THIN GEM DETECTORS DEVELOPMENTS FOR THE MAGIX EXPERIMENT

MAINZ ER SUPERCONDUCTIVE ACCELERATOR

Multi-turn, superconducting ERL

Energy recovery mode

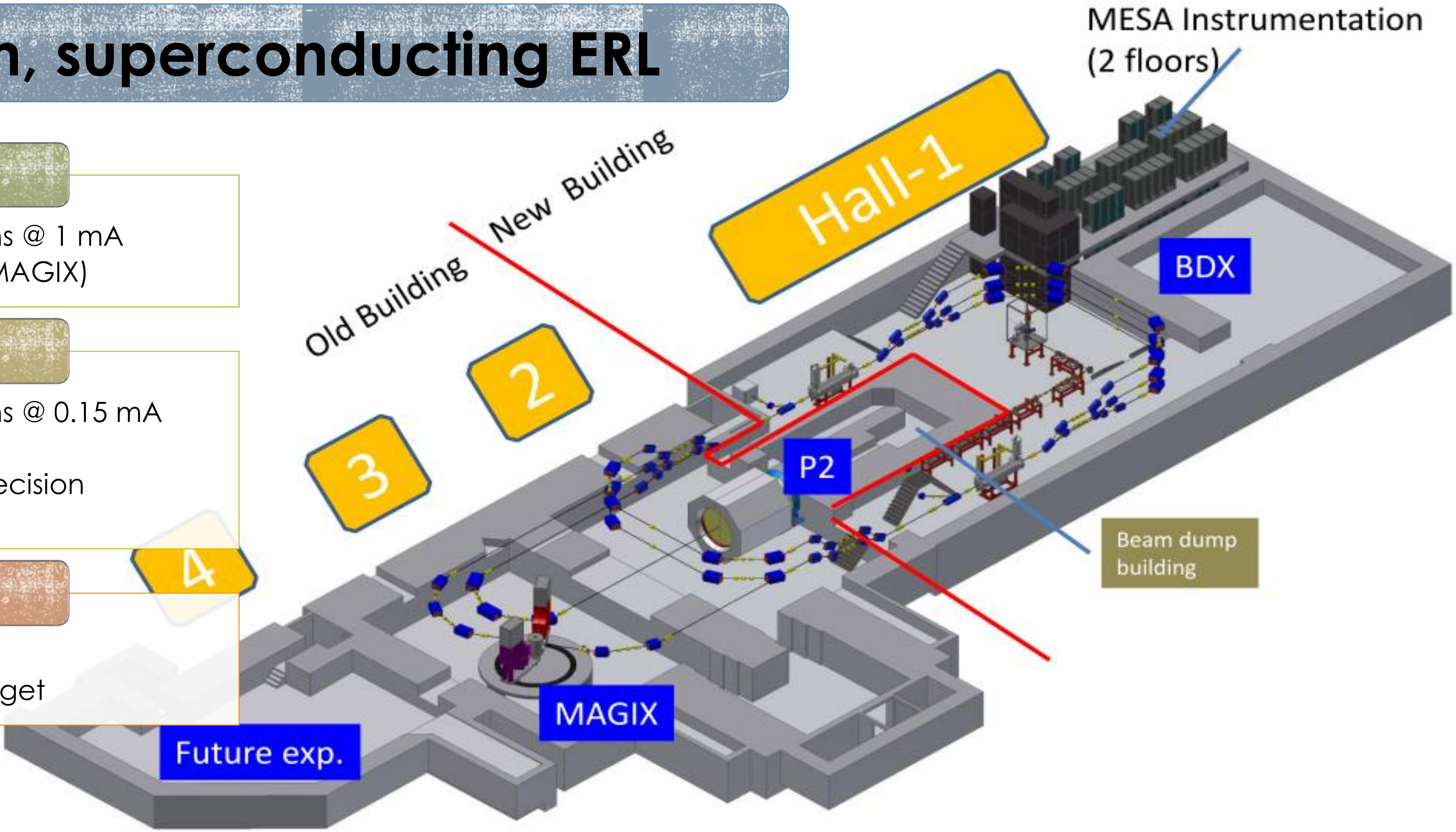
- 105 MeV polarized electrons @ 1 mA
- Internal target scattering (MAGIX)

External beam

- 155 MeV polarized electrons @ 0.15 mA
- Dedicated experiment (P2)
- Electroweak asymmetry precision measurement

