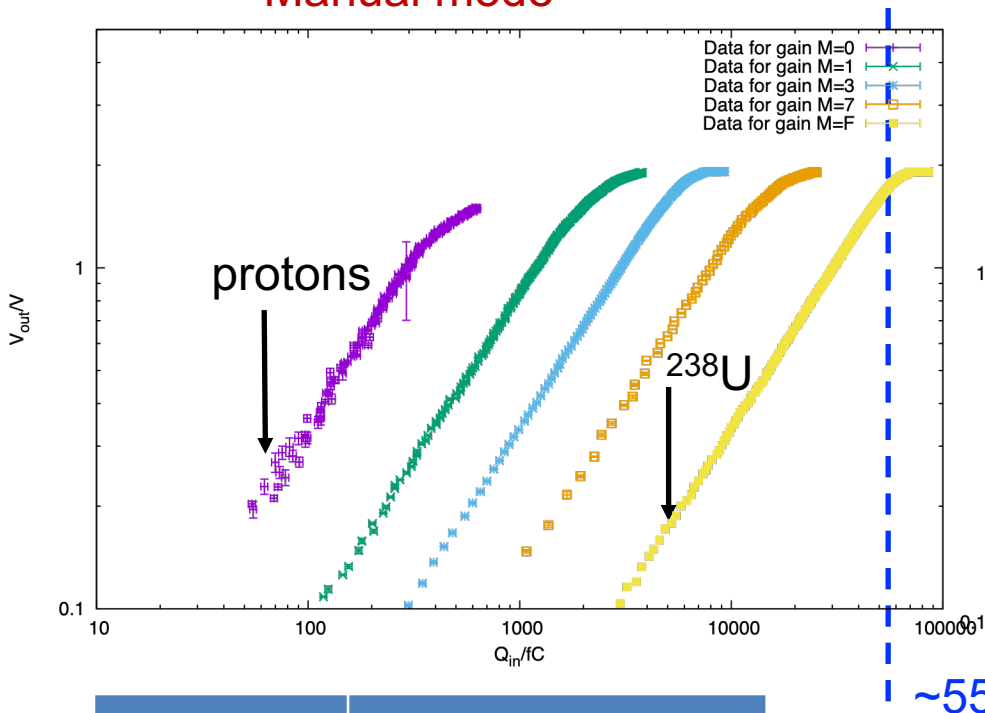
Measurements confirmed the simulation

Noise Summary Measurements

Channel #	Operation Mode	Noise (mV)	Noise (fC)
ch. 0	auto	1,416	0,381
ch. 1	auto	1,447	0,393
ch. 0	manual	1,862	0,501
ch. 1	manual	1,814	0,492

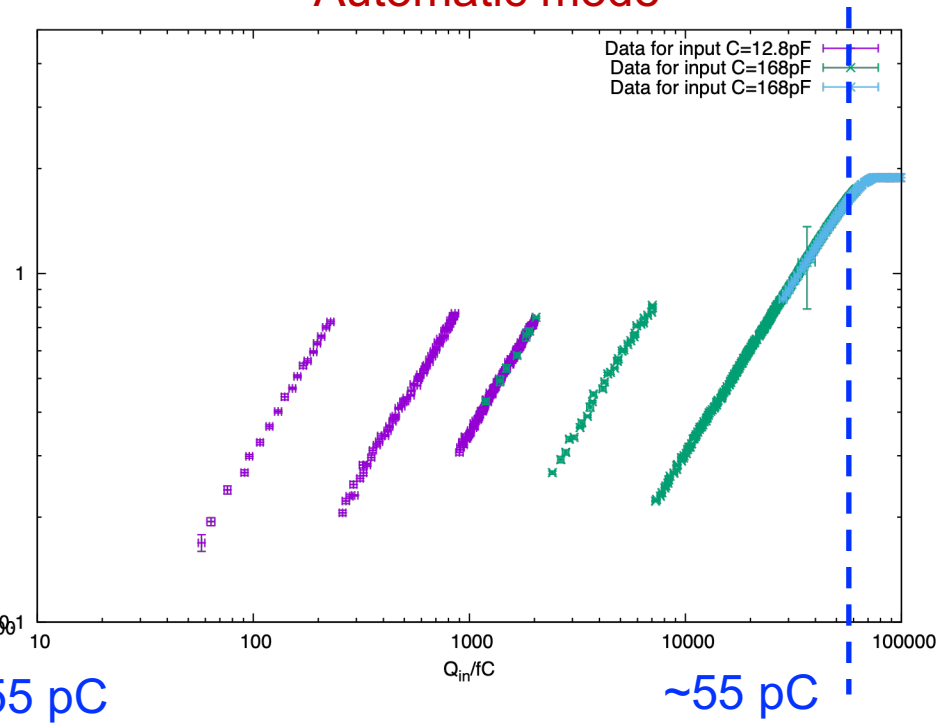
AWAGS-3 characterisation: gain scan in manual and auto mode

