It's a kind of MAGIX

New mysteries on long travelled roads

PRiSMA

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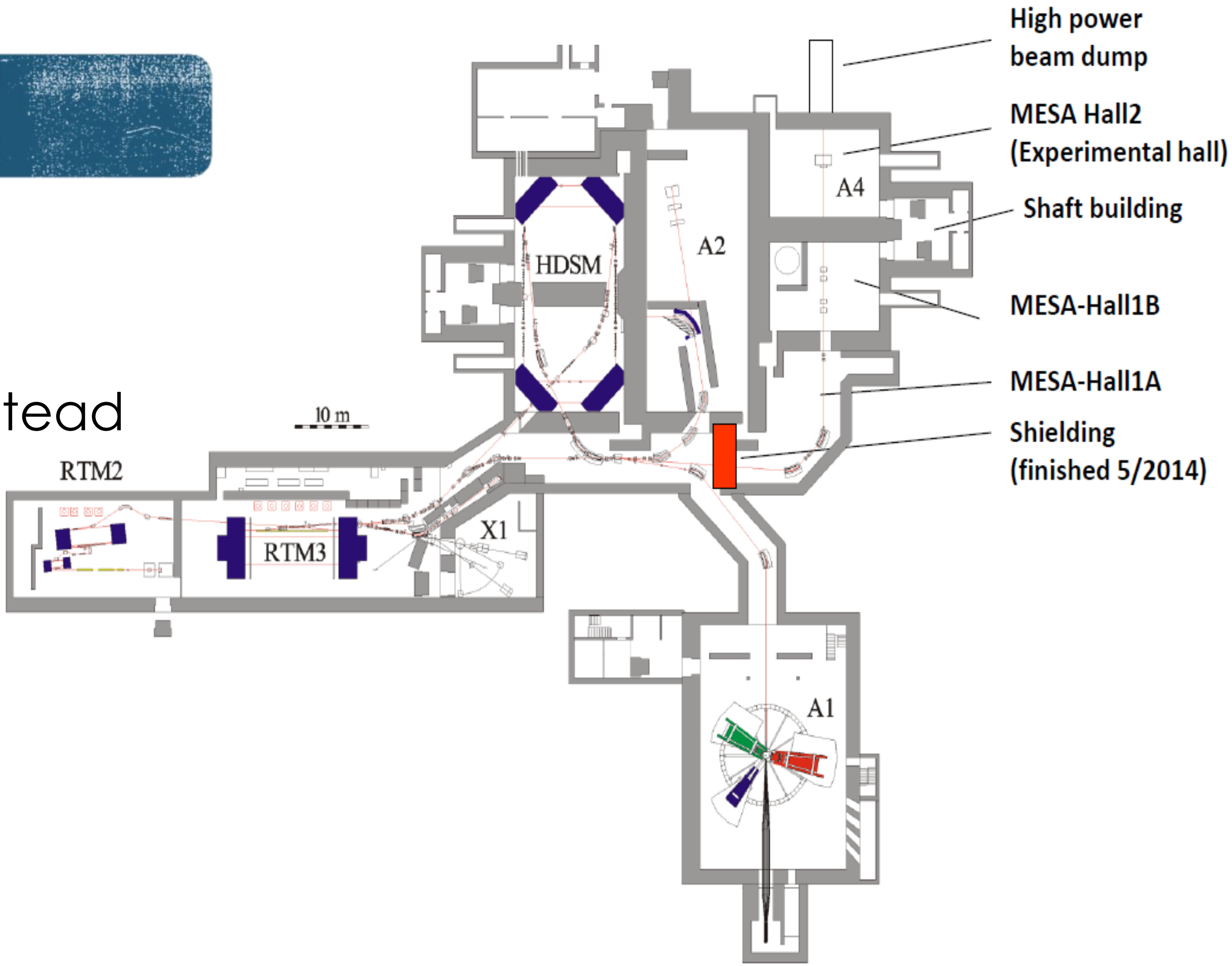
CURRENT SETUP: MAMI