Beam dump experiment

- Behind the P2 beam dump
- About 10^{23} electrons on target



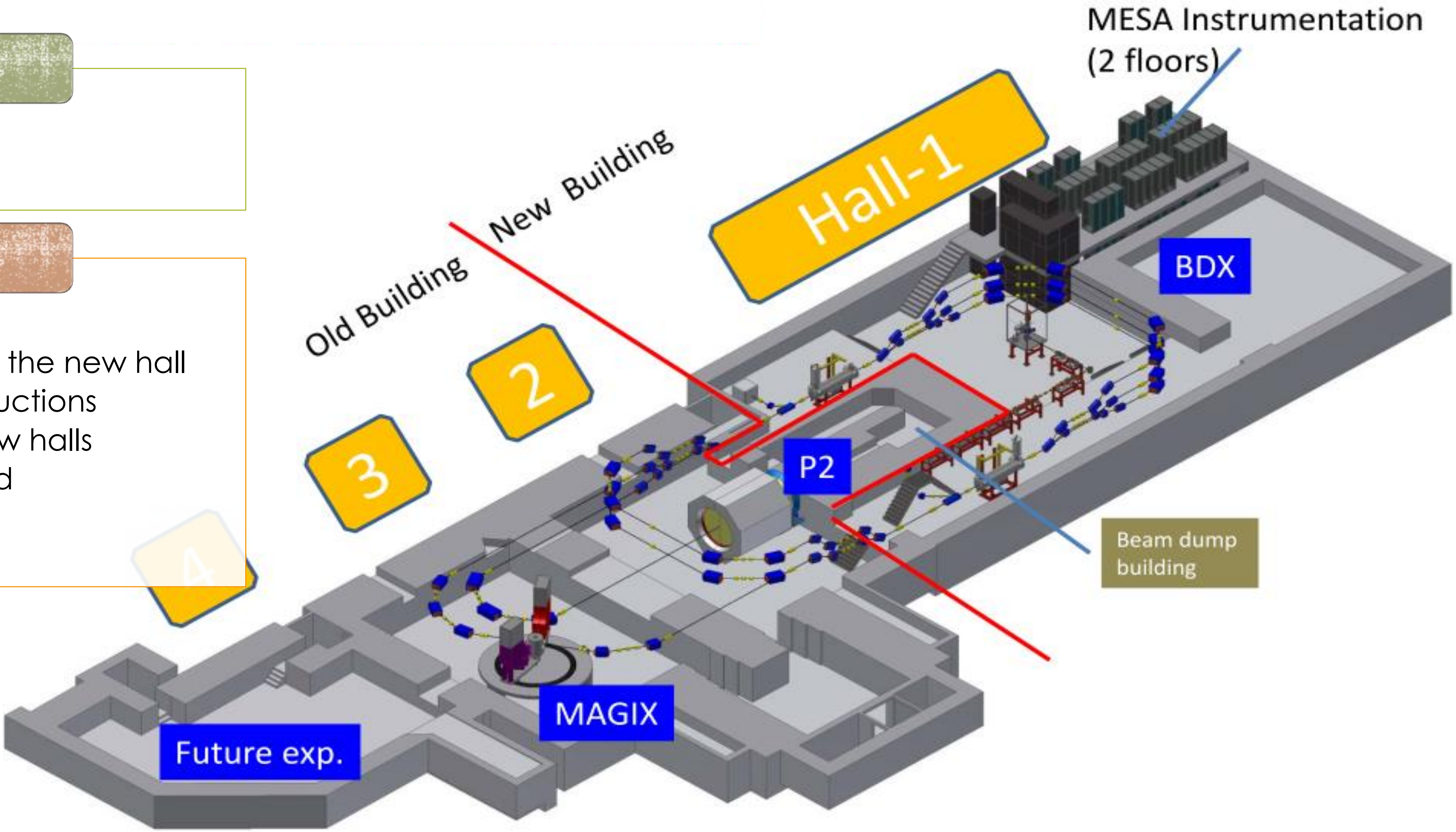
MESA SCHEDULE

Extension hall approved

- More space
- Delayed schedule

Construction schedule

- 2017 Ancillary buildings
- 2018 Ground breaking for the new hall
- 2019 Underground constructions
- 2020 Hand over of the new halls
- 2021 MESA installation and commissioning
- 2022 Start of operation



MAGIX EXPERIMENT

A versatile experiment for precision measurements at low energy

EXTENSIVE PHYSICS PROGRAM

Hadronic structure

- Proton form factors (electric and magnetic)
- Nuclear polarizabilities
- Light nuclei form factors (Deuteron and helium)

Few-body physics

- Deuteron and ^{3}He breakup
- ^{4}He monopole transition factors
- Test of effective field theories
- Inclusive electron scattering

