A NEW OPEN FIELD-CAGE TPC FOR THE MAGIX EXPERIMENT

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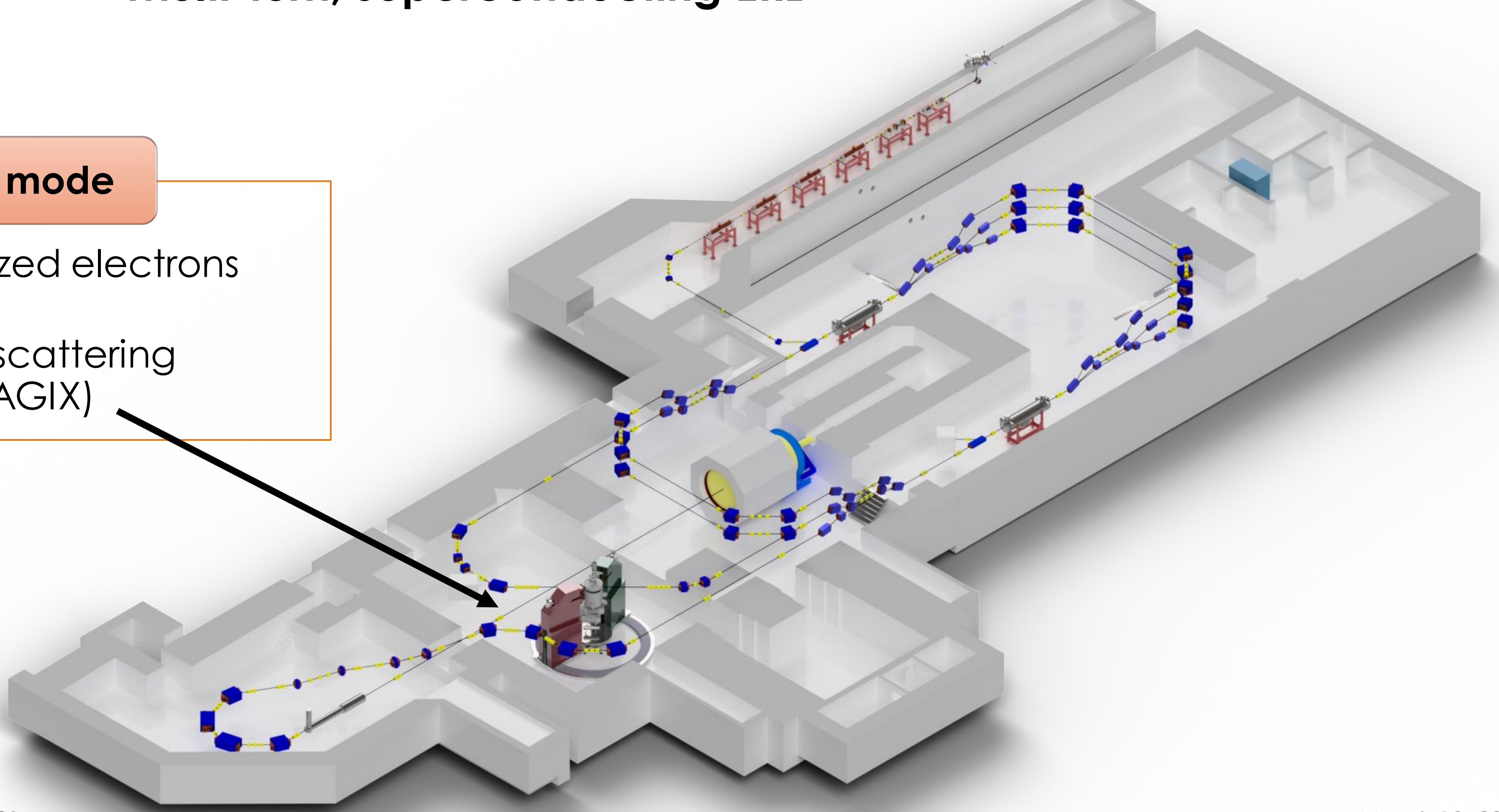
On behalf of the
MAGIX Collaboration - Mainz