Multi-stage microtron

- 1.5 GeV @ 0.1 mA
- Further energy upgrade unfeasible
- Let's start a new project instead



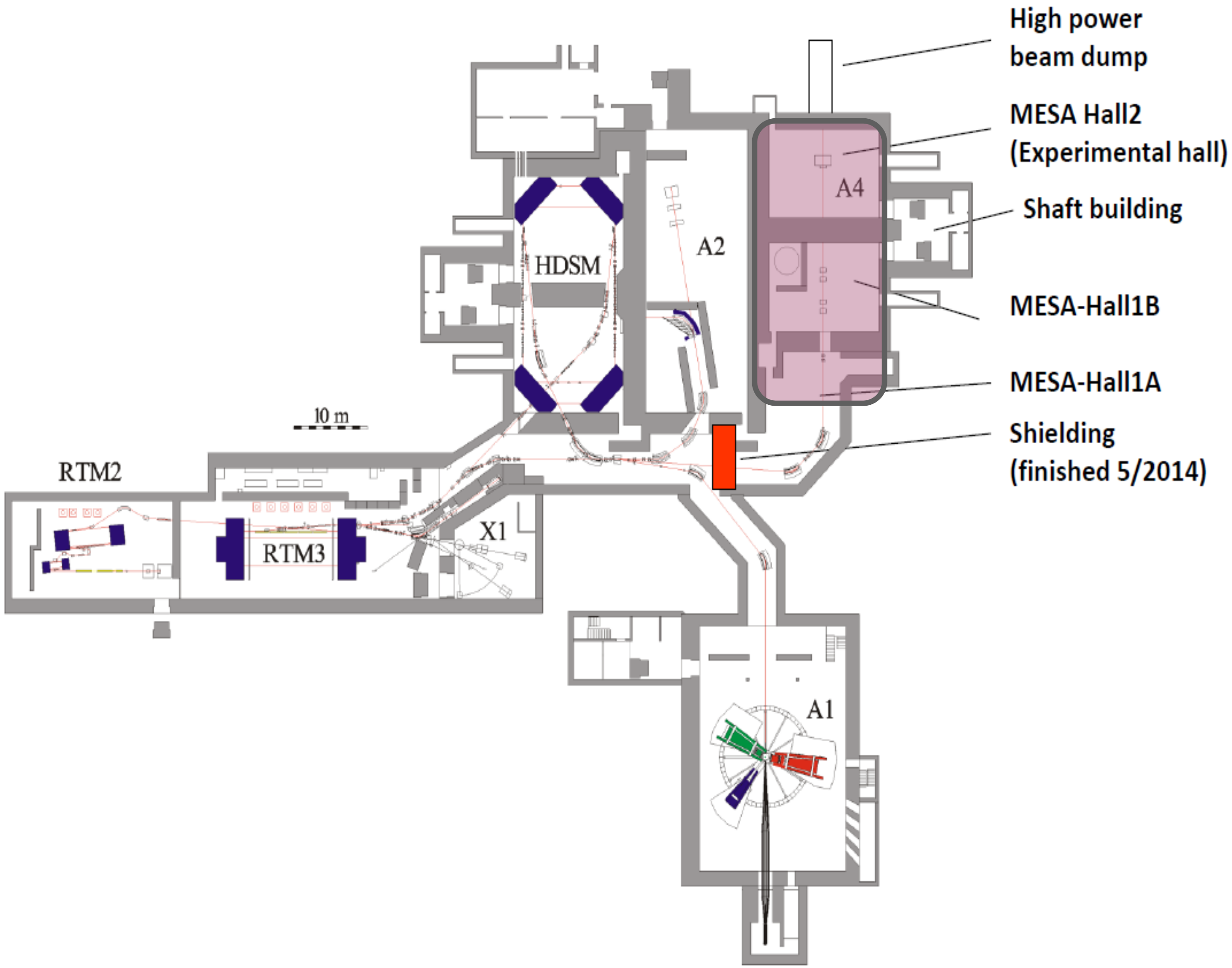
MESA LABORATORY

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



MESA GENERAL FEATURES

Search of rare events	Precision electro-weak physics	Low energy nuclear spectroscopy
High luminosity	High luminosity	High resolution
High resolution	Polarized beam	Polarized beam and target