Precision cross-sections

- ^{16}O(e, e'α)^{12}C S-factor

Search for exotica

- Direct dark photon search
- Invisible decaying dark photon search

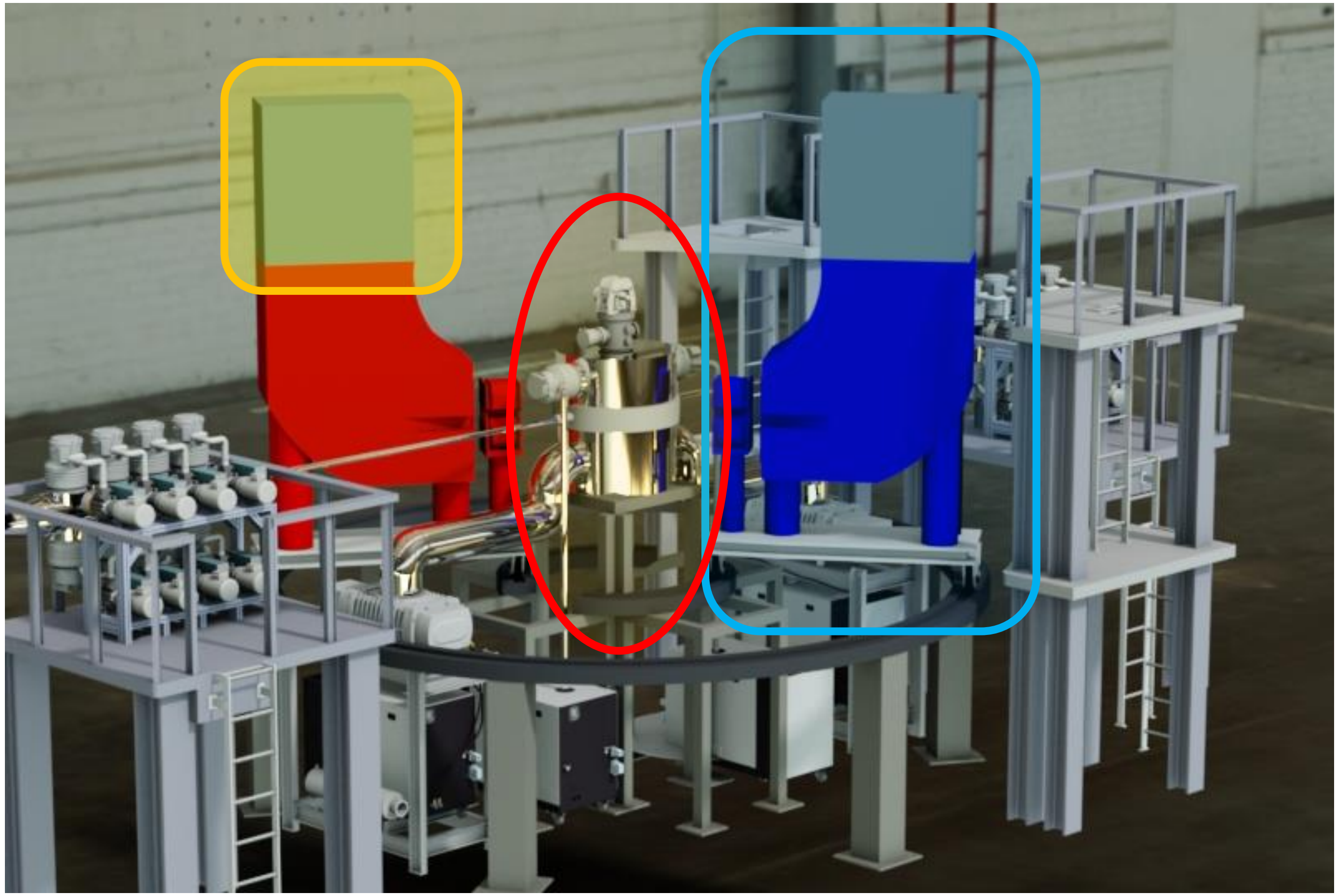
THE MAGIX SETUP

Internal Gas Target

Twin ARm DIpole Spectrometer

Focal Plane Detectors

A high-precision multi-purpose experimental setup



EXPERIMENTAL CHALLENGES

High resolution on low momentum electrons

- 1 < p < 100 MeV
- $\frac{\Delta p}{p} \approx 10^{-4}$
- $\Delta\theta \cong 0.9$ mrad

Recoil particle detection

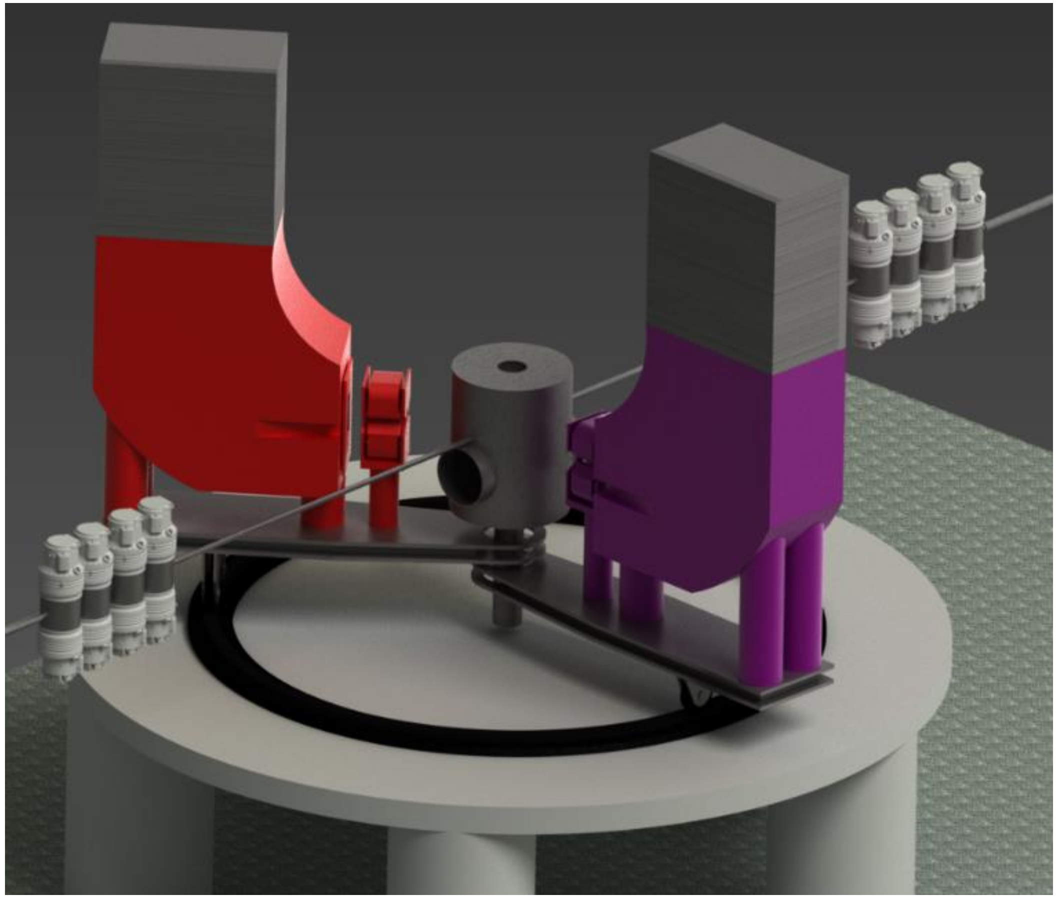
- Detection of recoil protons and alphas necessary for some planned experiments (e.g. DP invisible decays)

Material reduction

- Uncontained gas target
- No window before the magnet
- Thin detector design

High rate capability

- With a CW operation rates up to $O(1\ MHz)$
- Count rates of $O(100\ KHz)$



DETECTOR SYSTEM

Focal plane detectors

- Large area and low material budget → gas detectors
- 50 μm position resolution and high rate capability → MPGD (GEMs in our case)

Recoil detectors

- Naked silicon strip detector inside the scattering chamber
- Maybe using them in the spectrometers for specific measurements

Zero degree detector

- Electron tagger and photon calorimeter integrated in the first bending dipole.
- Still to be designed, possibly another MPGD.