Manual mode



~55 pC

Automatic mode



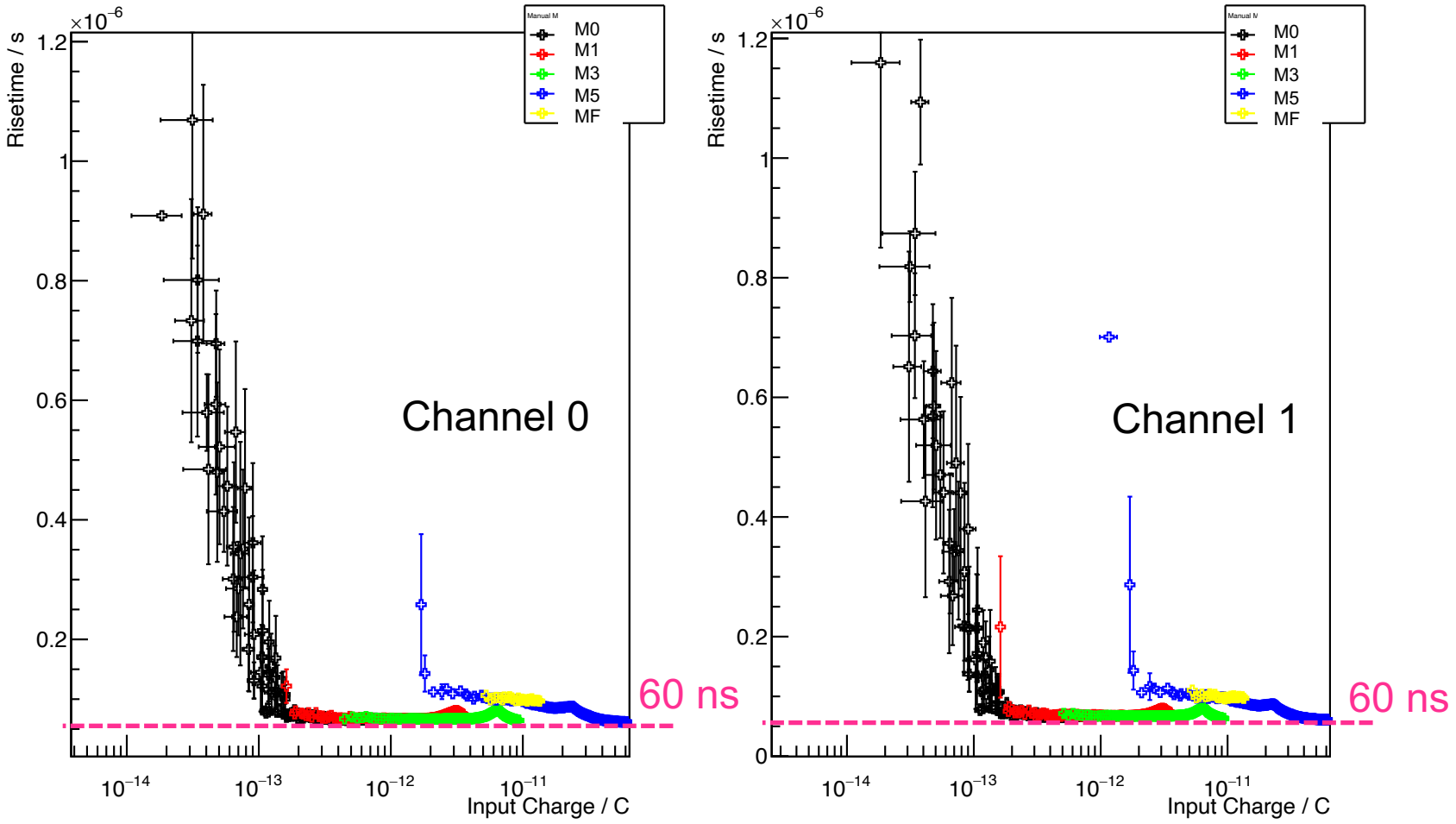
~55 pC

Gain label	Gain (V/fC)
M0	3,714 ± 0,046
M1	0,901 ± 0,003
M3	0,358 ± 0,0005
M7	0,118 ± 0,001
MF	0,031 ± 0,0001