Polarized electron beam

- 85% polarization

High intensity

- Continuous wave operation (100% d.f.)
- 10 mA for unpolarized beam
- 0.15 mA for polarized beam

Low energy

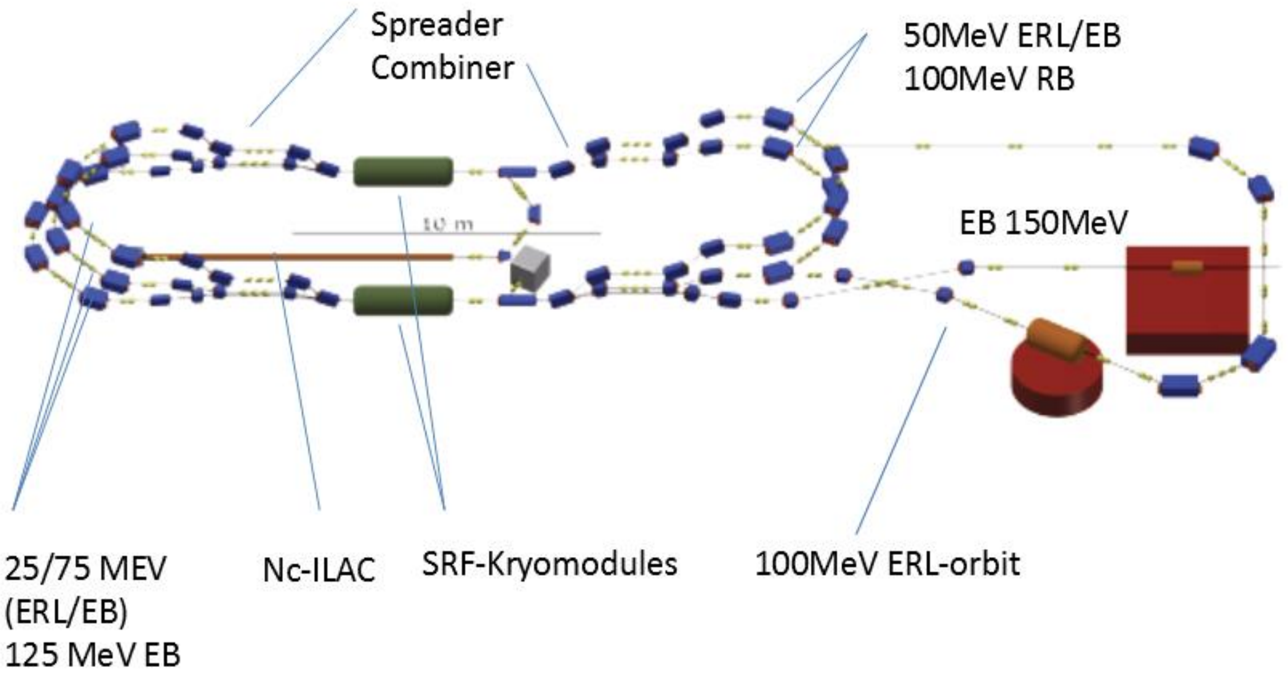
- 105 MeV on recirculating beams
- 155 MeV with extracted beams

Superconductive cavities

- Reduced cooling requirements
- Reduced operational costs

MESA LAYOUT

Multi-orbit recirculator with energy recovery



5MeV Normal conductive injector

2 recirculations

- Independent arcs for each momenta

Energy recovery

- External loop of half-wave length
- Particles reenter the cavities in the decelerating phase of the RF
- Particle energy transferred back to the cavity