FOCAL PLANE DETECTORS

Gas detectors

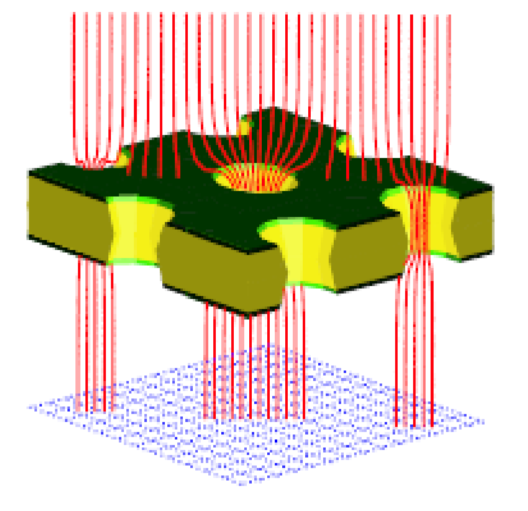
- Low material budget
- Low cost for large area coverage

MPGD

- Modern gas amplification systems
- Resolutions of the order of 50 µm achieved by several detectors

GEM

- High rate capability
- Good stability at high rate
- Adaptable to many exp. needs



2 Layer Hodoscope

- Simple detector to built
- Uniform and high position resolution
- Moderate material thickness
- Only 2 reconstructed points

Short drift TPC

- Challenging at very high rates
- Minimal material thickness
- Multiple samples and full track reconstruction possible

INFRASTRUCTURE FOR GEM DEVELOPMENT

PRISMA gas detector lab

- Construction and operation of advanced gas detectors

Student training

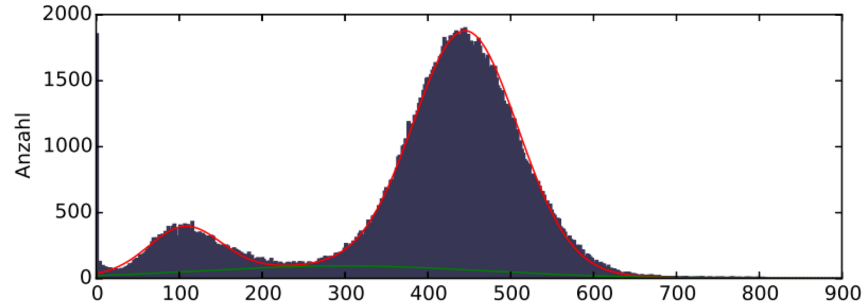
- 8 students at all levels directly involved in the GEM detector development in the previous years
- Establishment of a solid expertise in the group

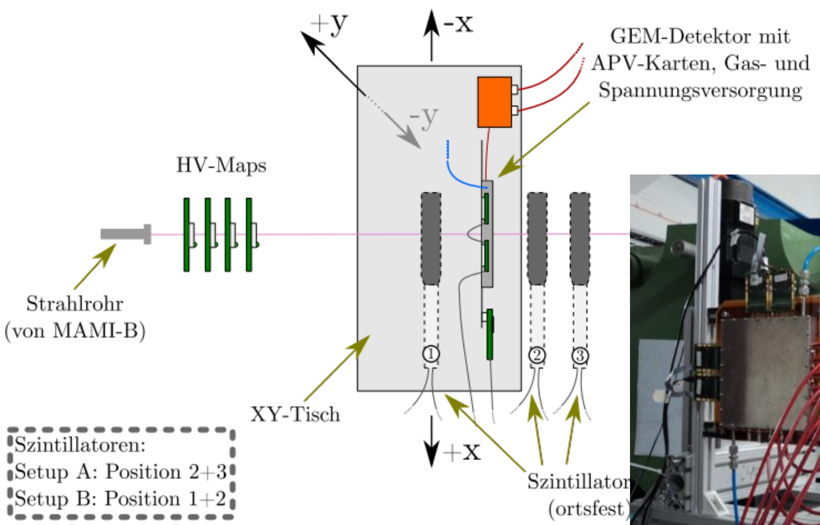
Detector development

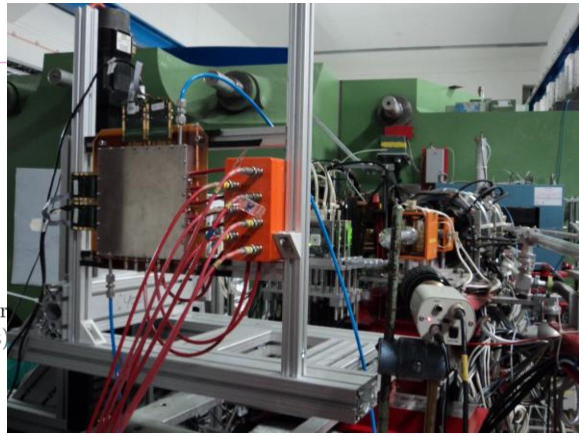
- Several 10x10 cm^2 developed and built
- Infrastructure for the development of middle-sized detectors (30x30 cm^2) under development

Detector testing

- Laboratory testing with cosmics and radiation sources
- 5 test-beam campaigns undertaken at MAMI
- Test-beam integration of the GEM detectors with the HV-MAPS system