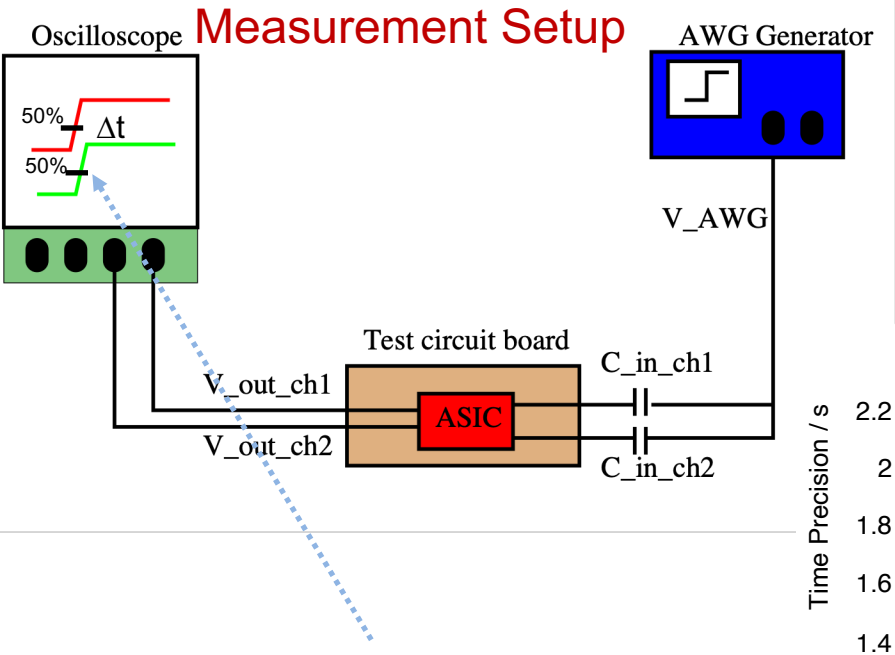
In both operation modes the dynamic range covered is ~ 10^5 starting from a noise level of ~ 0,4-0,5 fC

AWAGS-3 characterisation: rise time

Rise time measured in the 10%-90% interval for different gain settings in manual mode

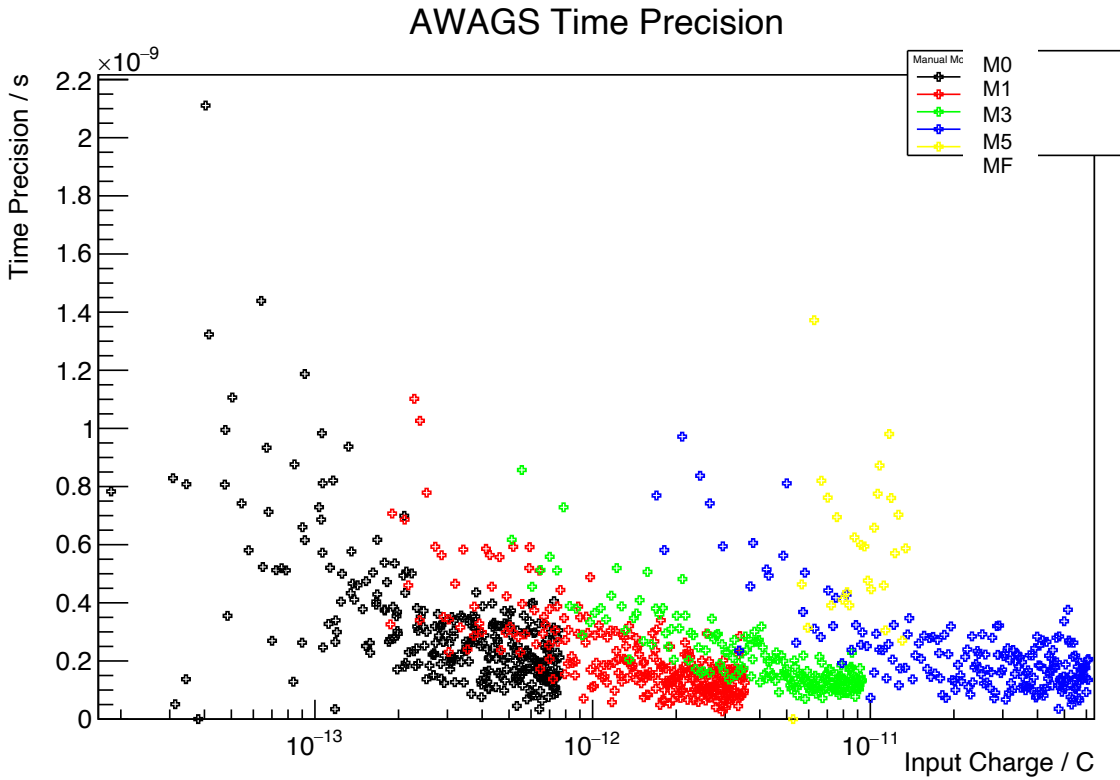


AWAGS-3 characterisation: time precision



The measurements are taken at 50% of the amplitude signal and the time difference, Δt, is reported in the plot