Experiment on the recirculating beam

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

Extracted beam @ 150 MeV

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

P2 EXPERIMENT

Measurement of the Weinberg angle

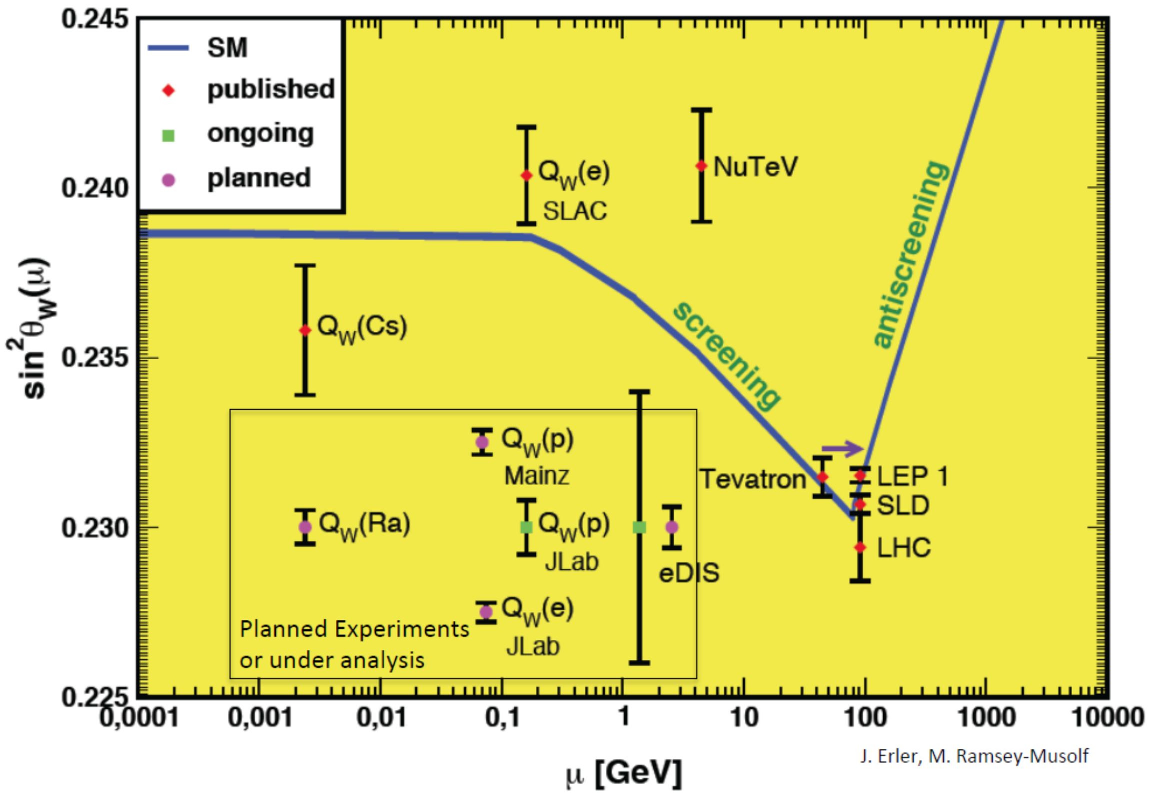
- Measured with high precision only at the Z-pole
- Several measurement planned at low energy
- High statistic and exquisite accuracy required

Dedicate experiment

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

Measurement technique

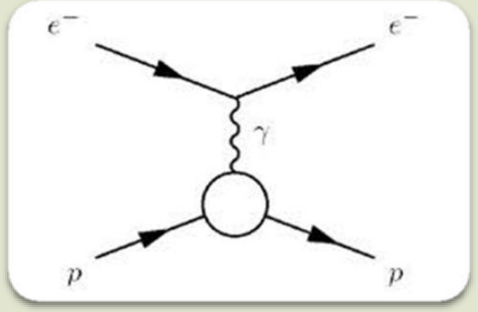
- Measure the parity violating asymmetry in electron-nucleon scattering