ULTRA-THIN GEM DETECTORS FOR MAGIX

Experimental challenge

- Reduce the multiple scattering of electrons of 10-100
- Detecting 50 MeV protons

GEM readout on a Kapton foil

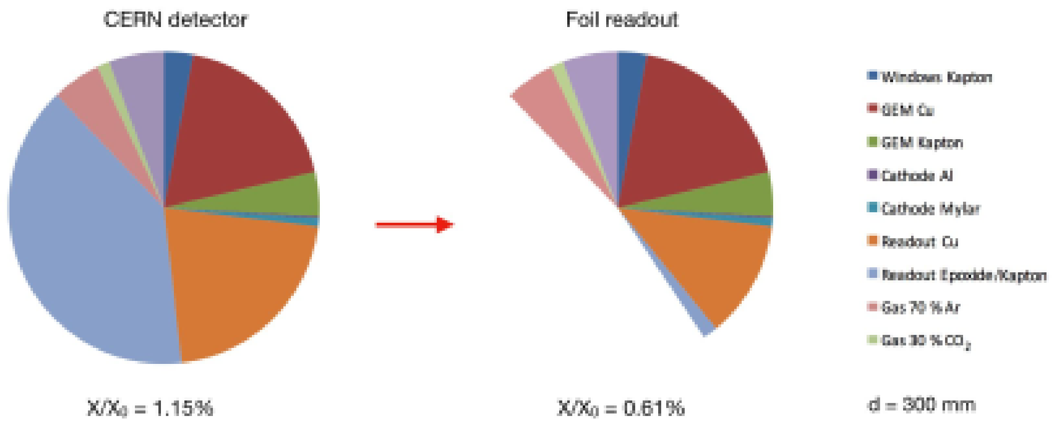
- PCB substrate is the main contributor to the detector thickness
- Replace the substrate with a Kapton foil $0.96\% \rightarrow 0.61\% \, X_0$
- The first prototype ready and tested

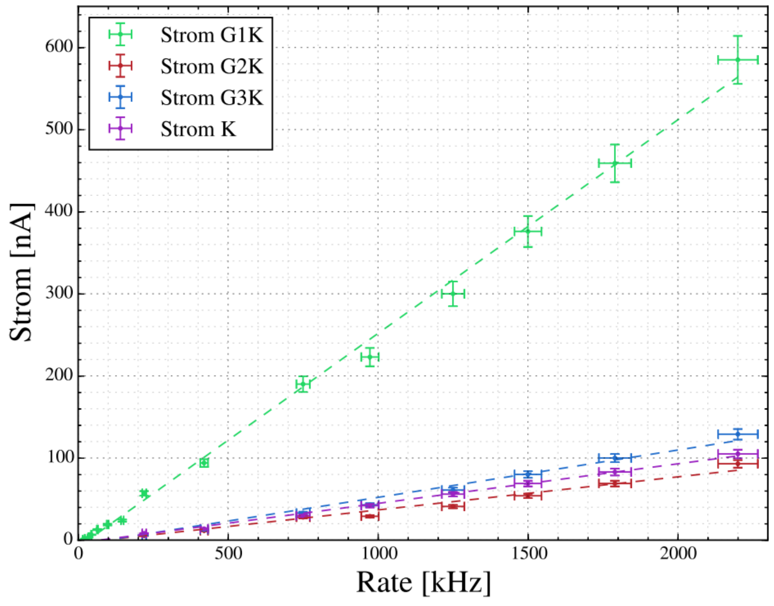
GEM copper reduction

- Replacing the copper layer with a atomic layer of Chromium
- First batch of Chromium GEMs successfully tested in August
- Data analysis ongoing

High-rate capability

- Expected single count rate in the MAGIX spectrometers O(MHz/cm²)
- Successfully tested at MAMI with similar rates (standard and chromium GEMS alike)
- New electronic system to be developed using VMM