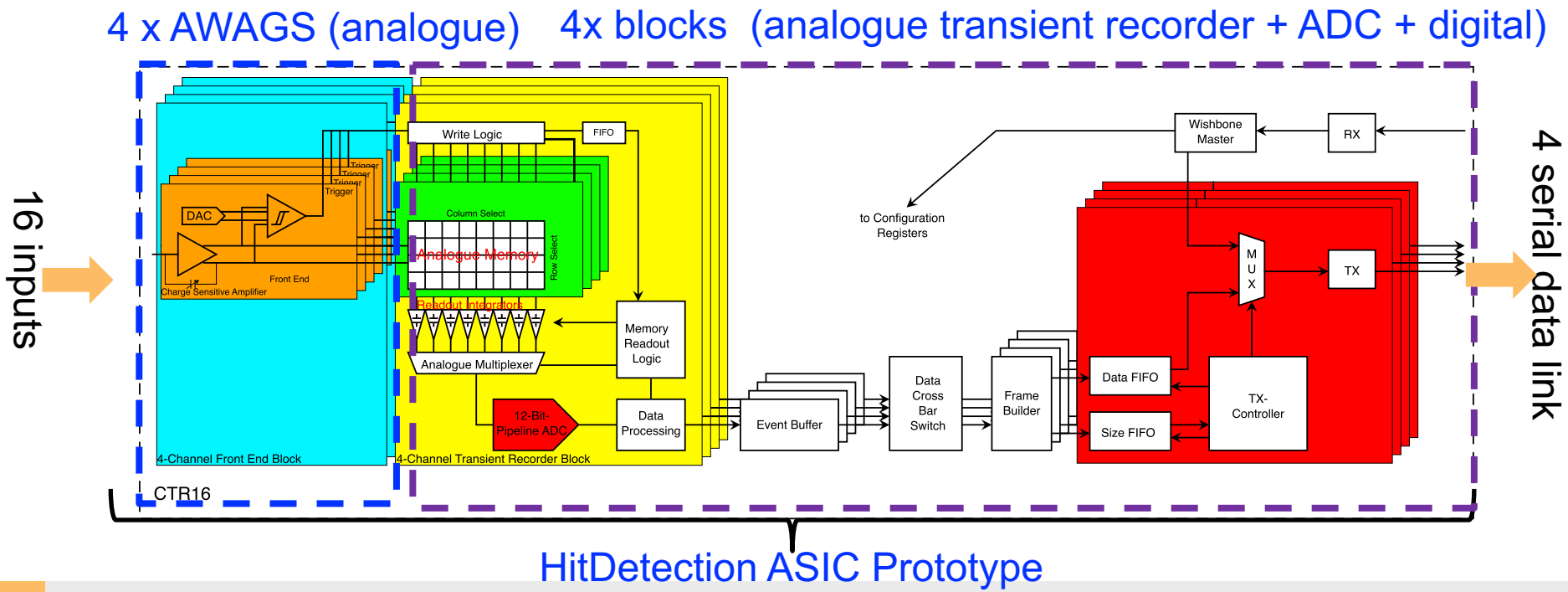
Time precision for different gain settings in manual mode



Outlook

- In March the GEM TPC FEE (AWAGS-3 based) characterised at GSI with Carbon beam
- In last quarter of the 2022 GEM TPC testing with FEE based on the HitDetection* chip

*H. Flemming, H.Deppe, P. Wieczorek. A family of transient recorder ASICs for detector readout.Poster presented on Topical Workshop for Electronics in Particle Physics (TWEPP), 2021



Conclusions

- the Amplifier With Adaptive Gain Setting (AWAGS) is a possible FEE solution for the GEM TPC, as beam diagnostic detector at Super-FRS at FAIR
- in the AWAGS development the produced ASIC showed performing results in laboratory and test beam measurements
- the integration of the AWAGS-3 in the Hit Detection chip performing analog and digital read out for the GEM TPC will be tested in the second half of 2022.