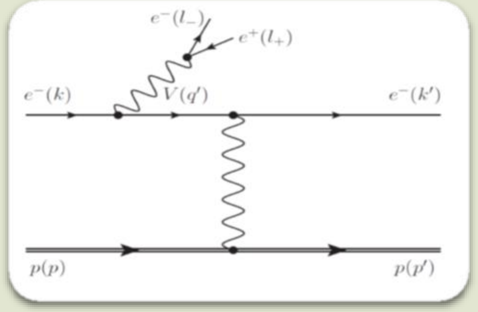


MESA GAS INTERNAL TARGET EXPERIMENT

LOW ENERGY ELECTRON SCATTERING

Electron scattering on fix target below the pion threshold





Simple scattering

- Elastic or inelastic
- 1 electron and 1 recoil nucleon

Trident pair production

- With SM or dark U(1) bosons
- 1 electron and 1 $e^+ e^-$ pair

Low momentum electron coincidence
- On the scale of the bunch frequency

High acceptance
- To improve the statistics on rare even searches

Good momentum resolution
- For high precision measurements
- Low momentum

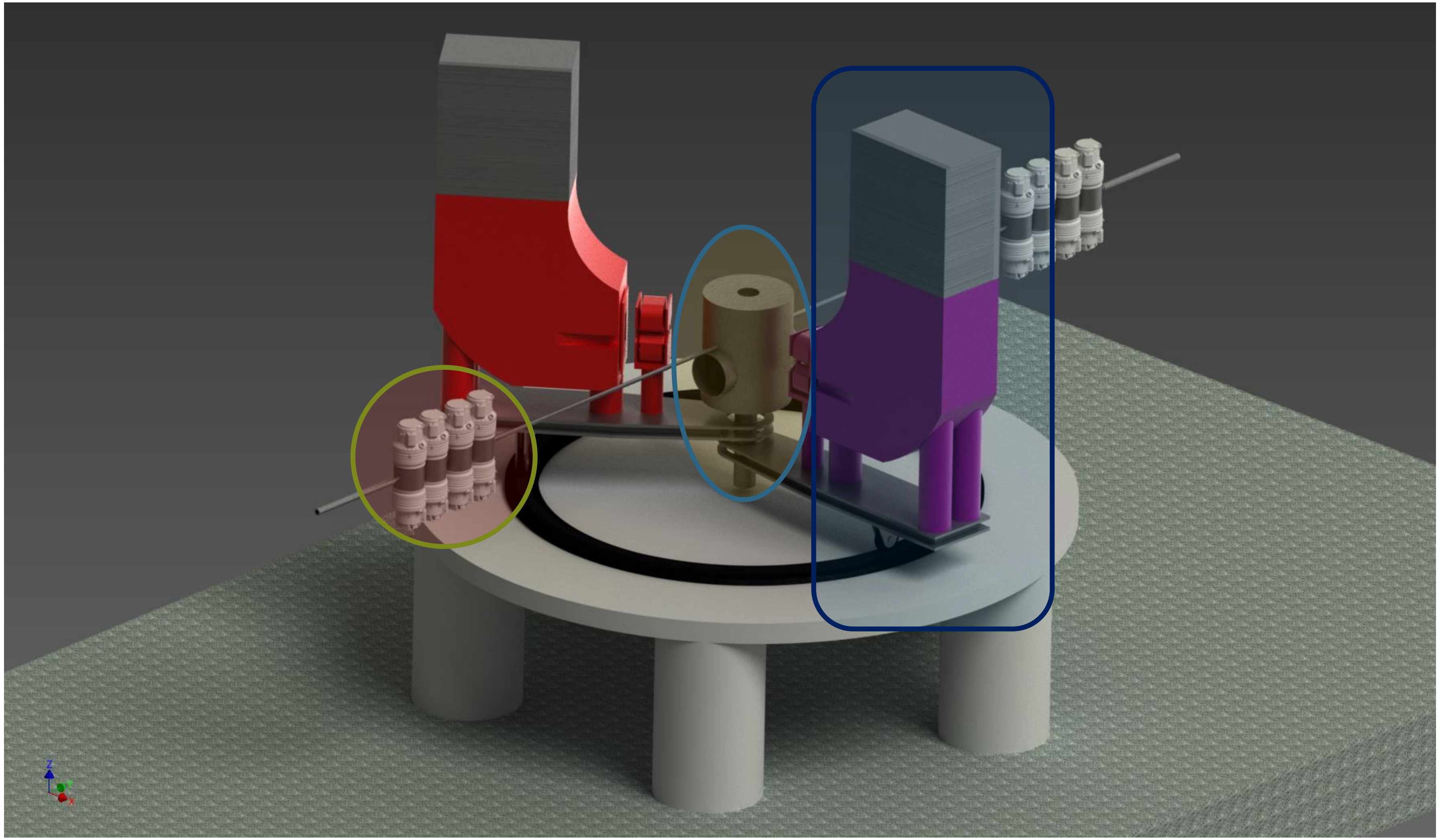
Good angular resolution
- For background rejection and vertex reconstruction