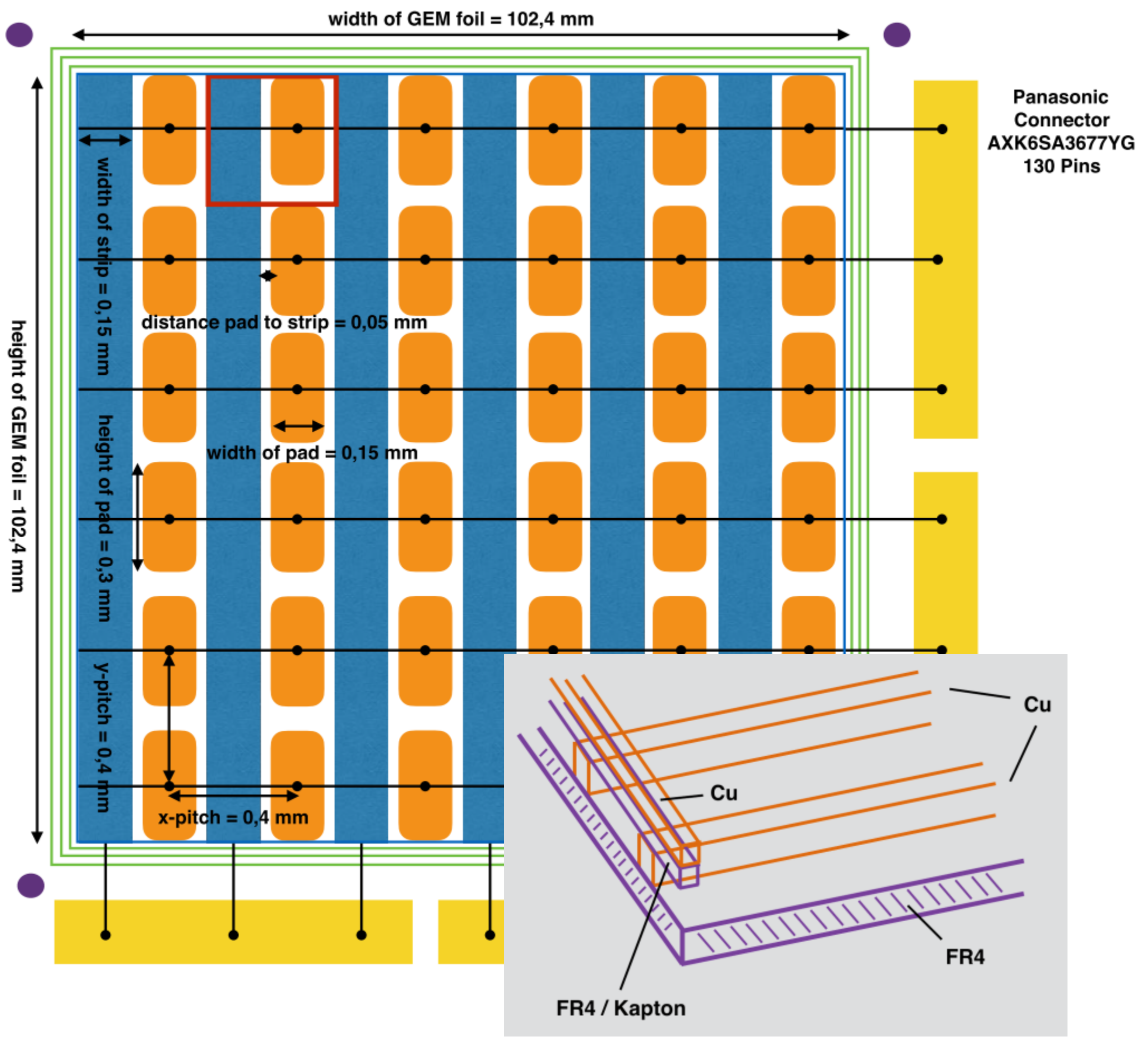
THE NEW KAPTON READOUT FOIL

Strips and pads design

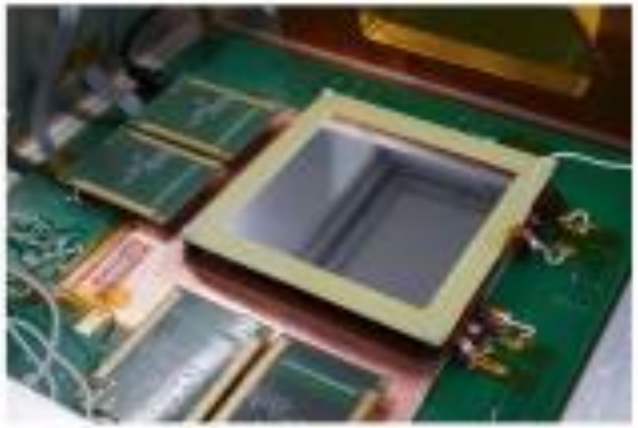
- Same pitch as the Standard CERN readout (0.4 mm)
- Simple double layer design
- 10x10 cm sensitive surface
- Scalable design for larger surfaces
- Integrated Panasonic connectors

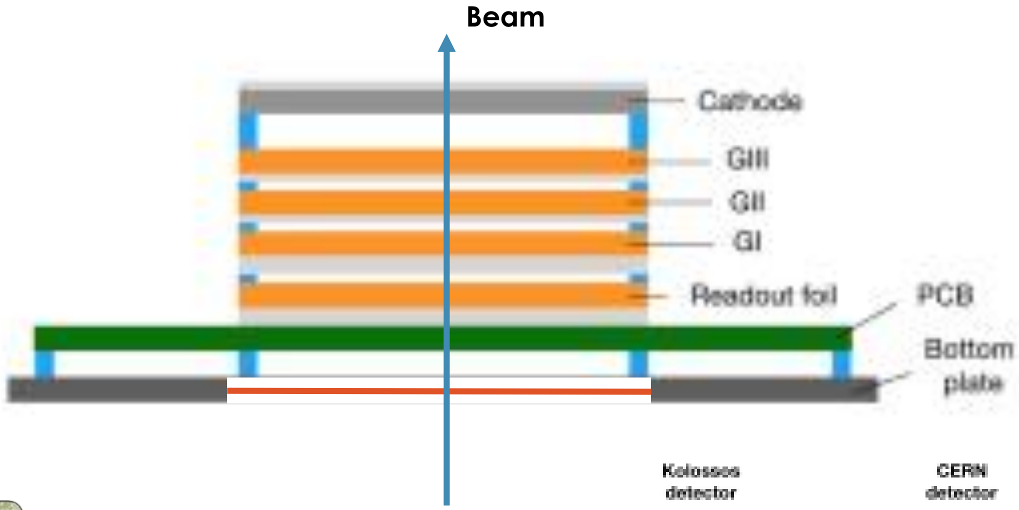
How to improve it?