THE MESA ACCELERATOR

Multi-turn, superconducting ERL

Energy recovery mode

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



THE MAGIX EXPERIMENT

A high-precision multi-purpose experimental setup

Internal Gas Target

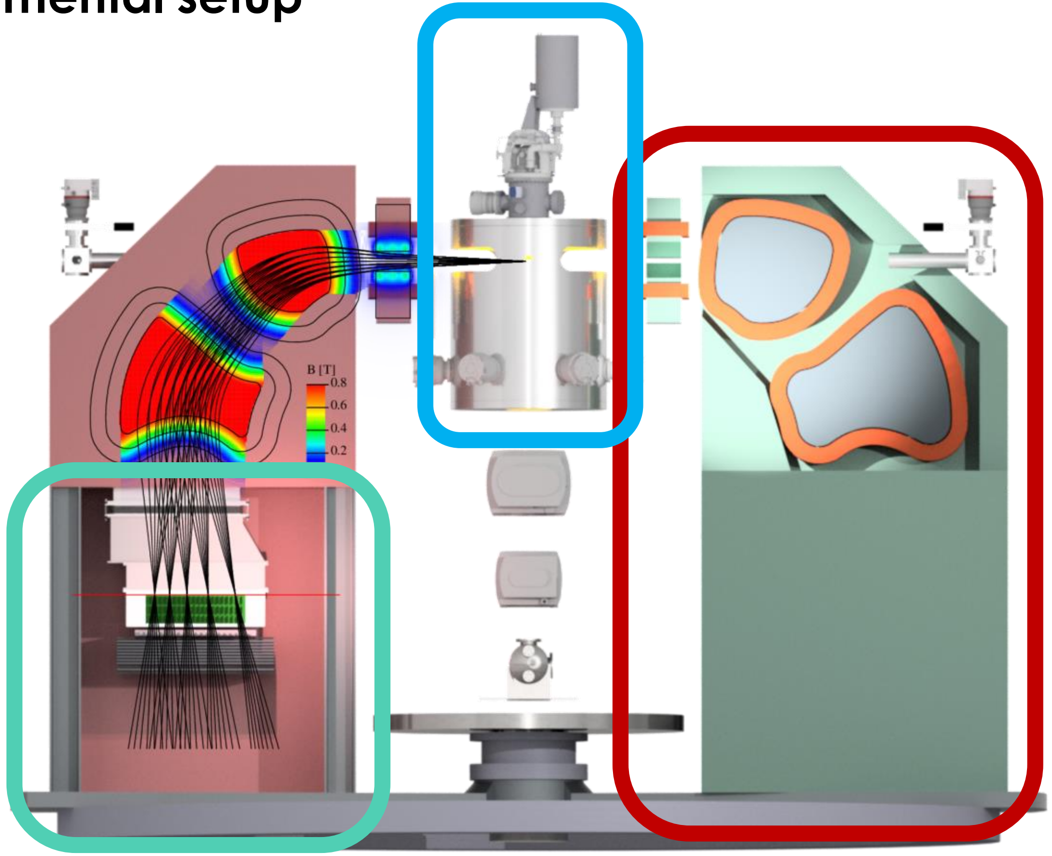
- Windowless gas target
- Integrated recoil silicon detectors
- Forward luminosity monitors

Spectrometers

- StarPort magnetic spectrometers
- Zero-degree tagger spectrometer

Focal Plane Detectors

- GEM-based TPC tracker
- Timestamping trigger



WHY A TPC?

Minimal material budget

- Reduces the detection threshold and the effect of multiple scattering

Efficiency and uniformity

- Up to 24 samples along each track allows to achieve close to 100% efficiency
- All samples neighboring each other allows for an easier tracking even with multiple tracks
- A single gas volume with the same geometry for all angles and energies

Compact and cost effective

- A single detector with a single amplification layer can fulfill all the tracking needs

THE MAGIX TPC DESIGN

DESIGN CONSTRAINTS

Tracking requirements

- Dependent on the specific channel
- Constrained by the spectrometer optics
- $\frac{\delta P}{P} < 10^{-4} \rightarrow \sigma_x \approx 100\ \mu m$ at the focal plane
- Tracker angular resolution $\sigma_\omega < 3.5$ mrad

Vacuum foil effect

- The momentum resolution will still be dominated by the TPC point resolution
- Multiple scattering in the foil dominates the angular resolution
- The lever arm between the foil and the first measurement point amplifies the effect

Construction constraints

- Place the foil as close as possible to the sensitive area
- Reduce the thickness of the foil
- Avoid structures in the foil that will make the uncertainties non-uniform