MAGIX COMPONENTS

Internal Gas Target

Differential pumping system

Twin ARm DIpole Spectrometer



INTERNAL GAS TARGET

DESIGN REQUIREMENTS

Fixed Target luminosity

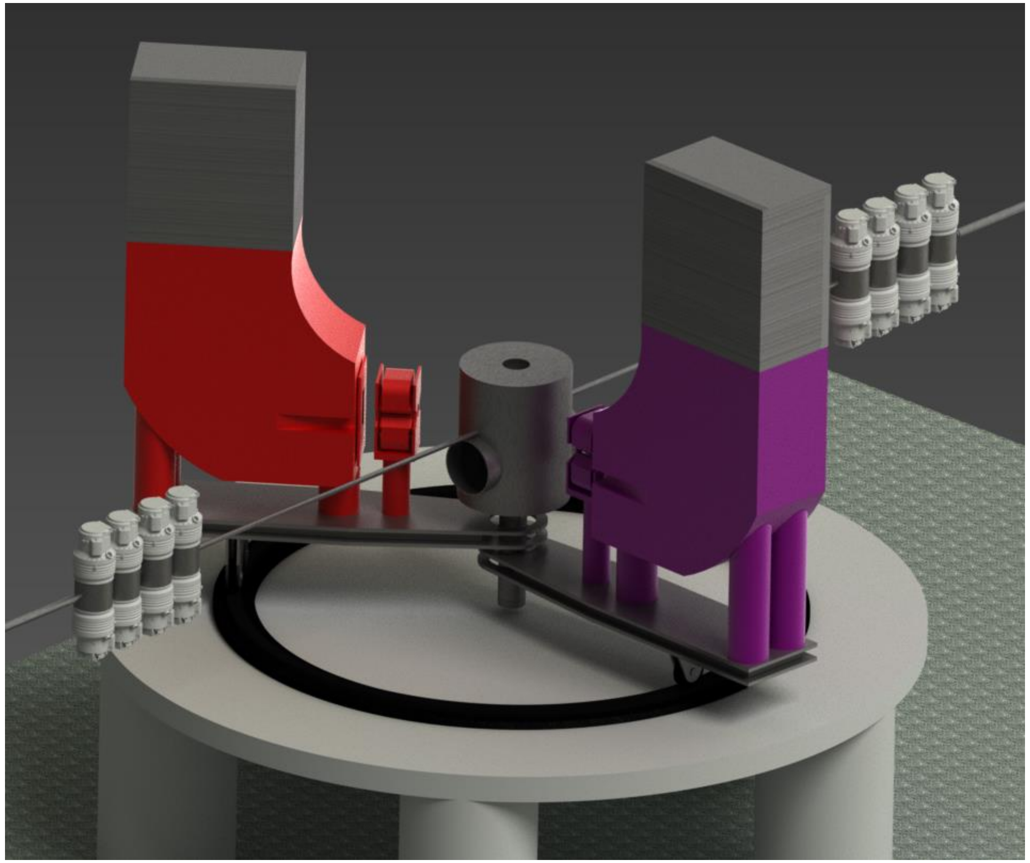
- $L \cong I_b * \rho_t * l_t$
- High gas density recommended

