JOHANNES GUTENBERG UNIVERSITÄT MAINZ

It's a kind of MAGIX

The development of the Magix experiment

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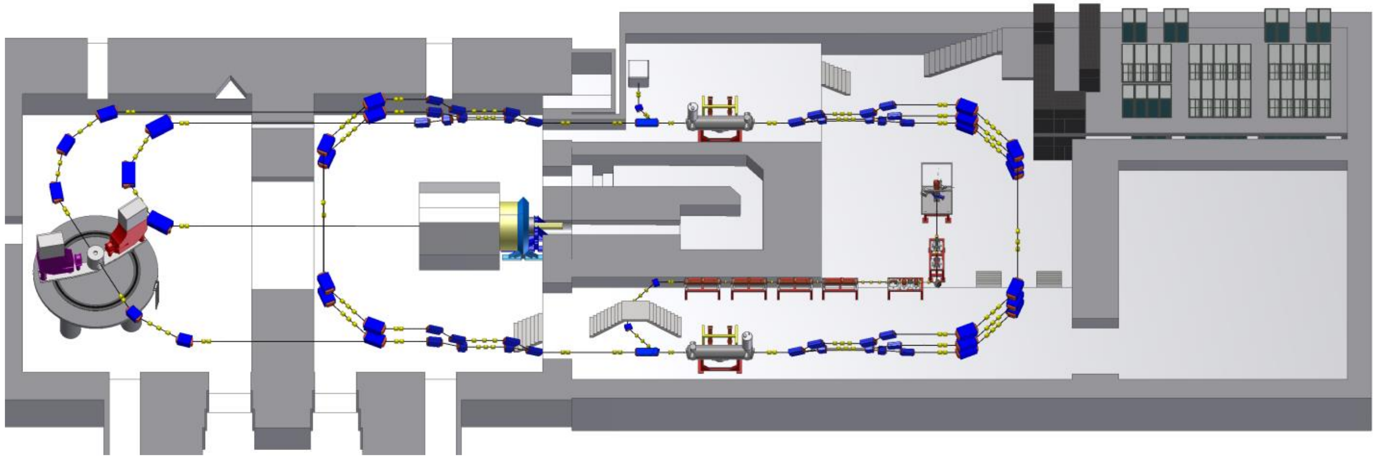
LEPP 2016 – Mainz - Apr. 06 2016

MESA LAYOUT

Multi-orbit recirculator with energy recovery



Energy recovery

- External loop of half-wave length
- Electron energy transferred back to the cavity

Experiment on the recirculating beam (MAGIX) @105 MeV

- External loop after two recirculation
- Thin gas target on the beam path with a dedicated detector

Extracted beam @ 155 MeV

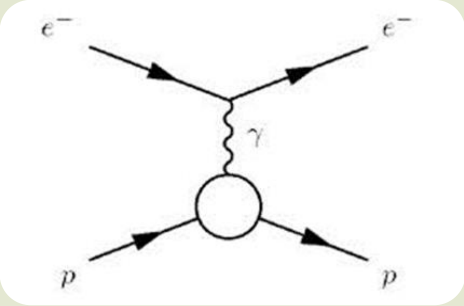
- After a final recirculation, then dumped
- Dedicated experiment (P2)

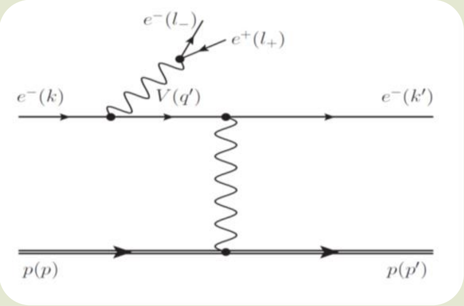
Financed by the PRISMA Cluster of Excellence

MESA
GAS
INTERNAL TARGET
EXPERIMENT

LOW ENERGY ELECTRON SCATTERING

Electron scattering on fixed target below the pion threshold





E-Nucleon scattering

- Elastic or inelastic
- Form factor measurements
- Proton radius

Pair production

- $e^+ e^-$ coincidence
- With SM or dark U(1) photons

Low momentum electron coincidence

- On the scale of the bunch frequency (ns timestamping)

High acceptance

- To improve the statistics on rare event searches

Good momentum resolution

- For high precision measurements
- Low momentum

Good angular resolution

- For background rejection and vertex reconstruction

RESEARCH PROJECTS

Dark photon and dark matter

- Good momentum resolution, off-plane angle measurement
- Proton recoil

Form factors and proton radius

- Scattering angle resolution, forward angles with possibly polarized targets

Astrophysical cross-sections

- Scattering angle resolution and flexible gas target choice

Polarizabilities

- Photon detector, tagger and low-energy proton recoil

Test of chiral effective theories

- Good momentum resolution @ low momenta with polarized beam and target

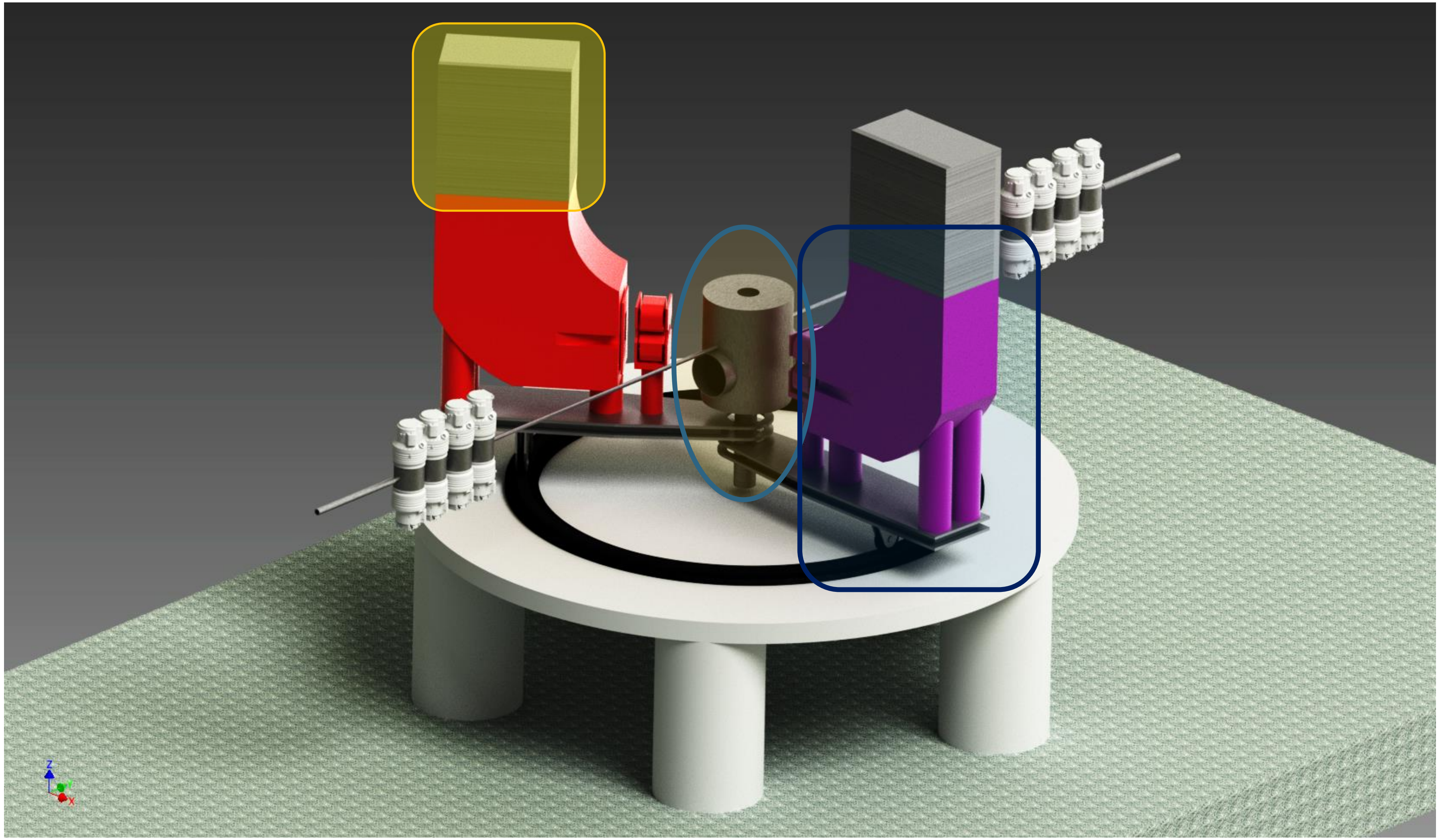
THE EXPERIMENT

MAGIX COMPONENTS

Internal Gas Target

Twin ARm DIpole Spectrometer

Focal Plane Detectors



INTERNAL GAS TARGET

DESIGN REQUIREMENTS

Fixed Target luminosity

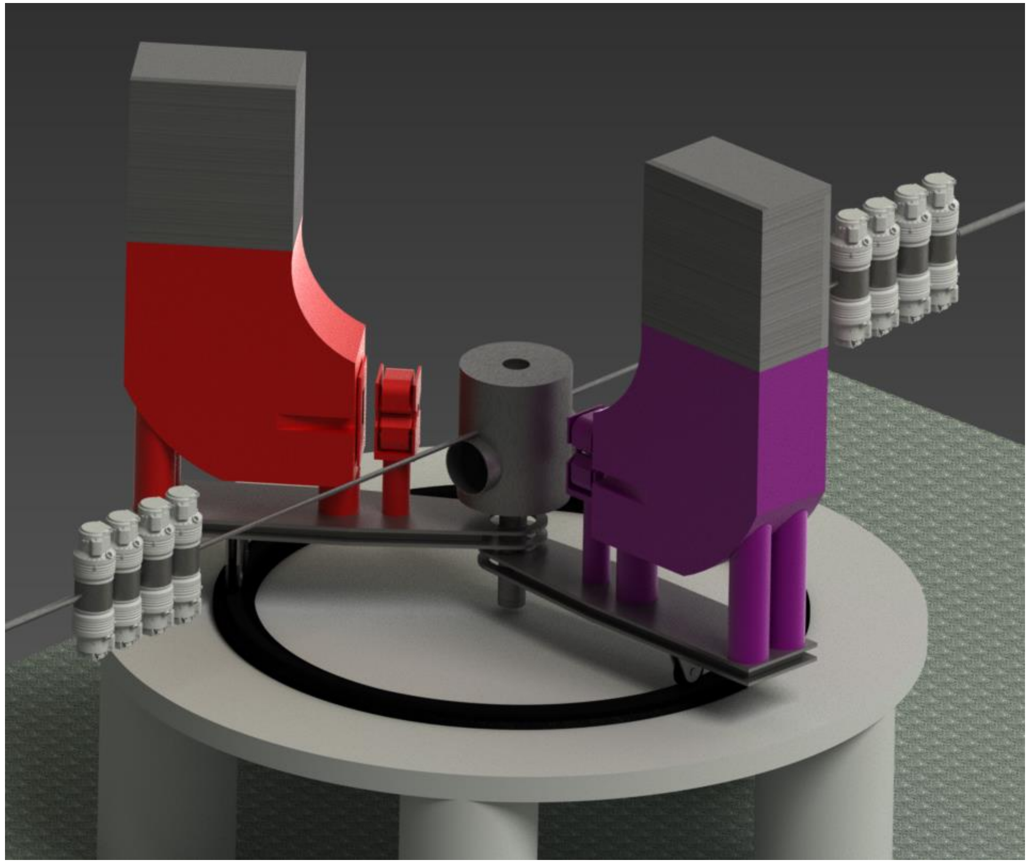
- $L \cong I_b * \rho_t * l_t$

Recirculating beam

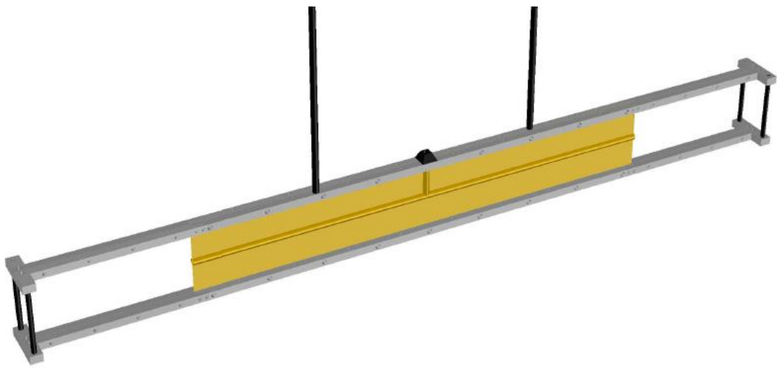
- Thin target required to recapture the beam
- Max energy loss O(10^{-3})
- Gas Density O(10^{25})