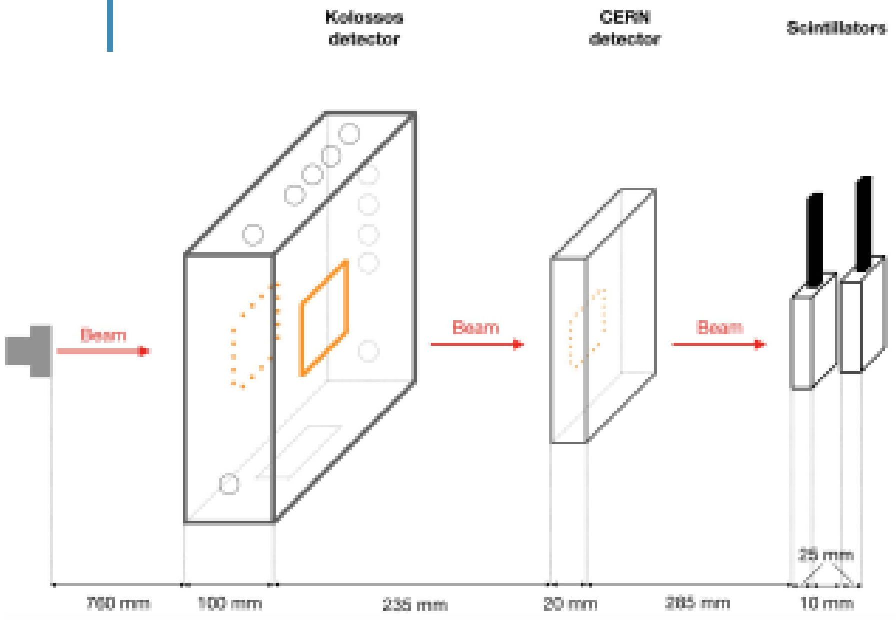
- Is the traditional crossed-strips design thinner?
- We didn't know of the necessary postprocessing increasing the copper layer thickness
- Are the thickness non uniformity (vias and crossings) a possible issue?



FIRST TEST BEAM







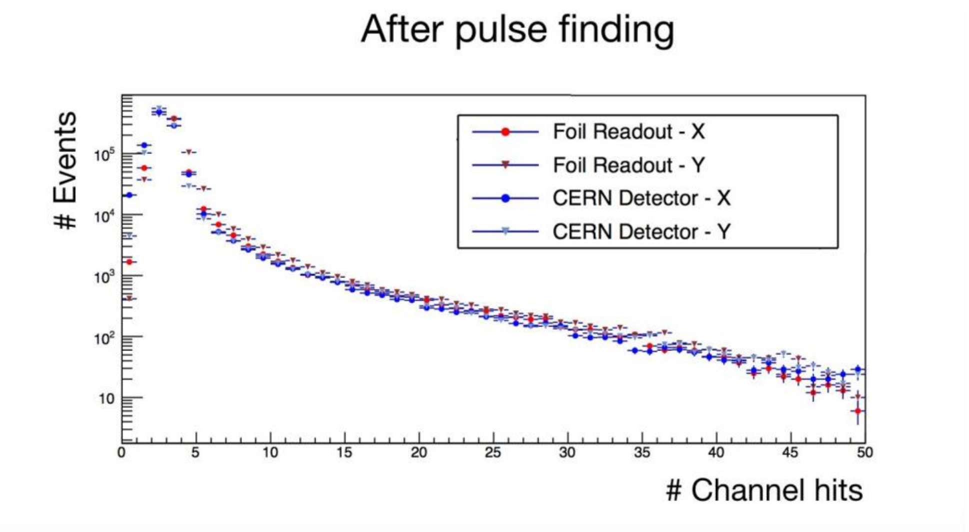
Detector setup

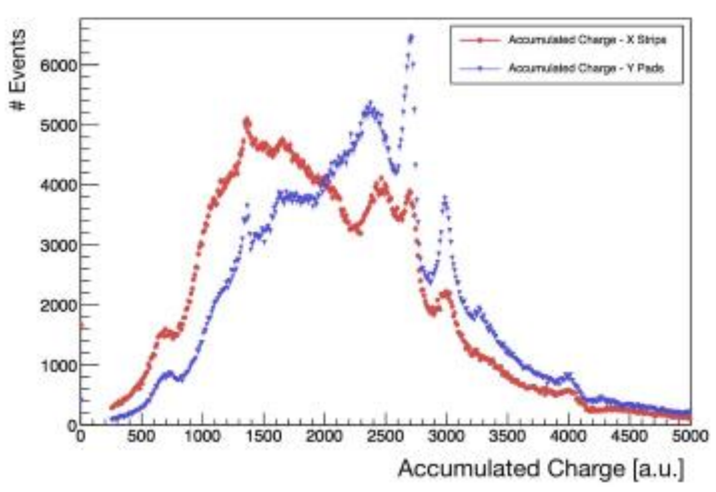
- Triple GEM stack
- 512 channels (APV + SRS)
- All installed in the same gas volume
- Kapton window above and below the sensitive area

Test-beam setup

- 885 MeV electrons from the MAMI accelerator
- CERN detector as a reference and comparison
- Double scintillator trigger

PRELIMINARY ANALYSIS





Software and algorithms

- Self-written software for reconstruction, simulation and analysis.
- Reconstruction currently up to the pulse level
- Hit finding and tracking under development

Charge sharing

- 2-3 strips typical width
- Slightly more charge on the pads than the strips
- More detailed analysis ongoing
- Comparable with CERN detector

COPPER REDUCTION – CHROMIUM GEMS

Current GEM set

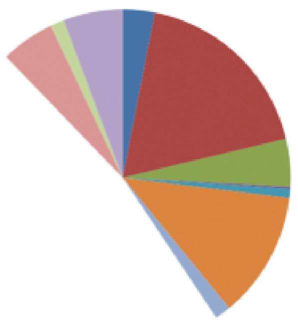
- 4 half-chromium 1 broken)
- 1 full-chromium
- Basic characterization showed no surprises