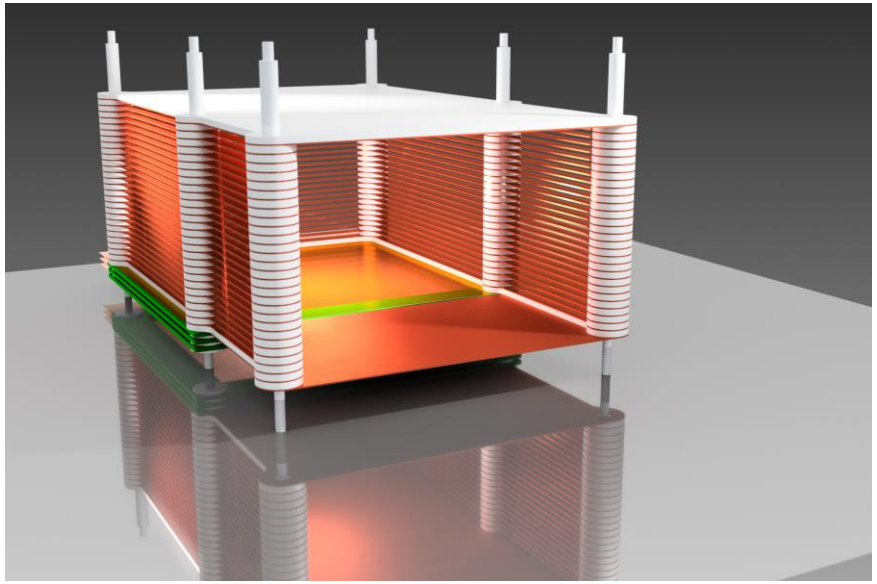
Sagitta mm	d mm	R_max mm	R mm	R/R_max	dl/l	Resolution mm	Angular mrad
10,12	0,050	114,0	213,8	187,6%	17,3%	0,029	2,874
10,12	0,075	171,0	213,8	125,0%	11,6%	0,036	3,601
10,12	0,125	285,0	213,8	75,0%	6,9%	0,048	4,780
17,70	0,050	114,0	128,2	112,5%	10,4%	0,051	2,874
17,70	0,075	171,0	128,2	75,0%	6,9%	0,064	3,601
17,70	0,125	285,0	128,2	45,0%	4,2%	0,085	4,780
29,95	0,050	114,0	85,5	75,0%	6,9%	0,086	2,874
29,95	0,075	171,0	85,5	50,0%	4,6%	0,108	3,601
29,95	0,125	285,0	85,5	30,0%	2,8%	0,143	4,780
H. Merkel - Field cage calculations					Goal:	< 0,1 mm	< 3,5 mrad

OPEN TPC CONCEPT

No field shaping in the entrance window

Extension plates in the spectrometer vacuum to reduce field distortions

Focal plane aligned to the first centimeters of the sensitive volume



The MAGIX focal plane TPC (Proceedings)

A REAL PROTOTYPE

Field cage

- Main field cage
- Entrance interface
- Extension system

Amplification and readout

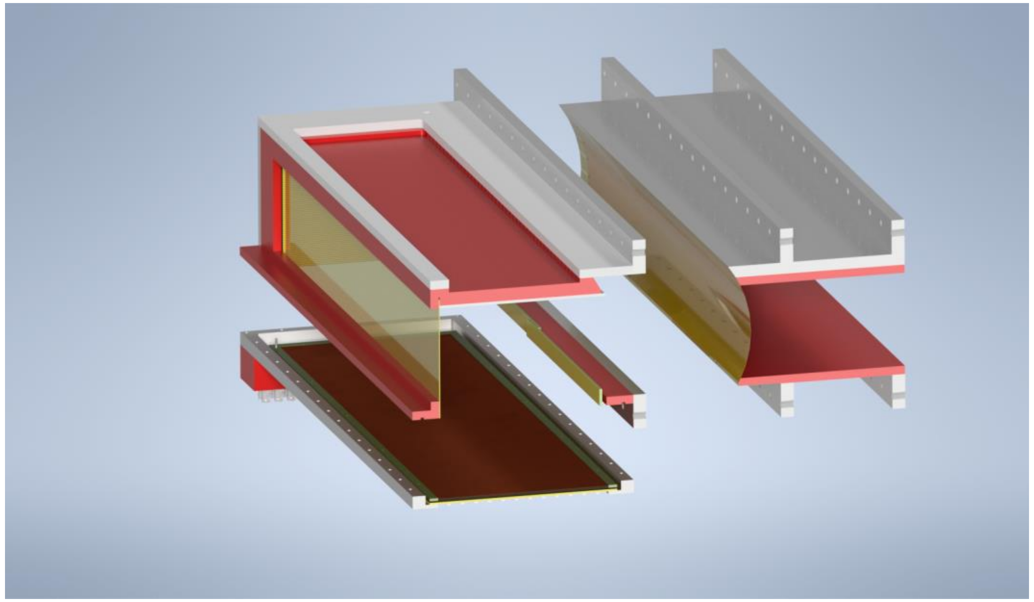
- Extensible triple gem setup
- Rectangular pad readout