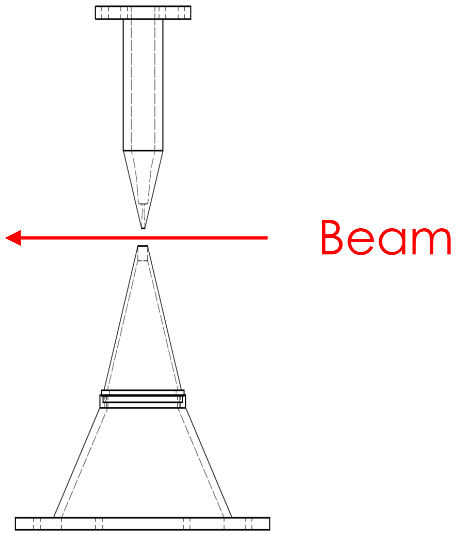
Windowless target

- Containing the gas flow without a container
- Minimize background interaction



TARGET LAYOUT





Foil-thin tube

- To be used with polarized gases
- Moderate gas density $O(10^{22}/m^3)$
- Length (~ 30 cm)
- Estimated luminosity with polarized beam $O(10^{32}\ cm^{-2}s^{-1})$

Jet Target

- Supersonic gas jet
- Higher gas density $O(10^{26}/m^3)$
- O(mm) target length
- Estimated luminosity $O(10^{35}cm^{-2}s^{-1})$

TWIN ARM DIPOLE SPECTROMETER

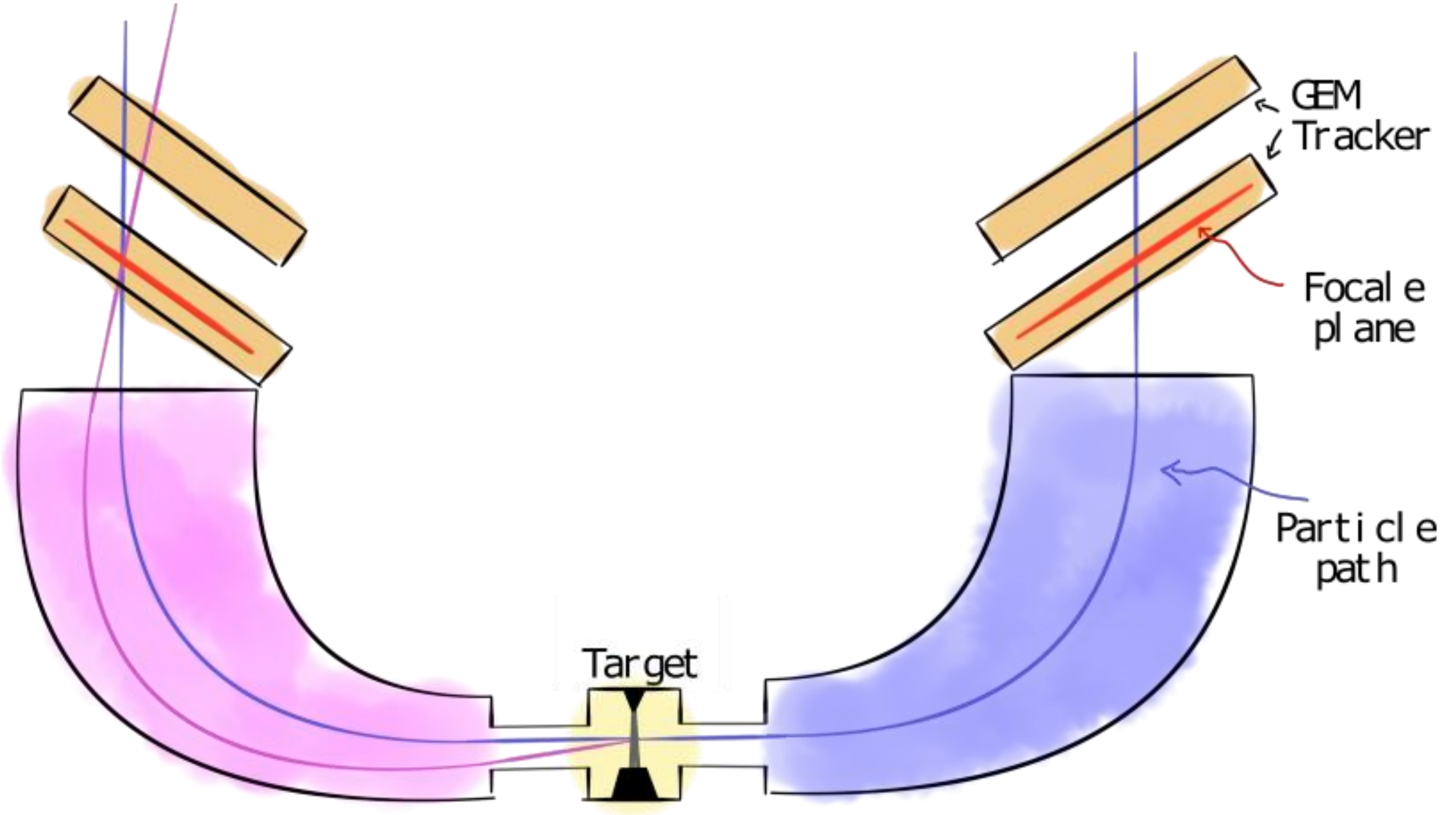
THE SPECTROMETER CONCEPT

Momentum focusing

- Particles of different momenta at different positions
- Mapping of momenta to position

Angular focusing

- Parallel-to-point focusing
- Mapping of angles to position



MAGNET OPTICS

Acceptance

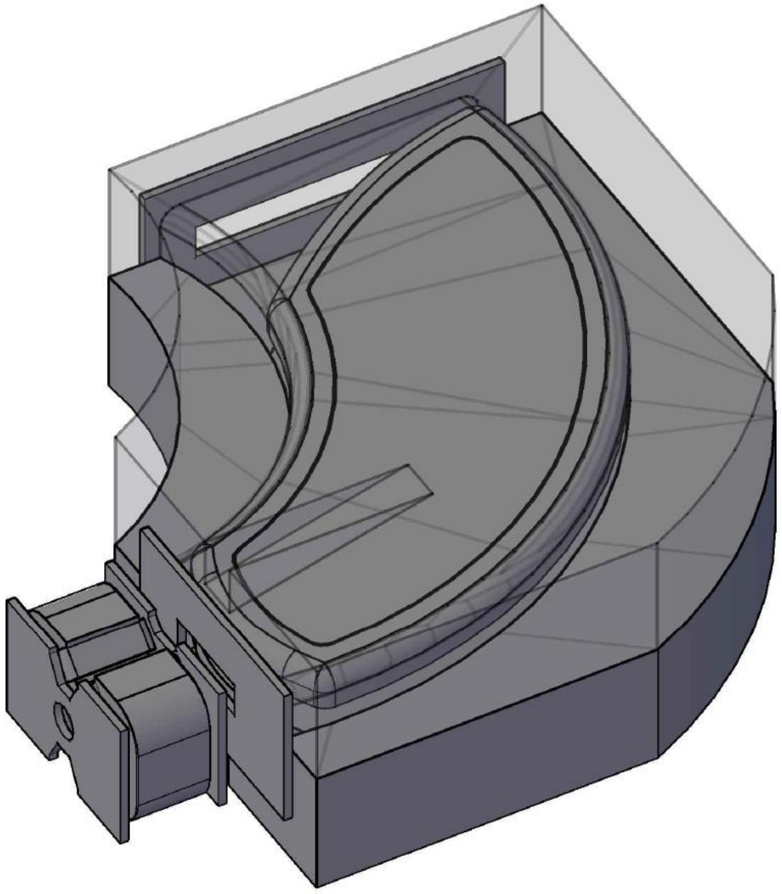
- 200 MeV maximum momentum
- 90 MeV momentum acceptance @ 200 MeV
- ± 3.25° θ and ± 3.75° φ
- 22 cm vertex acceptance at 90°

Momentum resolution

- 10^{-4} relative momentum resolution
- Assuming 50 µm resolution at the focal plane

Angular range

- $\Delta\theta \cong 5 * 10^{-2\circ}$
- $\Delta\varphi \cong 0.2\,^\circ$



FOCAL PLANE DETECTORS

DETECTOR CHALLENGES

High resolution on low momentum electrons

- $1 < p < 100$ MeV
- $\frac{\Delta p}{p} \approx 10^{-4}$
- $\Delta\theta \cong 5 * 10^{-2}\,{}^\circ$

Material reduction

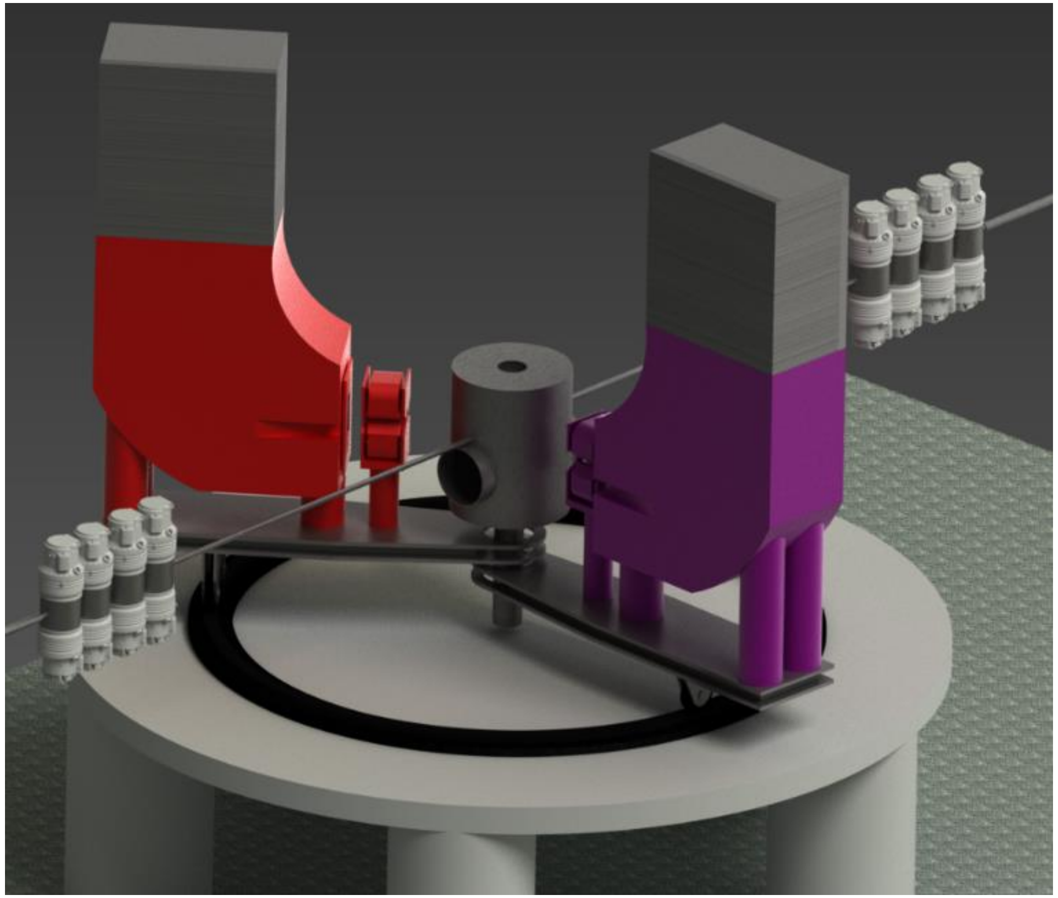
- No window before the magnet
- Thin detector design