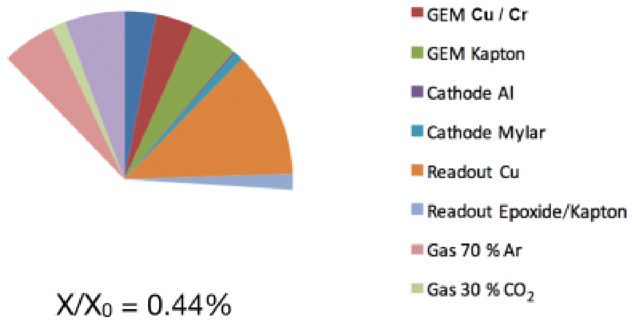
The long term reliability issue

- Measured efficiency drop by other groups as a function of accumulated charge
- How long can we efficiently use a chromium GEM in the different stack layers in beam conditions?
- Does the efficiency drops depends also on the rate?
- How does the efficiency changes depending on the chromium facing?

First in-beam try

- Drift layer of the triple stack
- 2 MHz 885 MeV electrons for 1 hour
- No efficiency drop in the data but visible marks

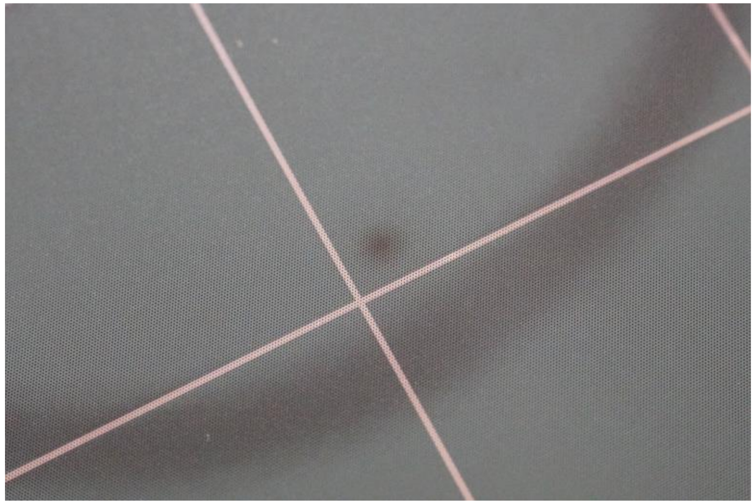




After 1 hour

Facing the drift

2MHz electron beam



CHROMIUM GEMS RELIABILITY STUDY

Second beam test

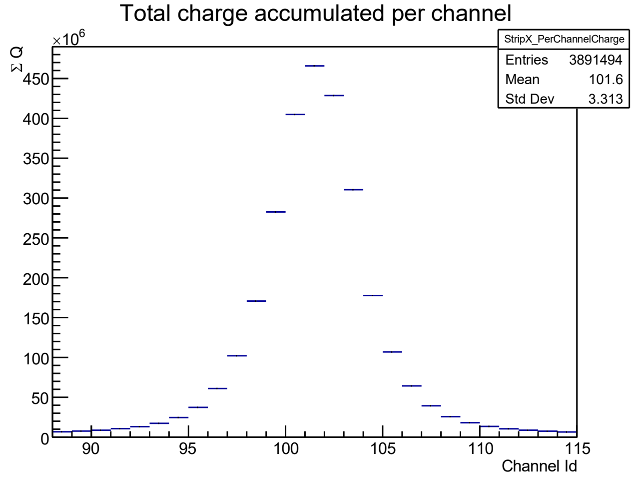
- Additional measurement during the Kapton foil beam test
- 5 hours at 1.4 MHz with 885 MeV electrons from MAMI
- Fixed beam point
- Chromium GEM facing the anode

Preliminary results

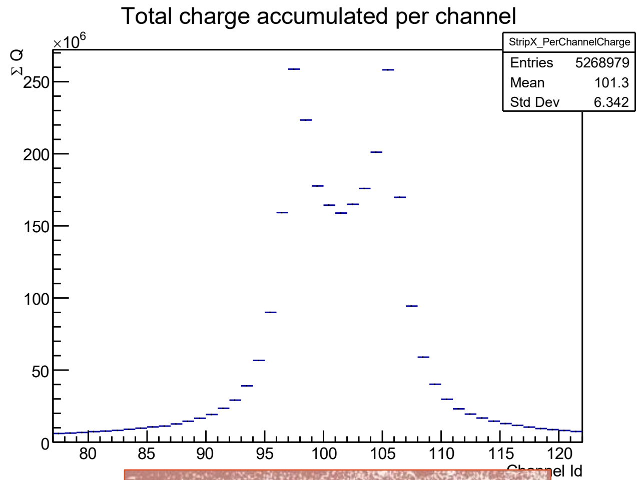
- Only pulse-level analysis
- Clear efficiency drop in the middle of the beam spot

Follow-up program

- Time evolution of the efficiency
- Rate and charge dependency
- Perform a systematic beam-time measurement with different positions of the chromium GEMs
- Estimate the lifetime of a Chromium GEM in experimental conditions



First 30 minutes



Last 60 minutes

SHORT DRIFT TPC

Detector design

- 2 x 10-15 cm drift volume with middle cathode
- 2x8 mm pads
- 10-12 track samples over ~ 10 cm track length
- About 600 channel per row – 6000-7200 per spectrometer, half the channel budget of the hodoscope design
- Different electronics requirements than the hodoscope tracker
- A new student starting to work on it

Challenges

- High rate capability. How far can we go?
- Focal plane position and angular resolution - how many samples do we need?

What's the current experience?

- Has anyone tried a similar design?
- What are the possible show-stoppers?
- What should we avoid?