Electronics

- VMM3a frontend with SRS DAQ system
- Integrated cooling system

Calibration system

- Cathode electron extraction
- Laser tracking



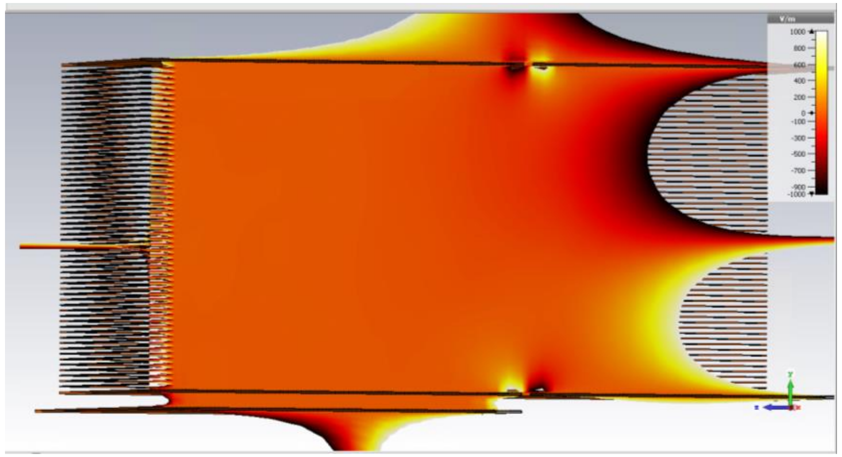
THE MAIN FIELD CAGE

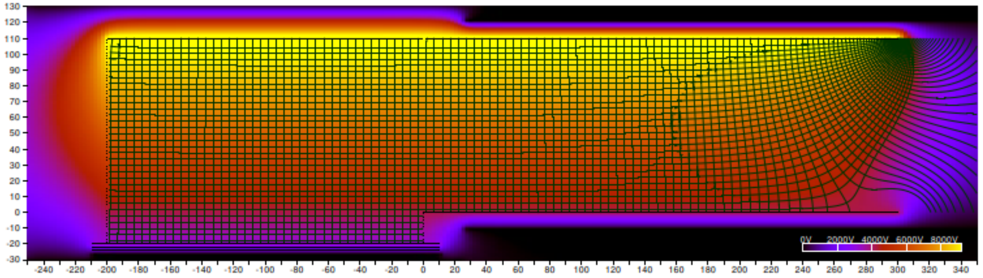
Simulations

- FEM simulation to define the design parameters
- BEM simulation to accurately calculate the field configuration

Field shaping in the sensitive volume

- No constraints on the distance between the field cage and the sensitive area
- 2 mm gap between field shaping strips without mirror strips
- Rigid panels on the sides, flexible membrane on the exit to reduce energy threshold to the timestamping detectors
- Field distortions dominated by the construction accuracy





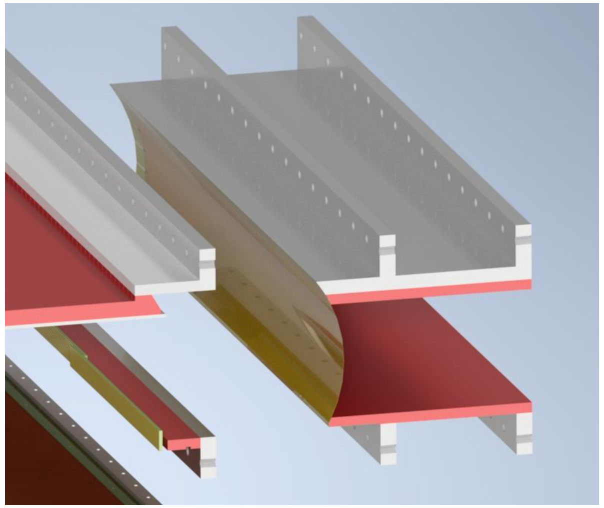
MEMBRANE AND EXTENSIONS

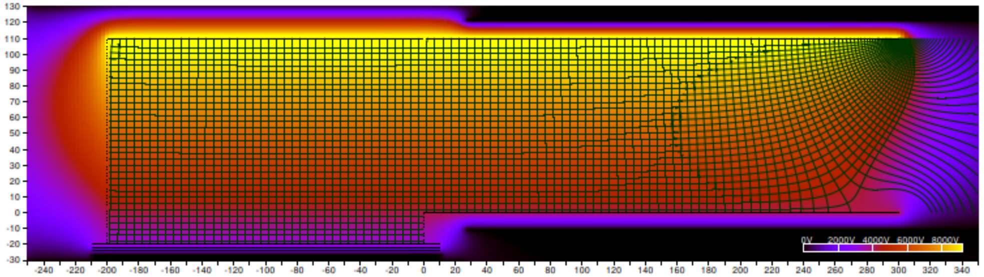
Focal plane extension

- Field shaping elements extending in the spectrometer vacuum, outside the sensitive volume
- Necessary to avoid the field cage on the entrance window
- 10-30 cm length depending on the field shaping configuration and the maximum field distortion required