Large sensitive surface

- $120 * 30\ cm^2$ focal plane surface
- $50\ \mu m$ point resolution in the focal plane
- At least 2 points to reconstruct the full kinematics

High rate capability

- With a CW operation rates up to $O(1\ MHz)$
- Count rates of $O(10\ KHz)$



FOCAL PLANE DETECTORS

Gas detectors

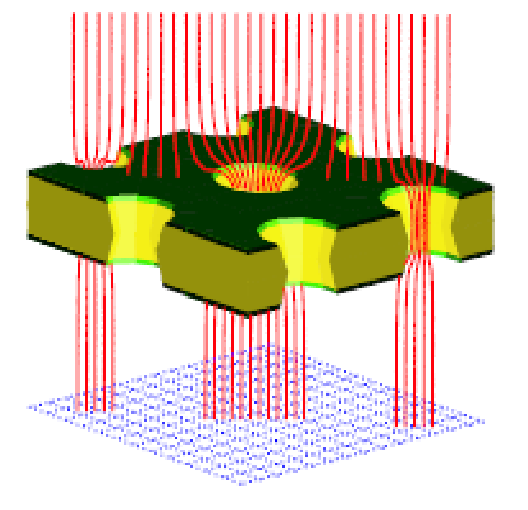
- Low material budget
- Low cost for large area coverage

Micro Pattern Gas Detectors

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

Gas Electron Multiplier

- Thin kapton foil coated with copper and pierced by microscopic holes
- Gas amplification in the holes



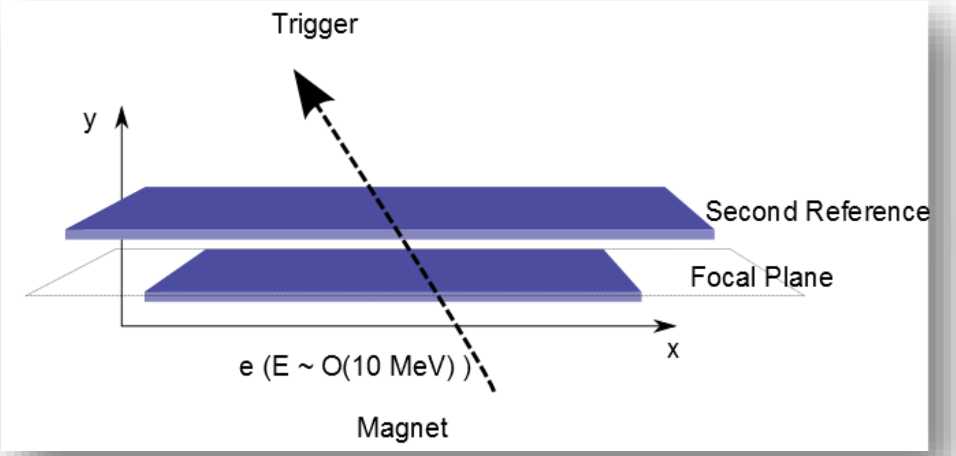
2 Layer Hodoscope

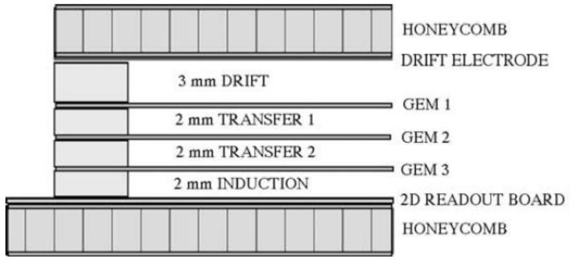
- Simple detector to built
- Uniform and high position resolution
- Moderate material thickness
- Only 2 reconstructed points

Short drift TPC

- More delicate to optimize
- Worse single point resolution
- Minimal material thickness
- Multiple samples and full track reconstruction possible

HODOSCOPE TRACKER





2 Sensitive layers

- The first centered on the focal plane
- The second with a sizable lever arm to measure the angle

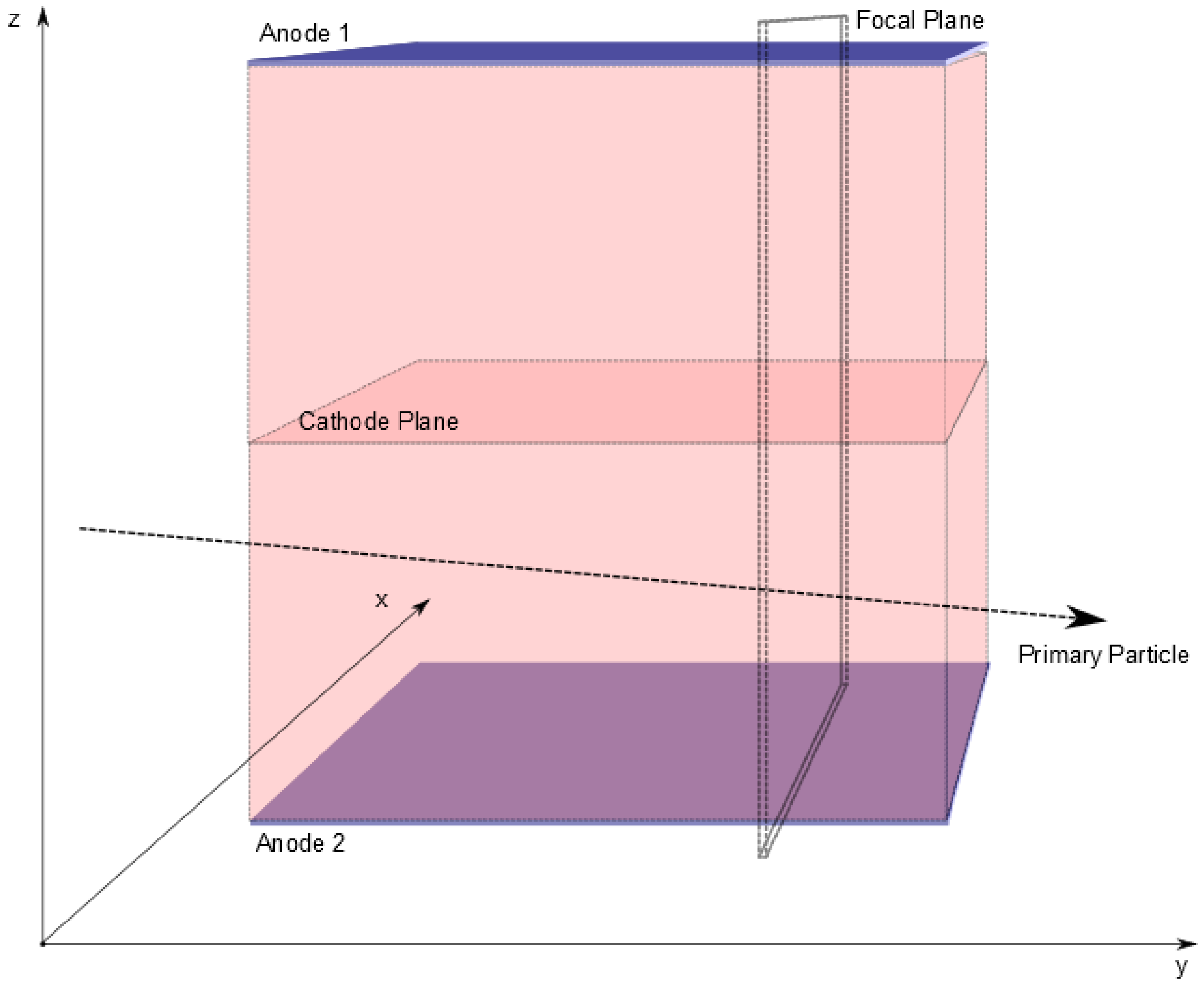
Reliable design

- 2 or 3 GEM
- 2D Strip readout
- Small drift
- ~ 0.7% radiation length

Optimization

- Material reduction to improve angular measurement
- Thin coated GEMs
- Foil based readout plane

SHORT-DRIFT TPC



Features

- Double sided TPC with middle cathode plane
- 15 cm max drift length
- 10 pad rows with 2 mm pads on GEM amplification
- Stretched foil entry window with printed field cage

Magnetic field

- Extension of the dipole to enclose the TPC

Performances

- Can we optimize it for the high rates we will have?
- What momentum resolution can be reached?
- Which angular resolution can be reached?

DETECTOR TESTING

Detector Characterization	Detector gain
	Gain uniformity
	Position resolution
	Rate Capability
Further developments	Increasing the detector size
	Testing a foil readout system
	Building a SD TPC prototype

CONCLUSIONS

MORE I DIDN'T SAY

Trigger	Fast scintillator fibers	
	ns timestamping, mm resolution	
Additional detectors	Recoil detector	
	Photon tagger	
Software &Simulation	Plugin based extendible framework	Slow Control
		Simulation
		DAQ
		Analysis

Versatile experiment for precision physics

- Nuclear and particle physics projects under study

Conceptual design

- Double spectrometer on a windowless target

Technical design

- Magnet simulation
- Target development
- Detector development

Prototyping and testing

- Target prototype will be used in an existing experiment
- Detector prototype tested with cosmics and test-beams

THANKS FOR YOUR ATTENTION

BACKUP

SOFTWARE AND SIMULATION

SOFTWARE FRAMEWORK

Core software

- Custom package extensible through plugin components
- Common versatile configuration system for all plugins.