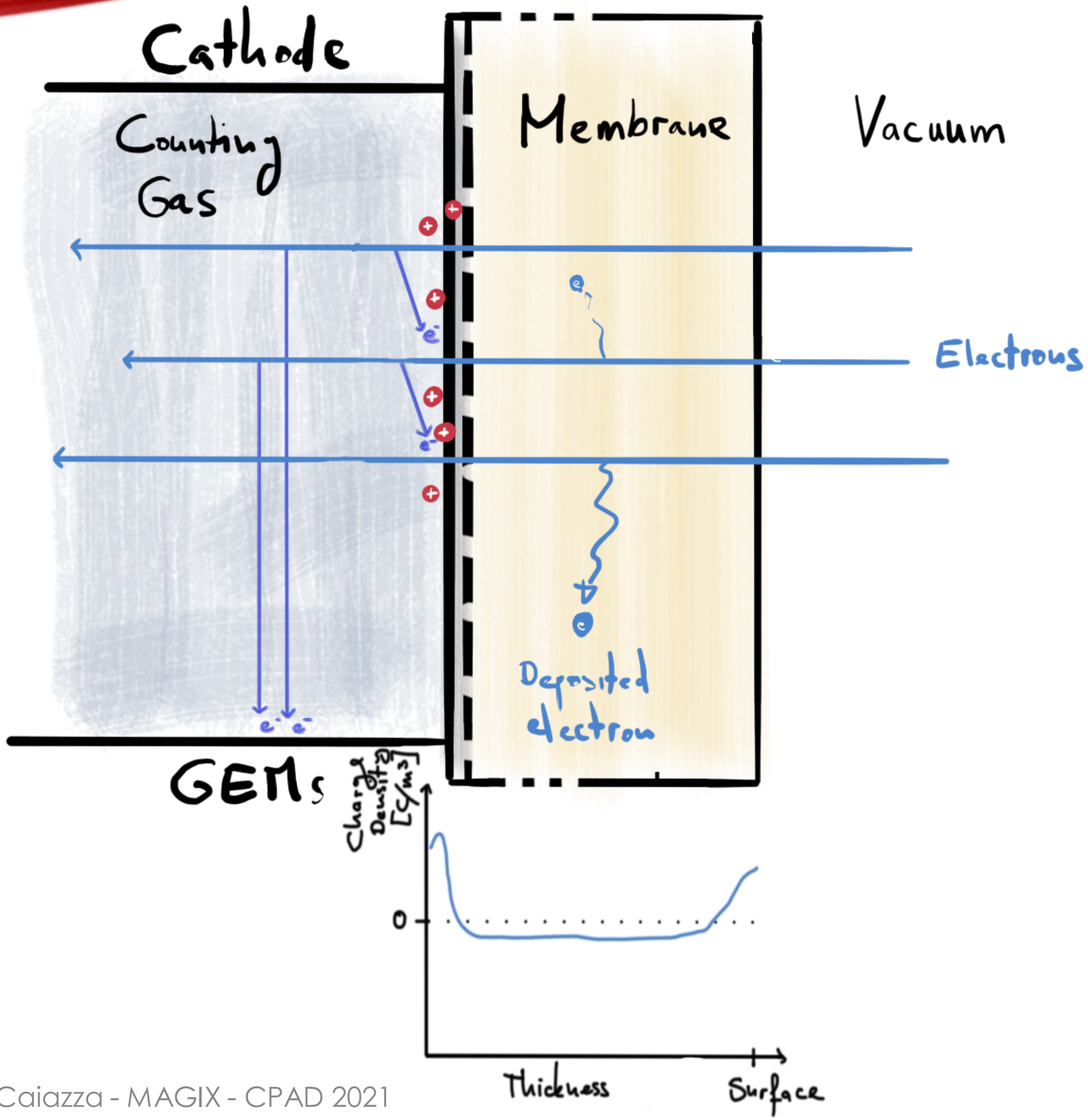
Vacuum interface

- Dielectric membrane without field shaping surfaces
- Clamped between the main field cage and the extensions to eliminate gaps
- Field shaping step above the GEM surface
- Electrode at the edges to improve the space charge evacuation





CHARGING UP



Deep dielectric charging

- Charge deposited in the bulk of the material by primary particles via ionization
- Dipolar polarization with positive charge on the surface and negative on the bulk
- Very slow moving and not interacting directly with the sensitive gas

Surface charging

- Direct attachment of the free charges, electrons or ions, to the surface of the dielectric
- Interacting with the counting gas, can be affected by its composition

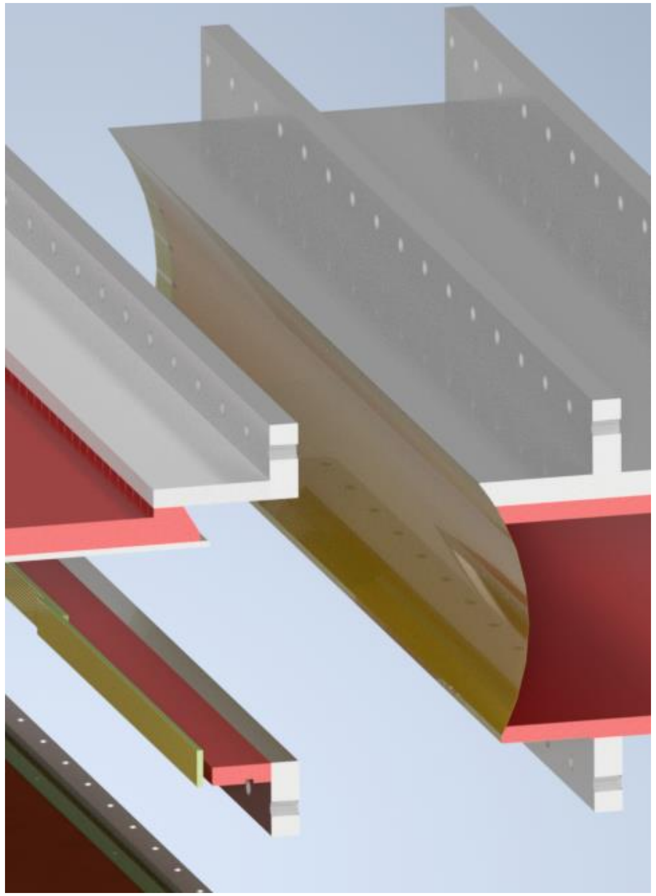
MAGIX VACUUM MEMBRANE

Membrane charging up

- Focused irradiation due to the spectrometer optics
- One side in direct contact with ionized gas

Competing effects

- The radiation will polarize the surface positively
- The free electrons in the gas will attach and neutralize the polarization effects
- What would the net effect be is difficult to quantify



WILL THIS BE A PROBLEM?

Step 1: Measure

- Use MAMI to achieve the required particle rates
- Short high-rate bursts to polarize the membrane
- Small currents to measure the effect
- The small prototype can be used for such measurements

Step 2: Possible solutions

- Embed electrodes at the edges of the foil to slowly diffuse and evacuate the charge
- Use a resistive foil to increase the evacuation rate.
- Increase humidity to depolarize the membrane faster

AMPLIFICATION AND READOUT

Why GEMs

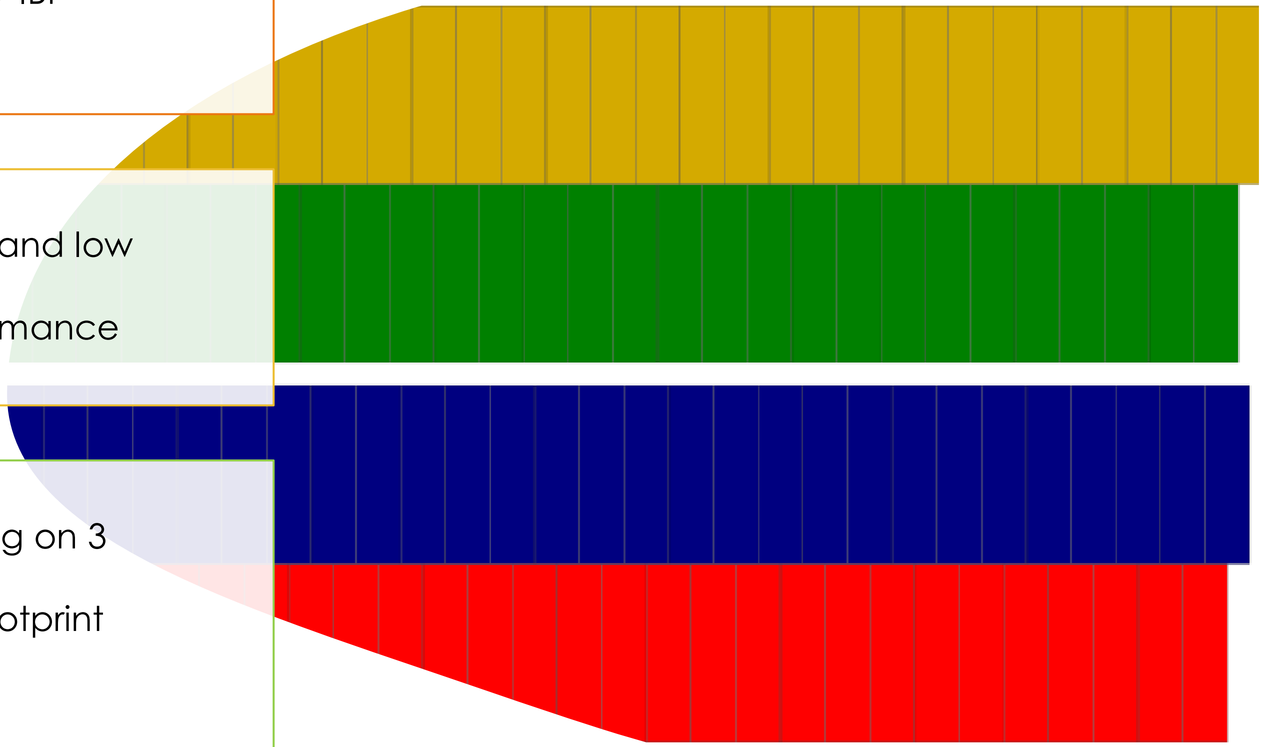
- Modern gas amplification system with high-rate and low-IBF capability
- Adaptable to a wide range of operational scenarios