Simulation

- Fast simulation plugin with special generators (rad. corrections and specific models)
- Generators linked to full simulation (GEANT or custom)

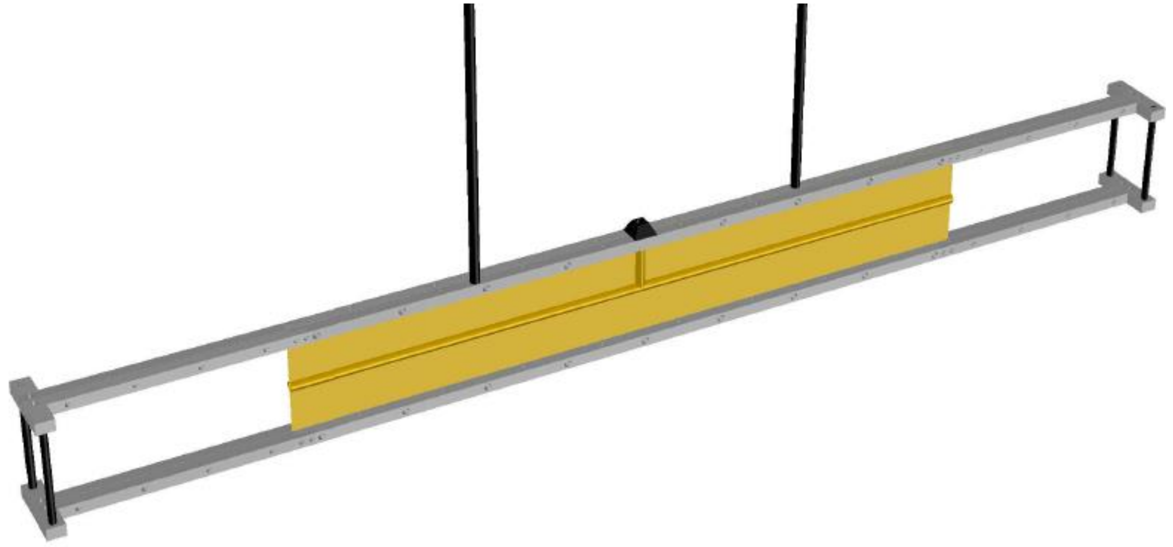
Analysis

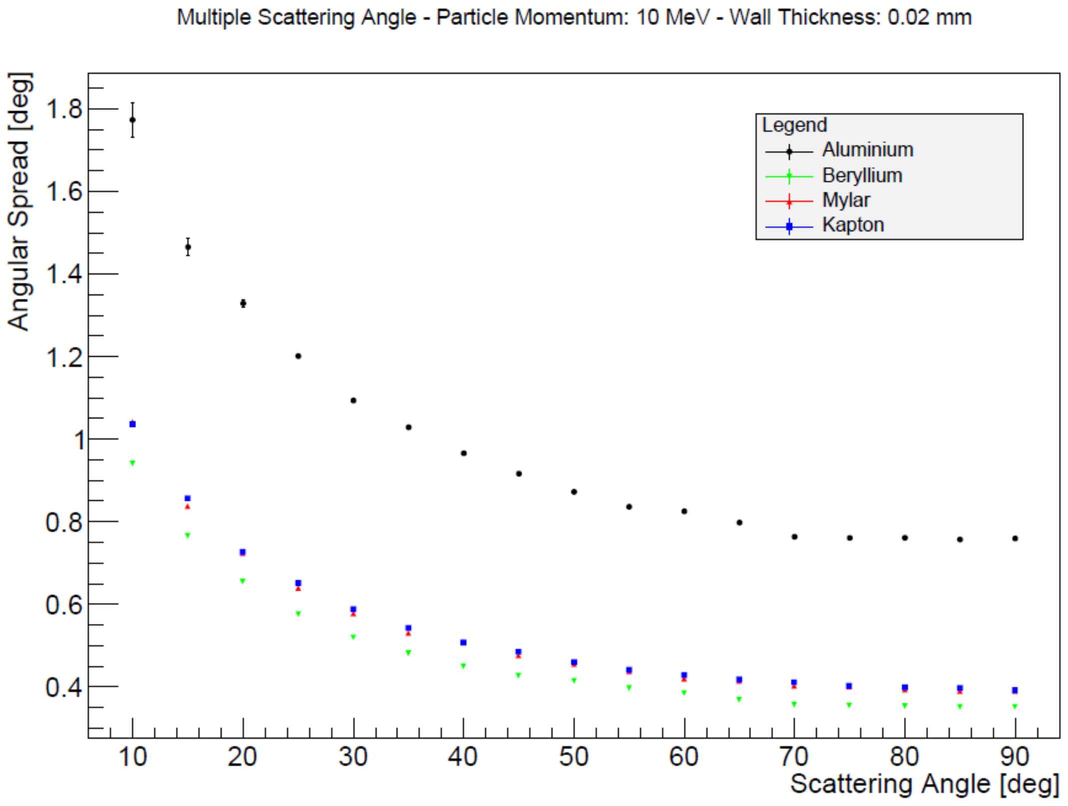
- Directly connected with the simulation tools
- Interfaced with your favorite histogramming tool

DETECTOR TRIGGER

SLOW CONTROL

TUBE TARGET





Thin polymer foil

- 20 µm mylar prototype
- Acceptable multiple scattering @ 10 MeV

Cryogenic injector

- Reduces the recombination of polarized gas

JET TARGET

High pressure supersonic jet

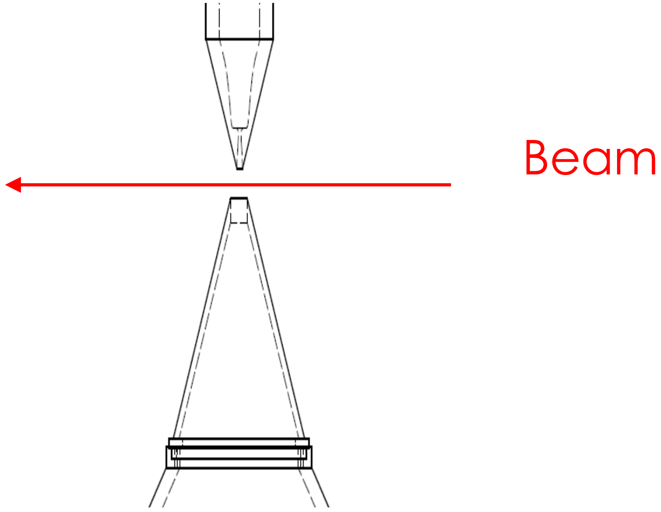
- Special gas nozzle to create a supersonic jet
- Gas catcher to evacuate the chamber

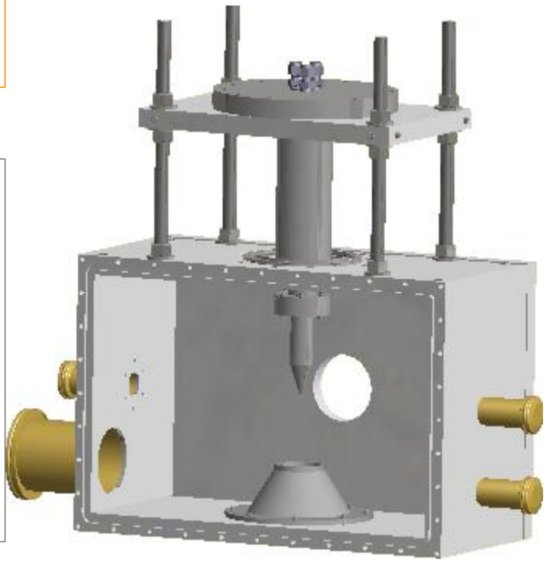
Multiple gas type usable

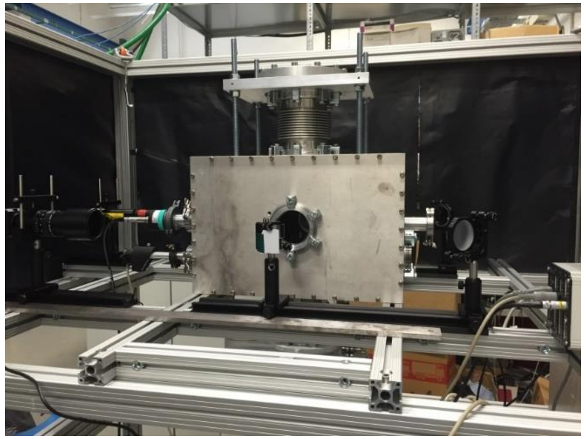
- Hydrogen, Oxygen, Helium already foreseen
- No polarized gases due to high recombination rate

Prototype development

- Injection development (Nozzle and cold head)
- Chamber evacuation system
- Monitoring and slow control
- Collaborative effort with Münster University







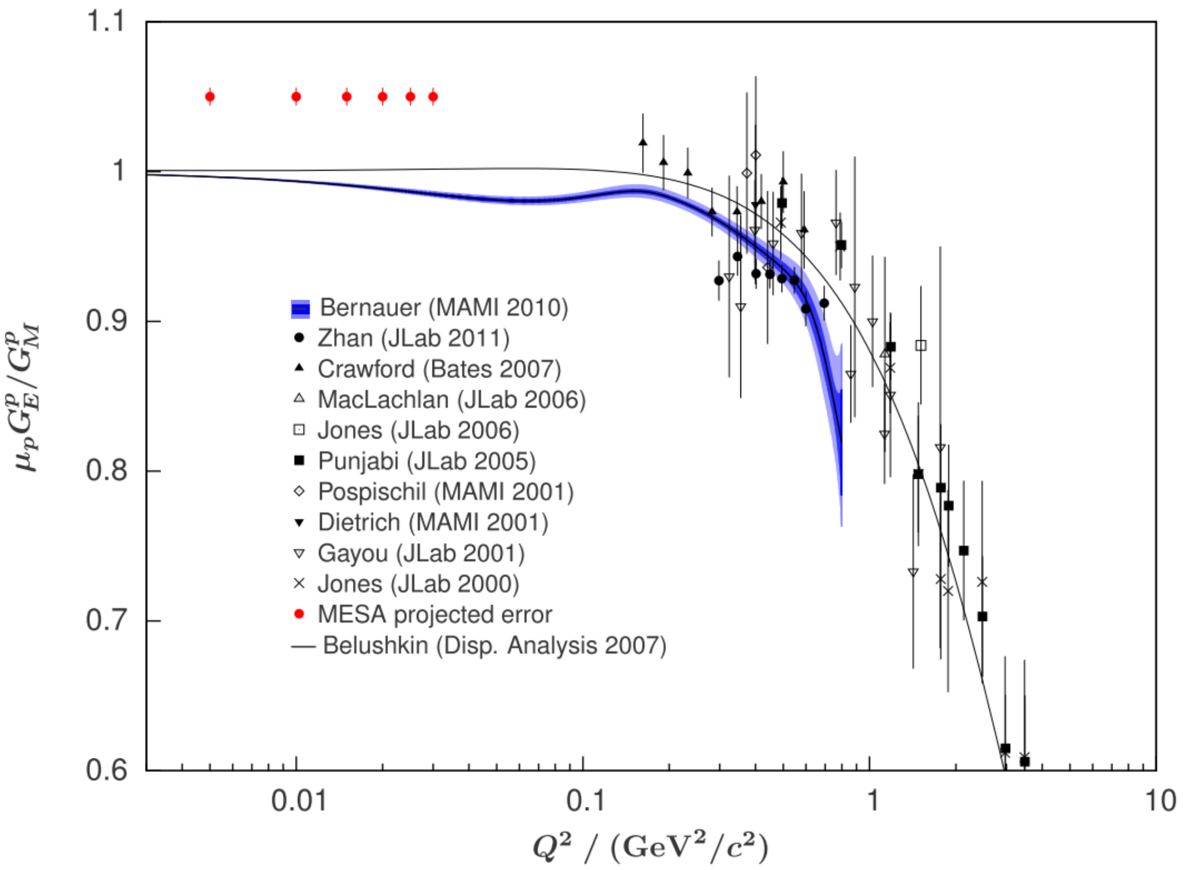
LOW Q² NUCLEAR FORM FACTORS

Electric form factors

- Low energy (5-100 MeV)
- Small forward angle (14°)
- Reduced extrapolation error and assumptions at $Q^2 = 0$

Magnetic form factors

- Polarized gas target
- Polarized electron beam
- Extension at lower Q^2 of measurements already done at MAMI
- Allows precise measurements of the magnetic radius of the proton



CURRENT SETUP: MAMI @ KPH

Mainz Institut für Kernphysik

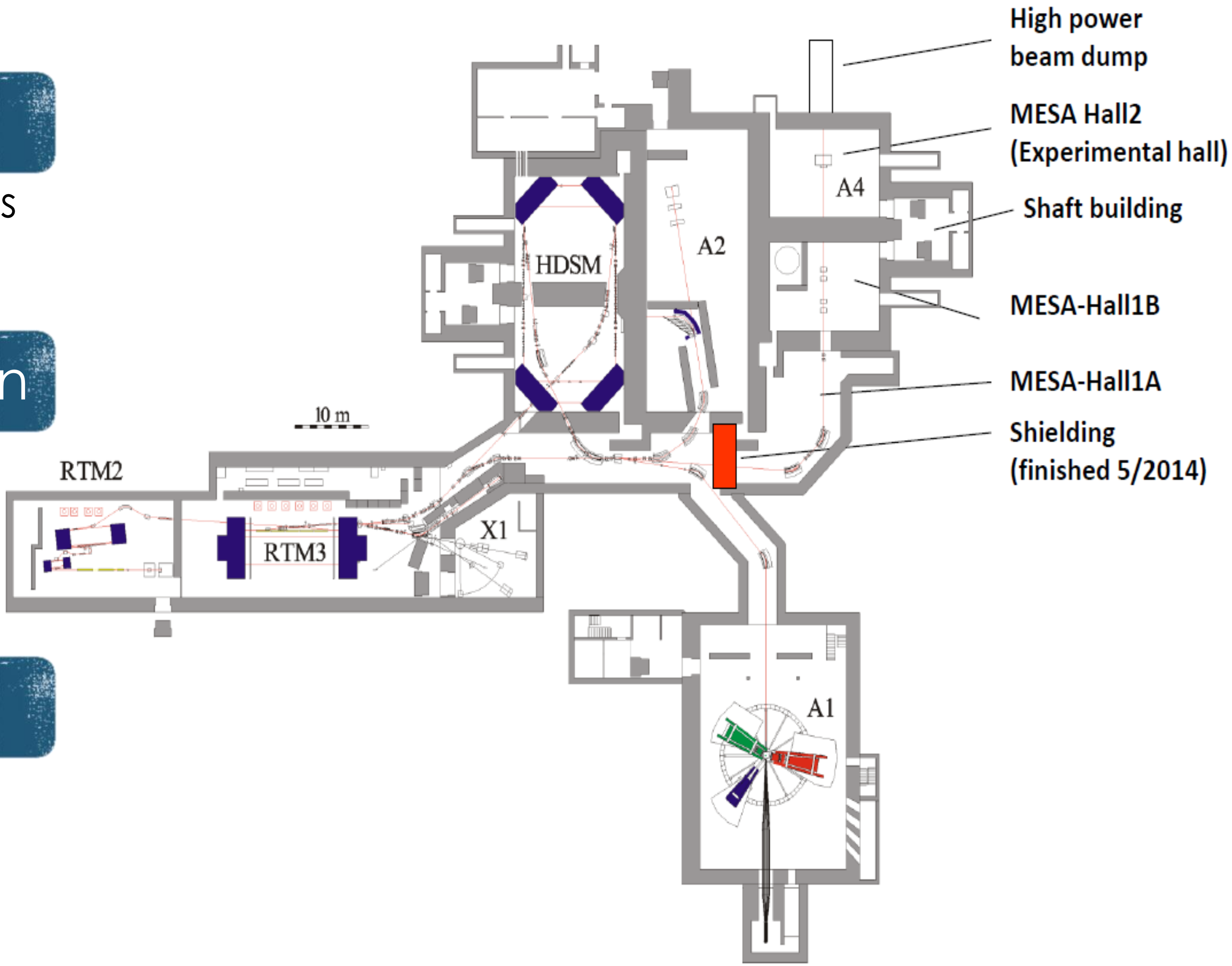
- Running cutting edge experiments for nuclear and hadron physics since 1957

MAMI - Multi-stage microtron

- 1.5 GeV @ 0.1 mA
- Long list of scientific accomplishments
- http://www.kph.uni-mainz.de

Some limitations

- Statistics on rare searches
- Multiple-scattering @ low energy
- Minimum Q^2



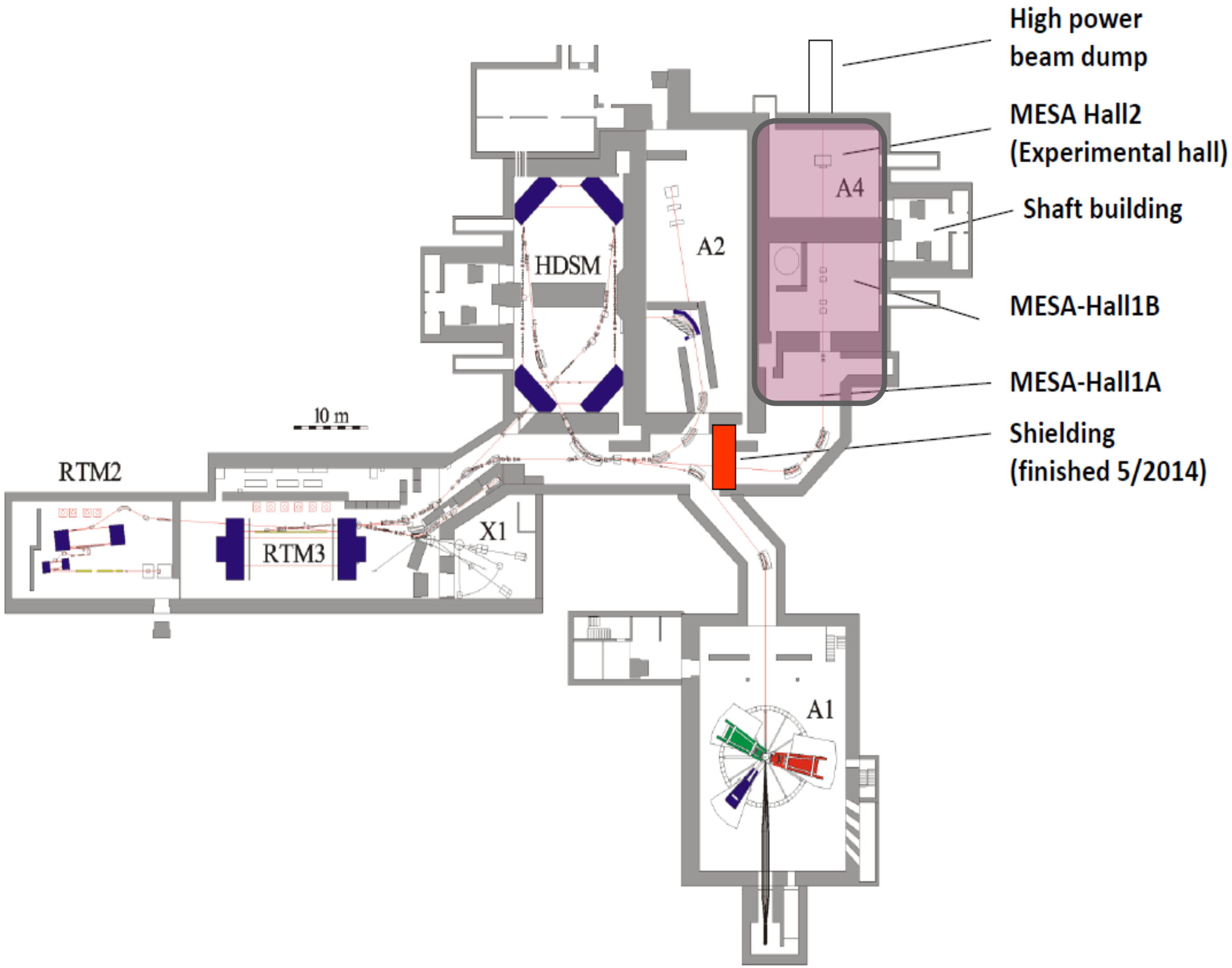
MESA LABORATORY

Using existing space

- Relevant time and money savings
- Hard space constraints
- Cannot hinder the ordinary operation of MAMI

The work is started

- Insulating shield finished
- Removal of obsolete services started
- The funding for additional space and equipment secured



ELECTRON SCATTERING SEARCHES

Parameter space coverage

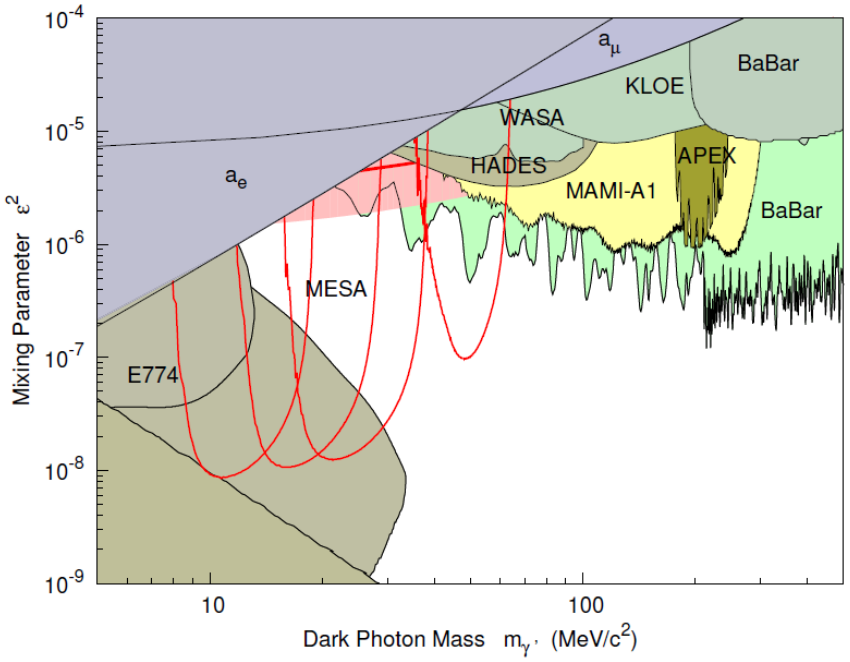
- Low dark photon mass
- Relatively high coupling
- Cover the area more promising to reconcile g-2