The GEM stack

- 3 GEMs are the minimum required for stable operations and low IBF
- The prototype will allow to install up to 4 GEMs for performance comparisons

Readout layout

- Small enough pads to ensure an average charge sharing on 3 pads per row
- Large enough pads to match the electronics surface footprint
- $2 \times 8\ mm^2$ rectangular pads
- 24 staggered rows of 384 pads (3*128)
- Integrated HV distribution system



READOUT ELECTRONICS

VMM3a frontend

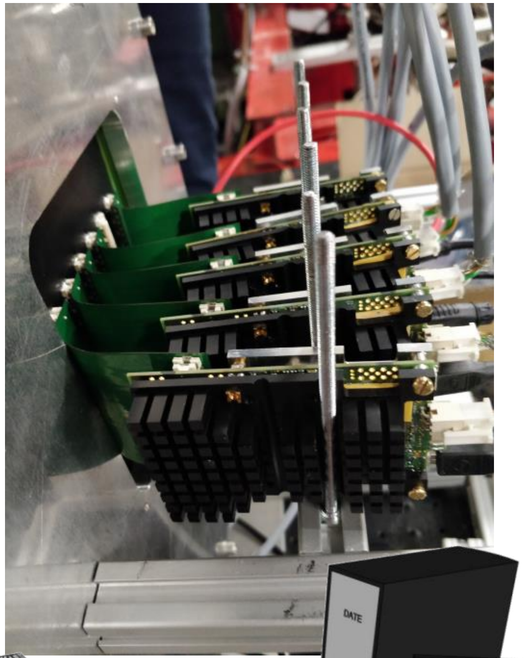
- Digitization integrated in the ASIC
- 64 channel per ASIC, 2 chips integrated in a frontend board (hybrid)
- Very large output bandwidth available (> 3 MHits per channel)

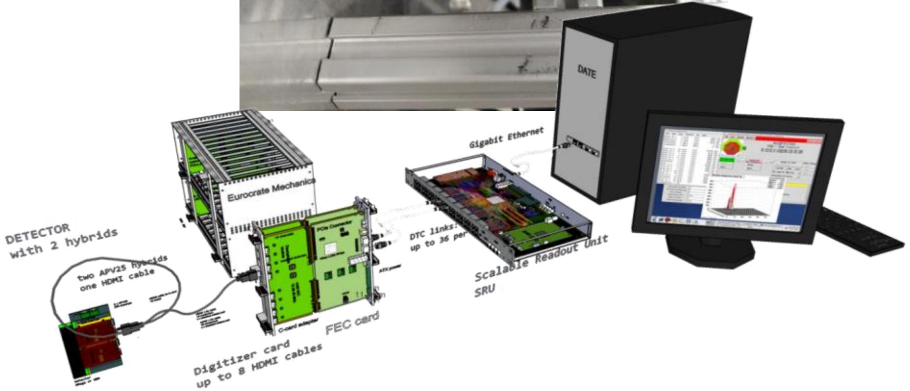
SRS data collection

- Scalable Readout System based on custom FPGA + commercial network components
- Expandible from a lab setup to a large experiment
- 1024 channels per readout board, synchronized by a common clock distribution