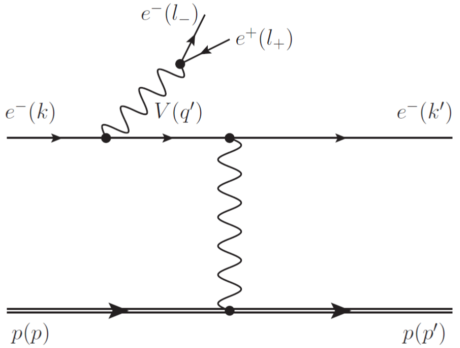
Measurement

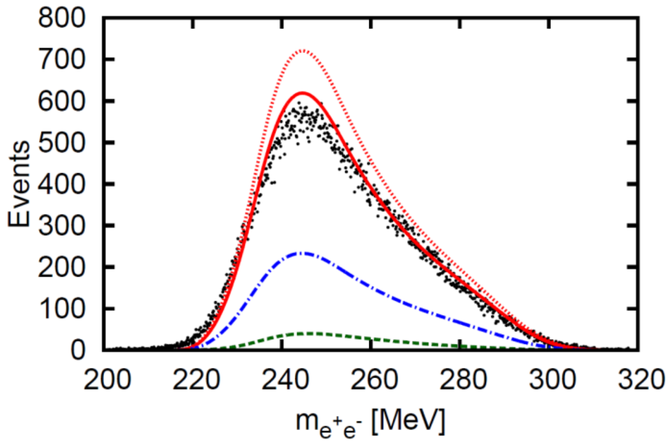
- Electron-nucleus scattering
- Measurement of the e^+e^- invariant mass
- Bump search on the SM spectrum

Requirements

- High luminosity
- High momentum resolution
- Minimize multiple scattering
- High efficiency at low electron momenta







TARGET DEVELOPMENT

Fluid-dynamic simulation

- Allows to design the pump system
- Estimated luminosity $O(10^{35})$

Polarized gas injection

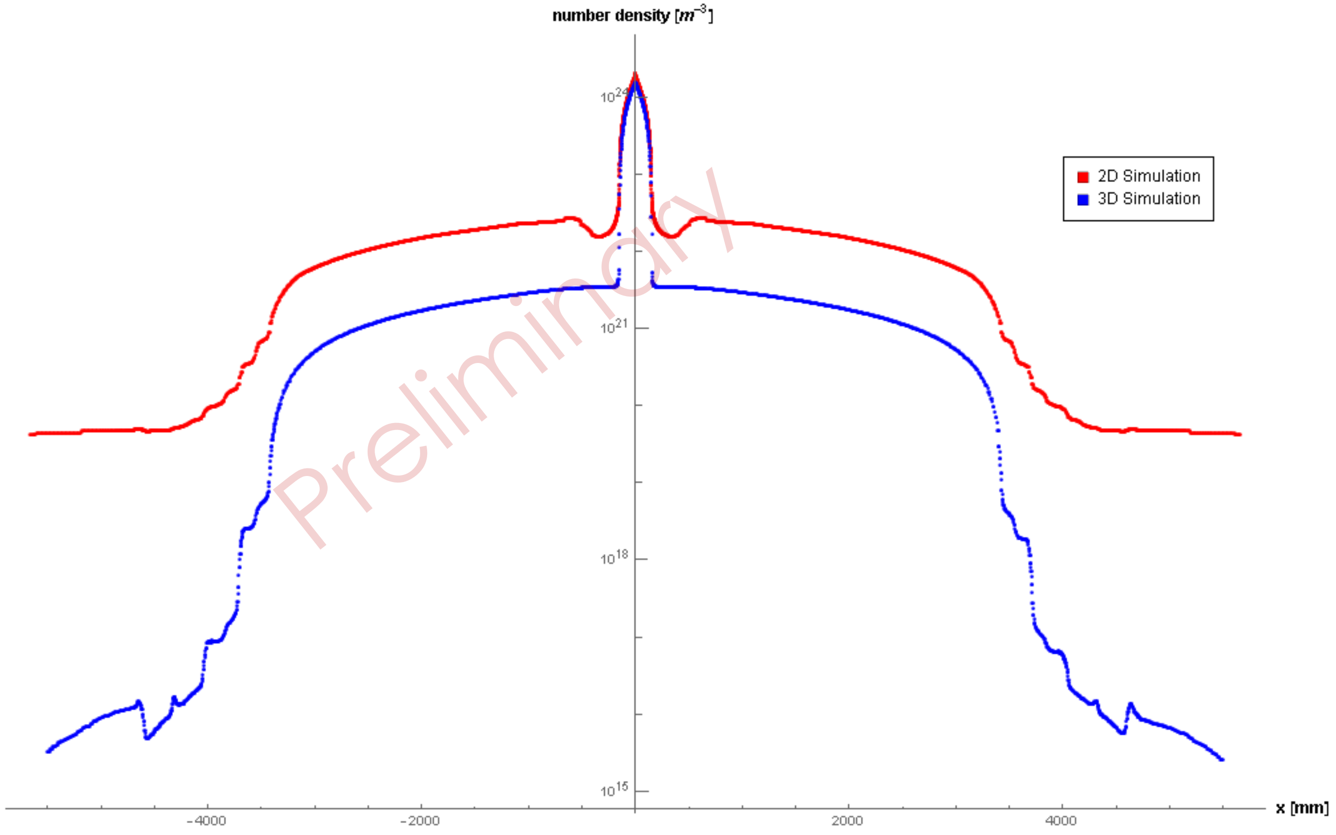
- Necessary for nuclear physics experiments

Target-machine integration

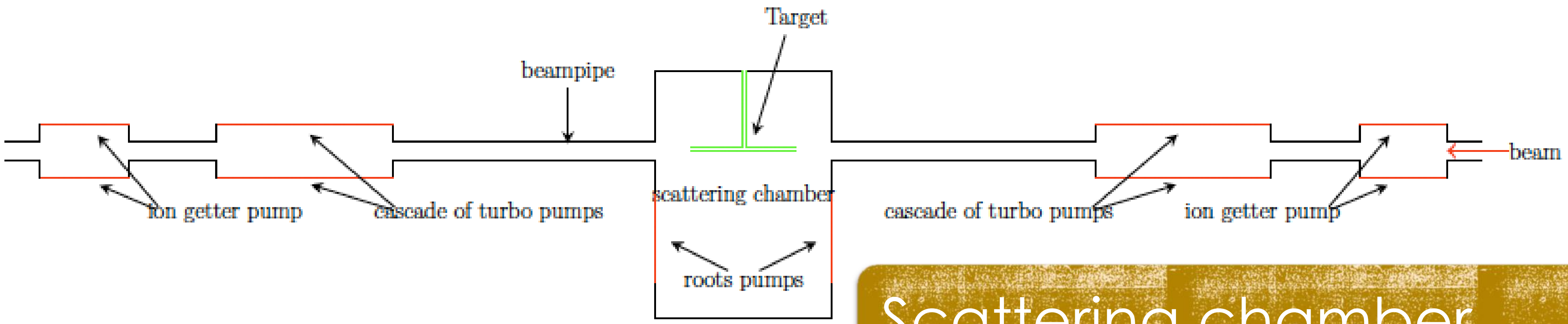
- Interactions with the beam-halo
- Target cooling
- Beam monitoring

Prototype testing

- Simulation validation
- On-beam test



DIFFERENTIAL PUMPING SYSTEM



Mi, 15:45 HK 42.6
Entwickling eines pseudo internen Gastargets (PIT) für MAGIX
•Stephan Aulenbacher

Scattering chamber

- High-volume root pumps to extract most of the gas

Cascade of turbo pumps

- Remove injected gas outside of target
- Do not pollute the beam pipe

SPECTROMETER GEOMETRY

Size

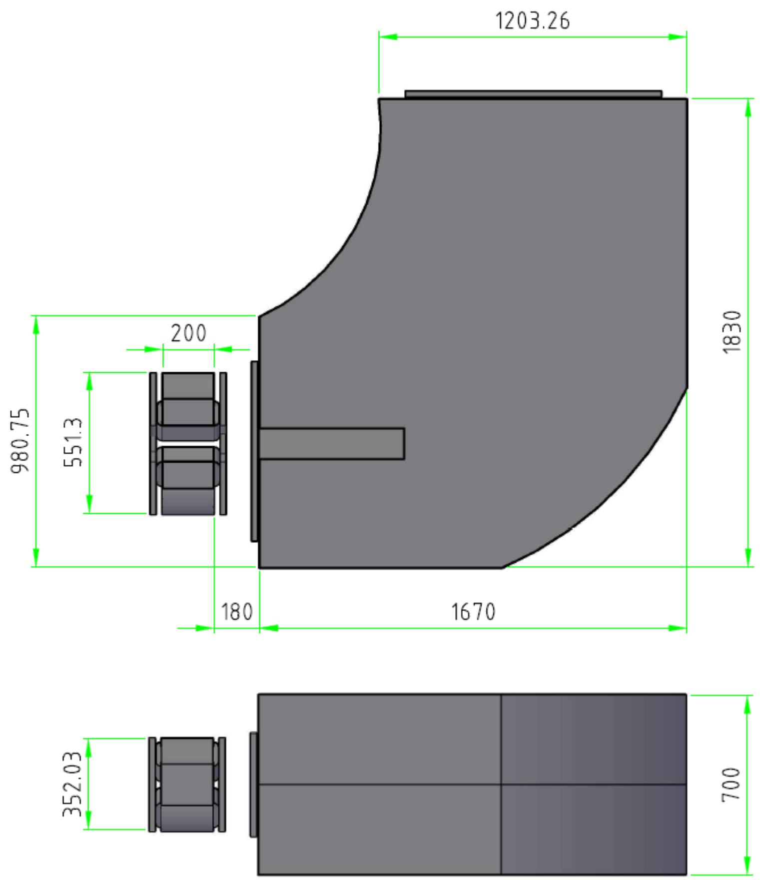
- 2.85 m in the radial direction
- Magnet section about 2 m high
- Detector section about 1 m high above the magnets

Spectrometer rotation

- 14° minimum rotation angle
- Symmetric in both directions

Focal plane

- 130 * 30 cm^2



P2 EXPERIMENT

Measurement of the Weinberg angle

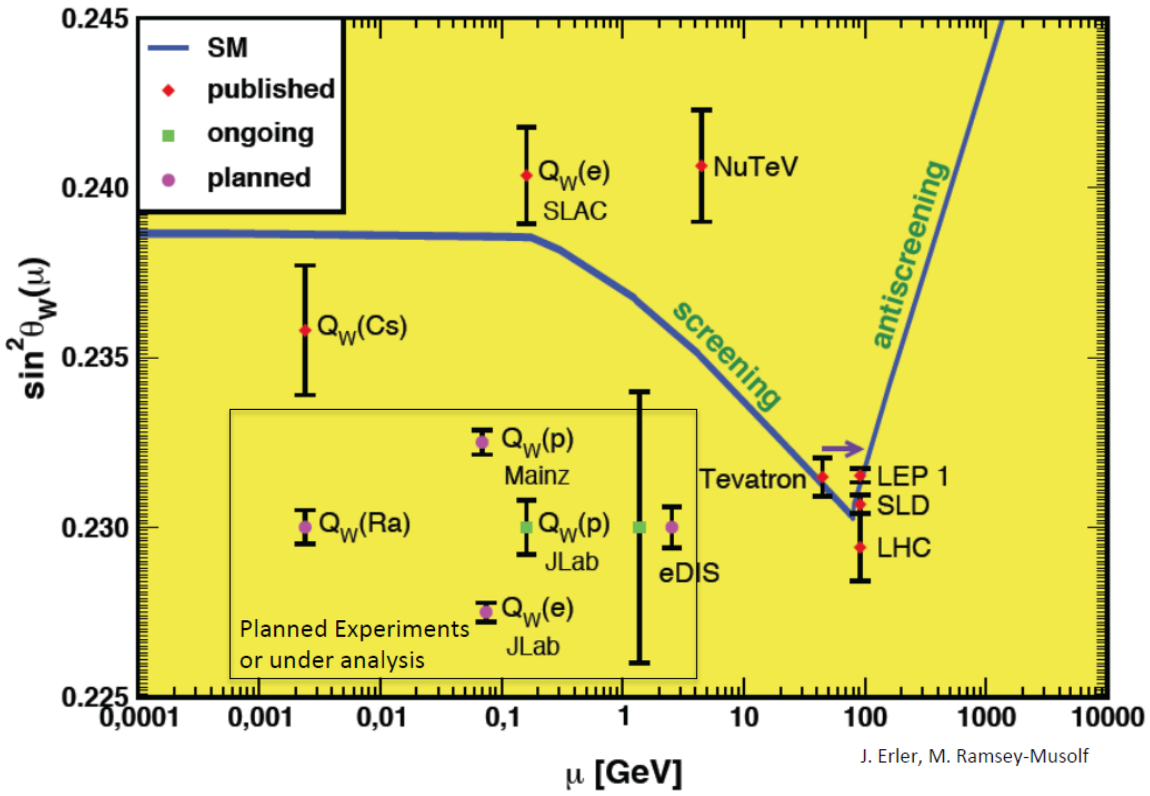
- Measured with high precision only at the Z-pole
- Several measurement planned at low energy
- High statistic and exquisite accuracy required

Dedicate experiment

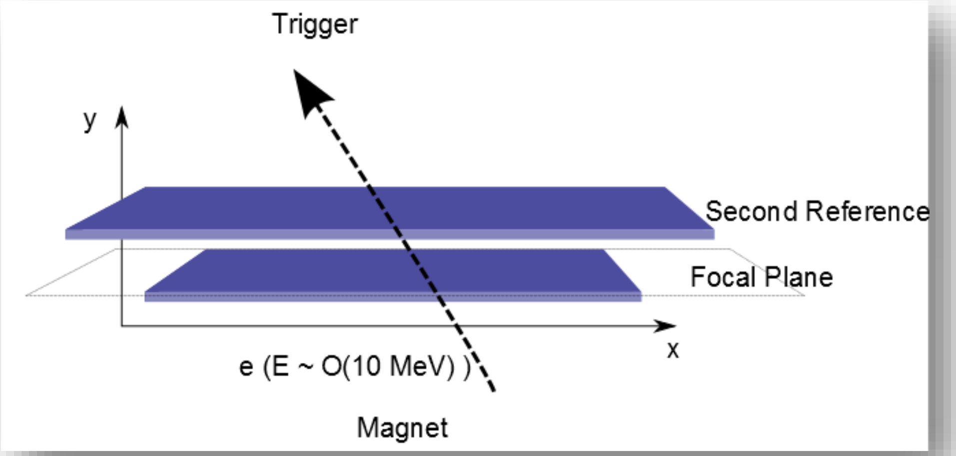
- 10000 hours scheduled at 10^{39} luminosity
- Fixed target
- Polarized beam (85% @ 0.15 mA)

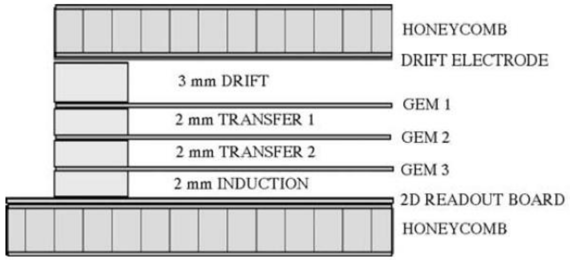
Measurement technique

- Measure the parity violating asymmetry in electron-nucleon scattering



HODOSCOPE TRACKER





2 Sensitive layer

- The first centered on the focal plane
- The second with a sizable lever arm to measure the angle

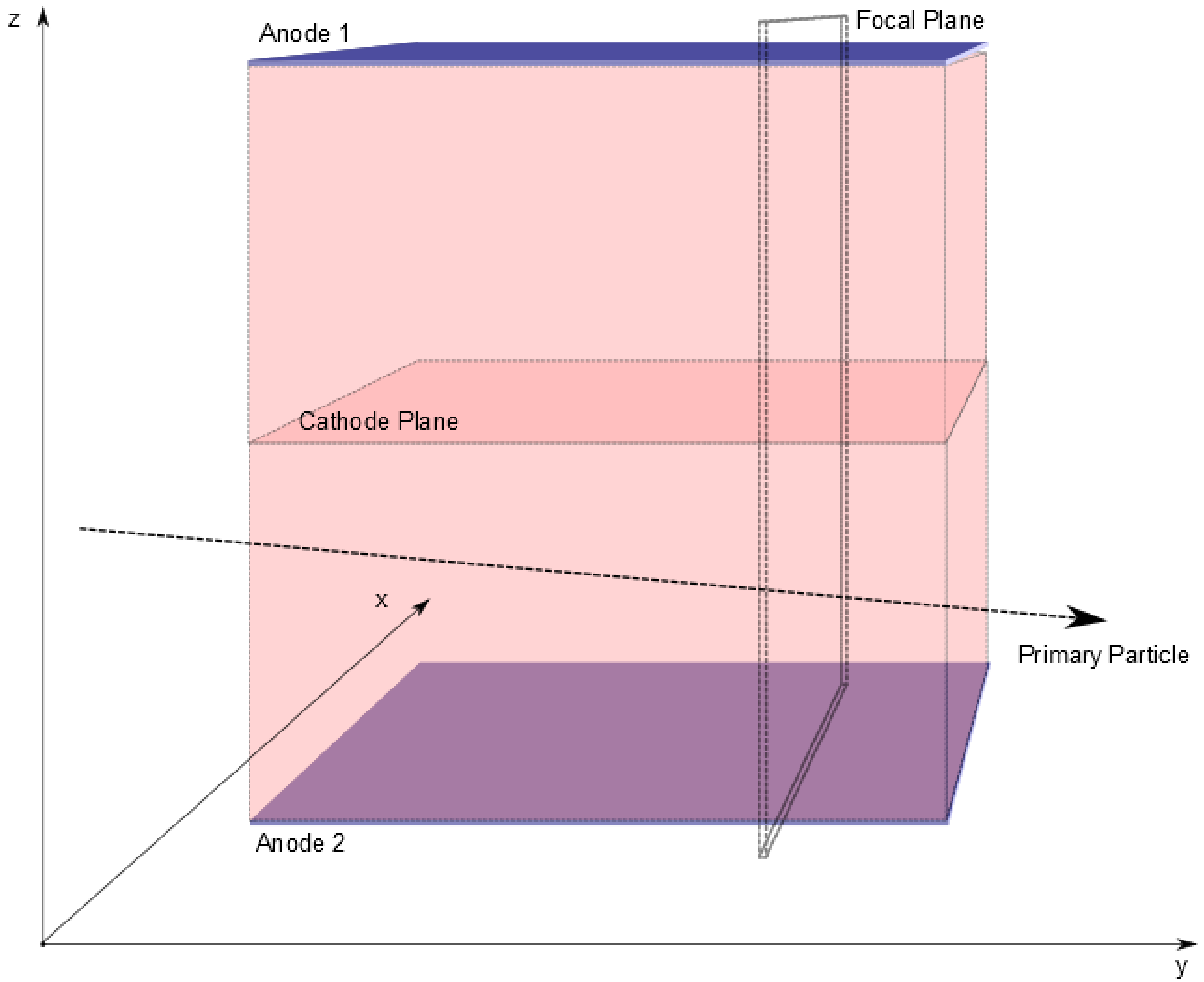
Reliable design

- 2 or 3 GEM
- 2D Strip readout
- Small drift
- ~ 0.7% radiation length

Optimization

- Material reduction to improve angular measurement
- Thin coated GEMs
- Foil based readout plane

SHORT-DRIFT TPC



Minimal material budget

- Only a thin entry window

No constraints on the readout system

- A traditional triple-GEM readout can be used

Full track reconstruction

- Multiple samples along the track
- PID possible

Rate capability

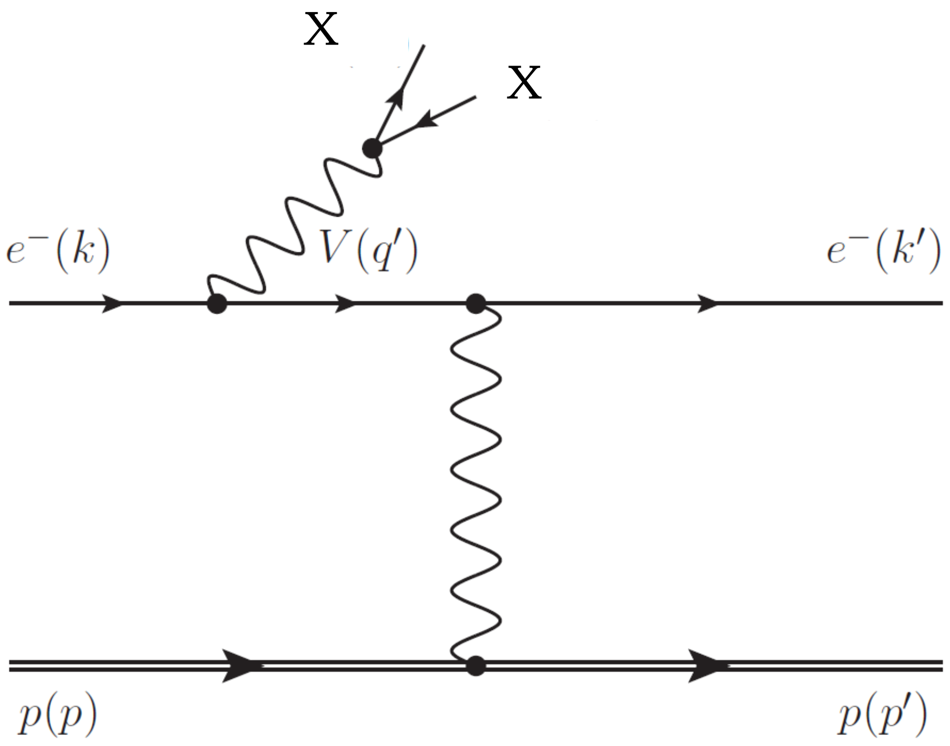
- Can we optimize it for the high rates we will have?