MAGIX integration

- 10000 channel per spectrometer
- 3 hybrid per row with neighboring channels matching neighboring pads to use the VMM neighboring logic





MONITORING AND CALIBRATION

Designing a TPC is managing distortions

- Project accurately and stably the trajectory of a primary particle to the readout surface
- The information travels with the free charge in the gas along the drift lines (≠ field lines)
- Uncontrolled imperfection of the electromagnetic fields leads to loss of information

Static distortions

- Deviation of the electromagnetic field caused by time-independent configuration features
- Granularity of the field shape, misalignment of components $E \times B$ effects
- Can be reduced with a static calibration

Dynamic distortions

- Deviation of the electromagnetic field correlated to the change of an environmental parameter
- Rate dependent or time dependent distortions are the most common
- Difficult to calibrate away without a system to monitor them on the same time-scale

MAGIX TPC CALIBRATION SYSTEMS

Engraved pattern

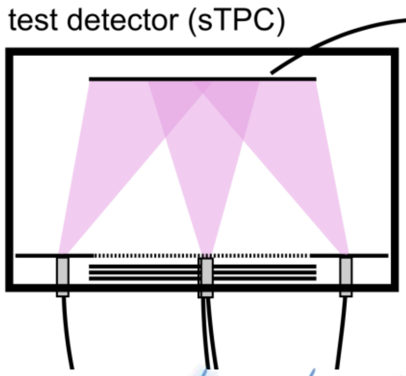
- Etched copper foil on an aluminum support structure
- UV lamp of the right wavelength extracts electrons from the aluminum
- Difficult to integrate in our geometry due to the short drift

Starry night

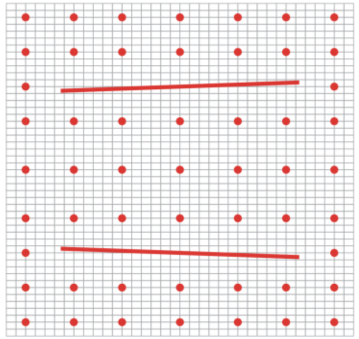
- Holes in the cathode in a well-defined pattern
- Fit optical fibers in the cathode holes connected to an UV source
- The end of the fibers will be coated with a thin aluminum layer to produce photoelectrons

Pulsed laser calibration

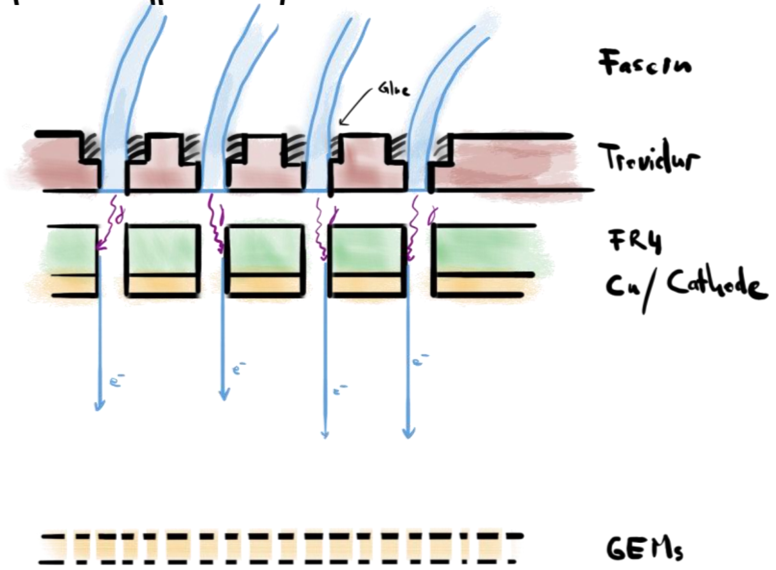
- Pulsed UV-laser reference tracks through the sensitive volume will be used to evaluate dynamic distortions



[Dimiti Schaab AG Ketzer]



[T2K arXiv:1012.0865v1]



CONCLUSIONS

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The MAGIX TPC

- Versatile detector for a versatile experiment with a long future ahead
- Innovative approach to achieve fast readouts on low energy particles
- First full-scale prototype under development

The open field cage concept

- Removing the field cage on the entry window of the TPC to minimize the material before the sensitive volume
- Extending the field shaping in the vacuum to minimize distortions even without field cage in the open window

VMM3 large scale integration

- One of the largest users of the VMM3 ASICs in combination with the SRS system

Innovative calibration system

- A network of optical fibers producing photoelectrons to evaluate static distortions
- Reference laser tracks to evaluate the dynamic distortions