Hidden assumptions

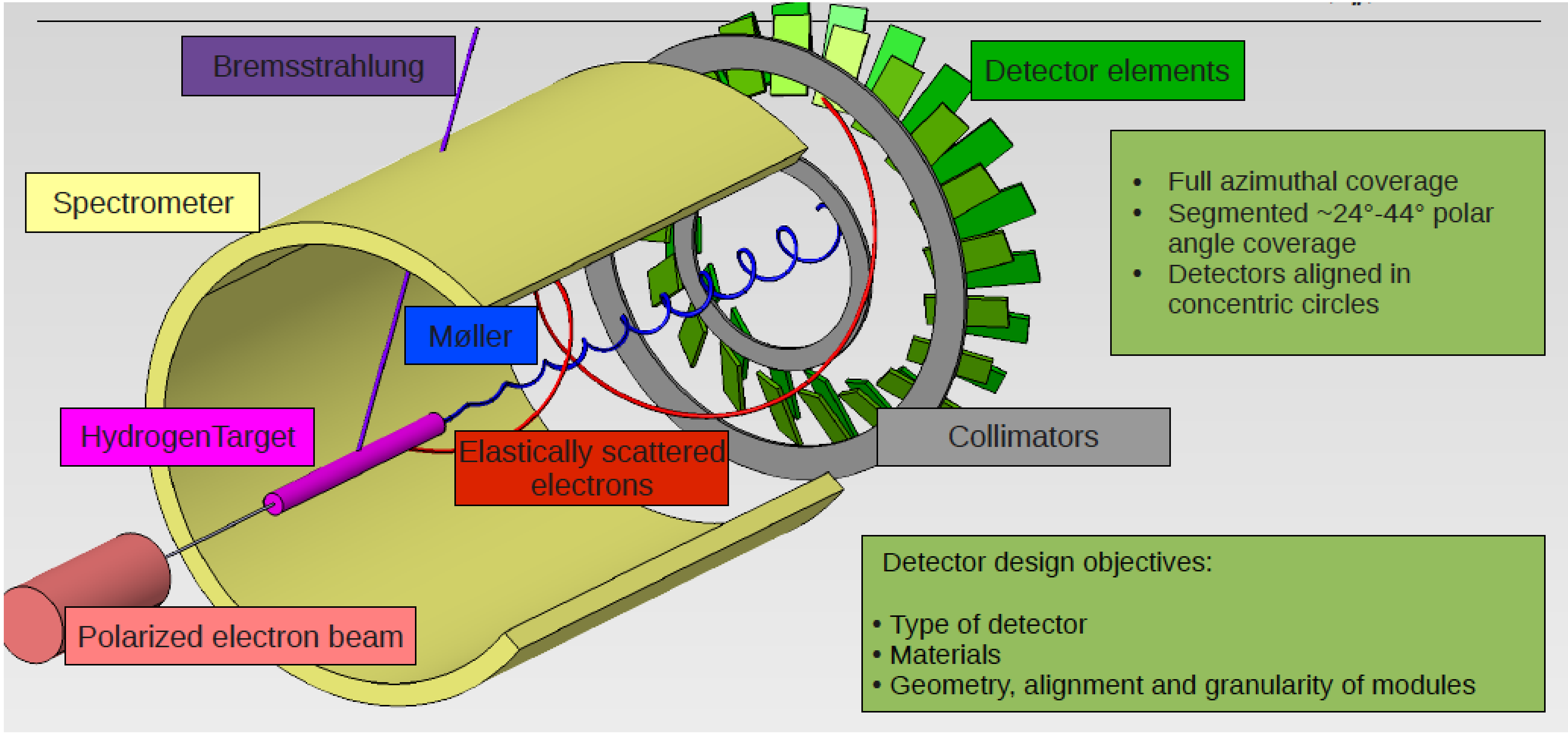
- DP only decays to electrons
- DP is the dominant contribute to the g-2 discrepancy

What if they are wrong?

- No bump
- Missing energy reconstruction if we detect the recoil nucleon
- Scenario under study
- Compatible with our detector concept
- Maybe with a complementary beam dump experiment

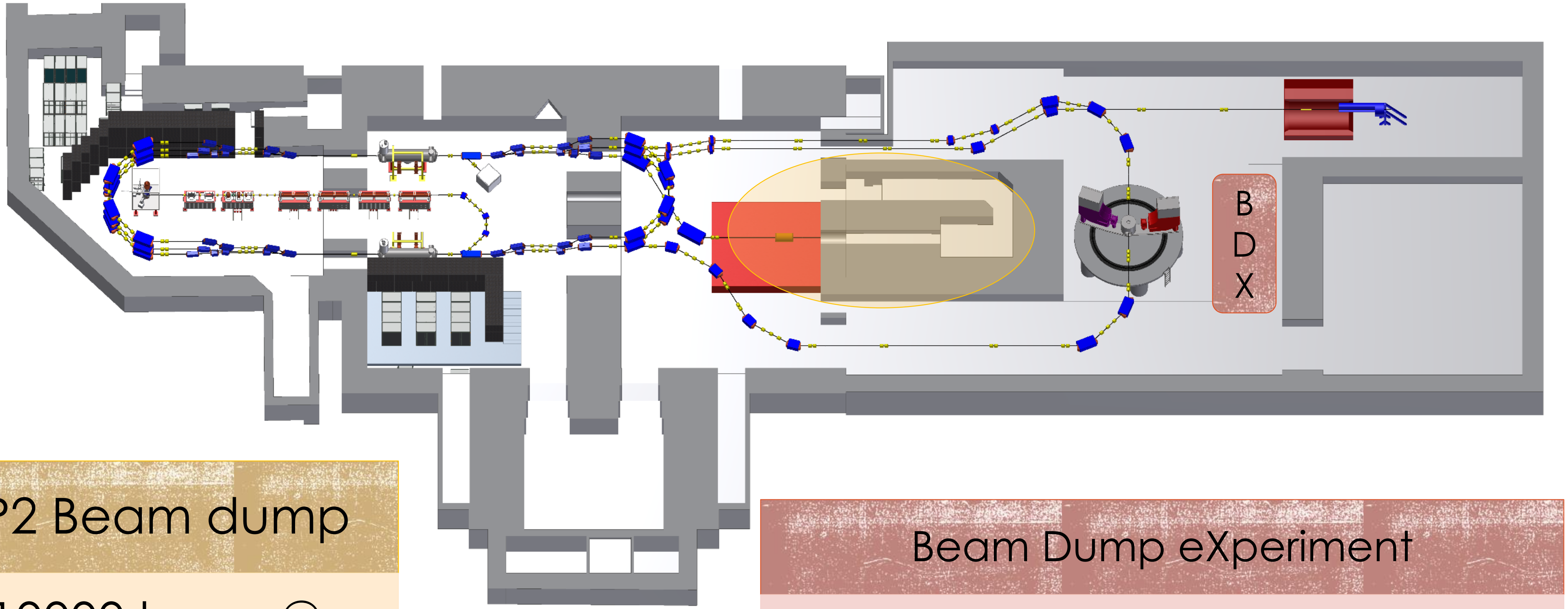


P2 DETECTOR CONCEPT



BEAM DUMP EXPERIMENT

HALL EXTENSION



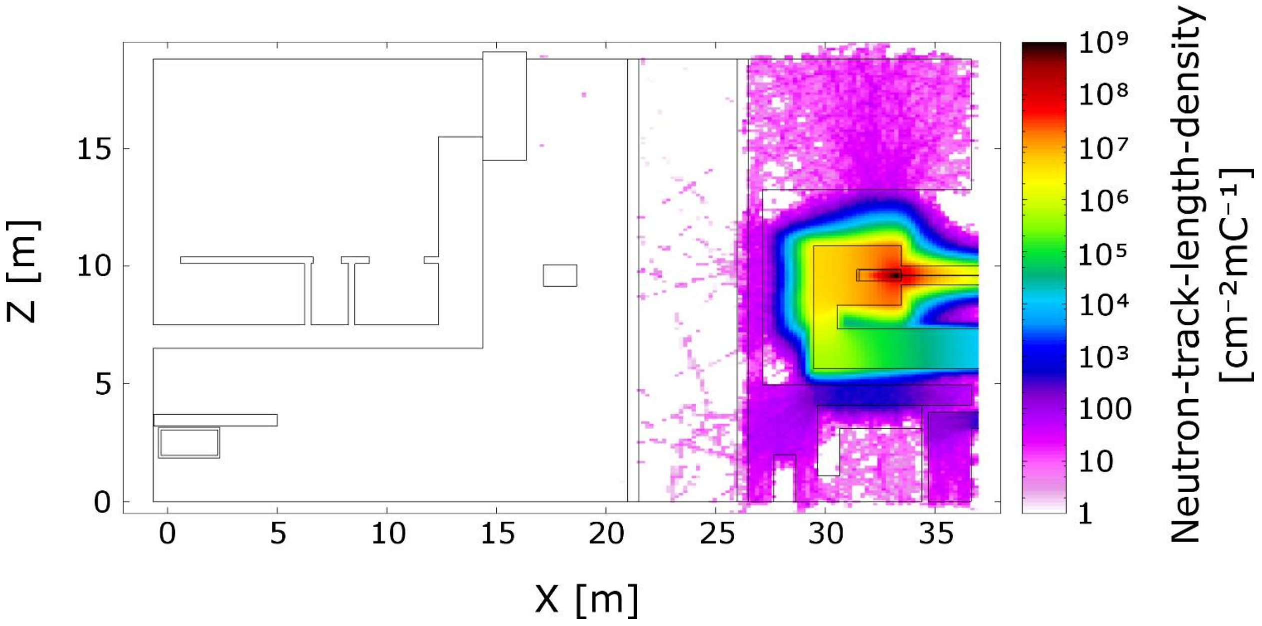
P2 Beam dump

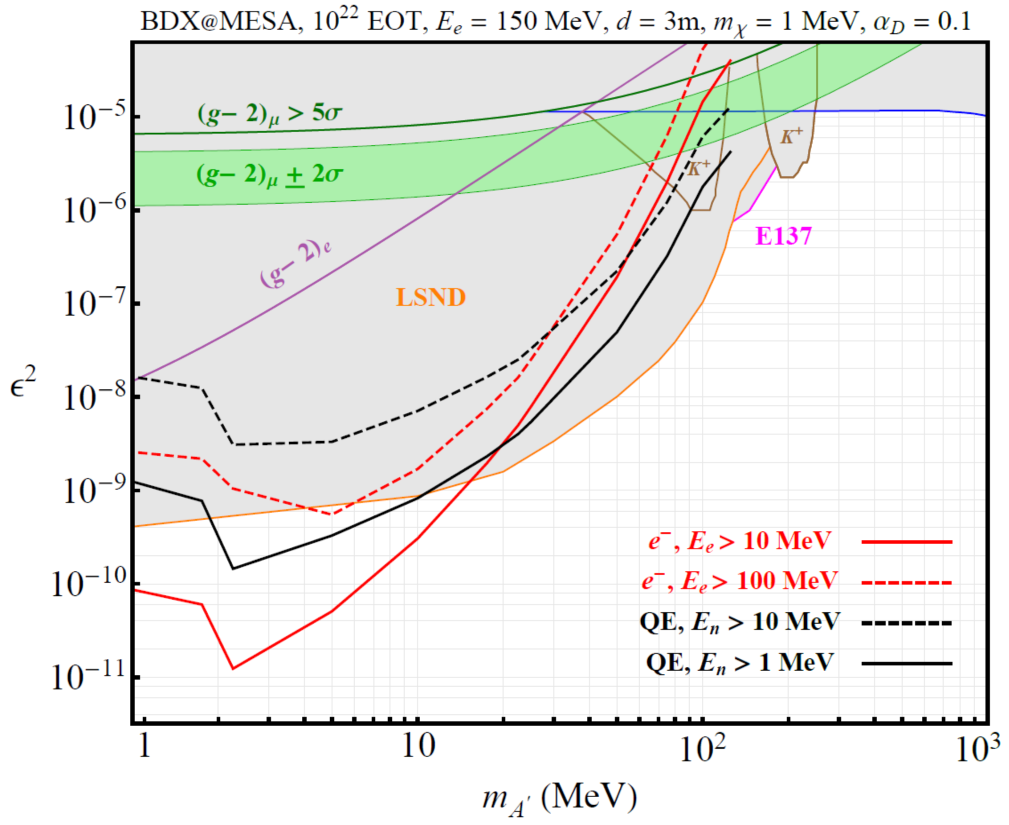
- 10000 hours @ 0.15mA
- 10^{23}EOT

Beam Dump eXperiment

- Potential dark matter beam for free
- Simple detector in low background

BDX OUTLOOK





Background evaluation

- FLUKA simulation of neutron background is promising
- Below pion threshold (no ν)

Sensitivity estimation

- Competitive at low mass
- Plot courtesy of M. Battaglieri