Recirculating beam

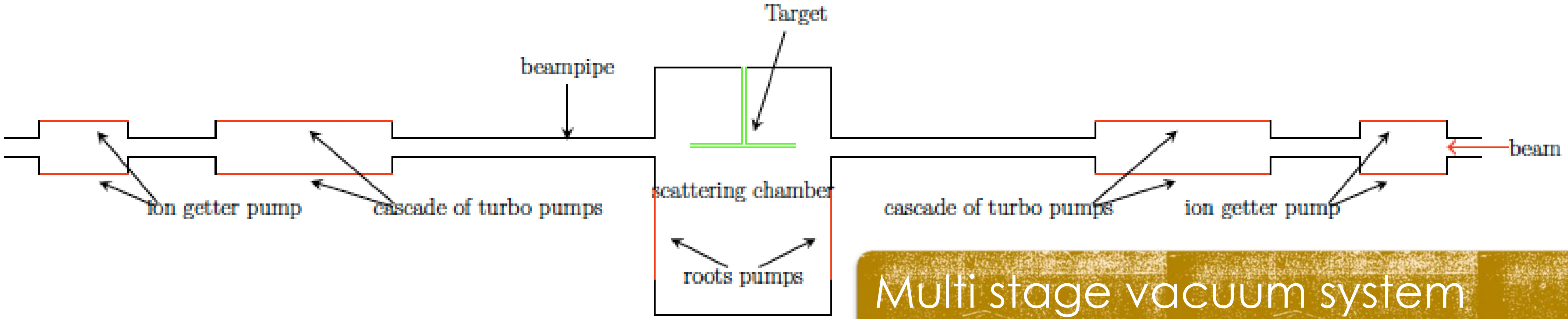
- Keep the beam quality
- Thin target required
- Limits the maximum density

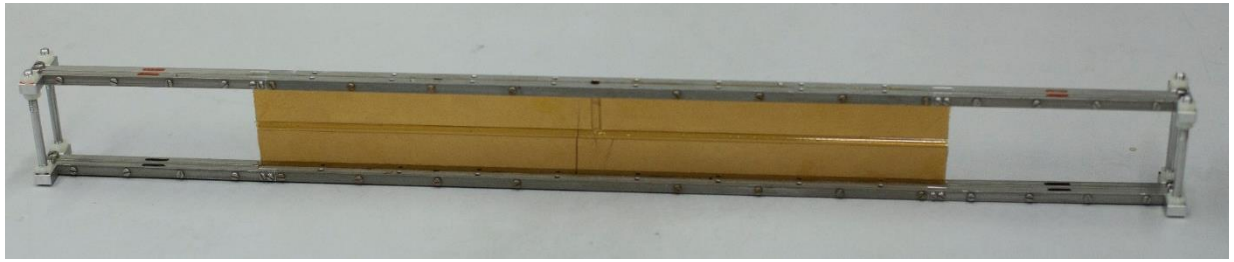
Open target

- A window will increase backgrounds
- 1 MW beams destroy any thin window
- Unique combination of an internal target on a powerful ERL accelerator



TARGET LAYOUT





Multi stage vacuum system

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

Thin walled inner volume

- 20 µm thick mylar pipe
- 4 mm diameter

FEM simulation

- Full fluid dynamic simulation completed
- Estimated luminosity $O(10^{35})$

TWIN ARM DIPOLE SPECTROMETER

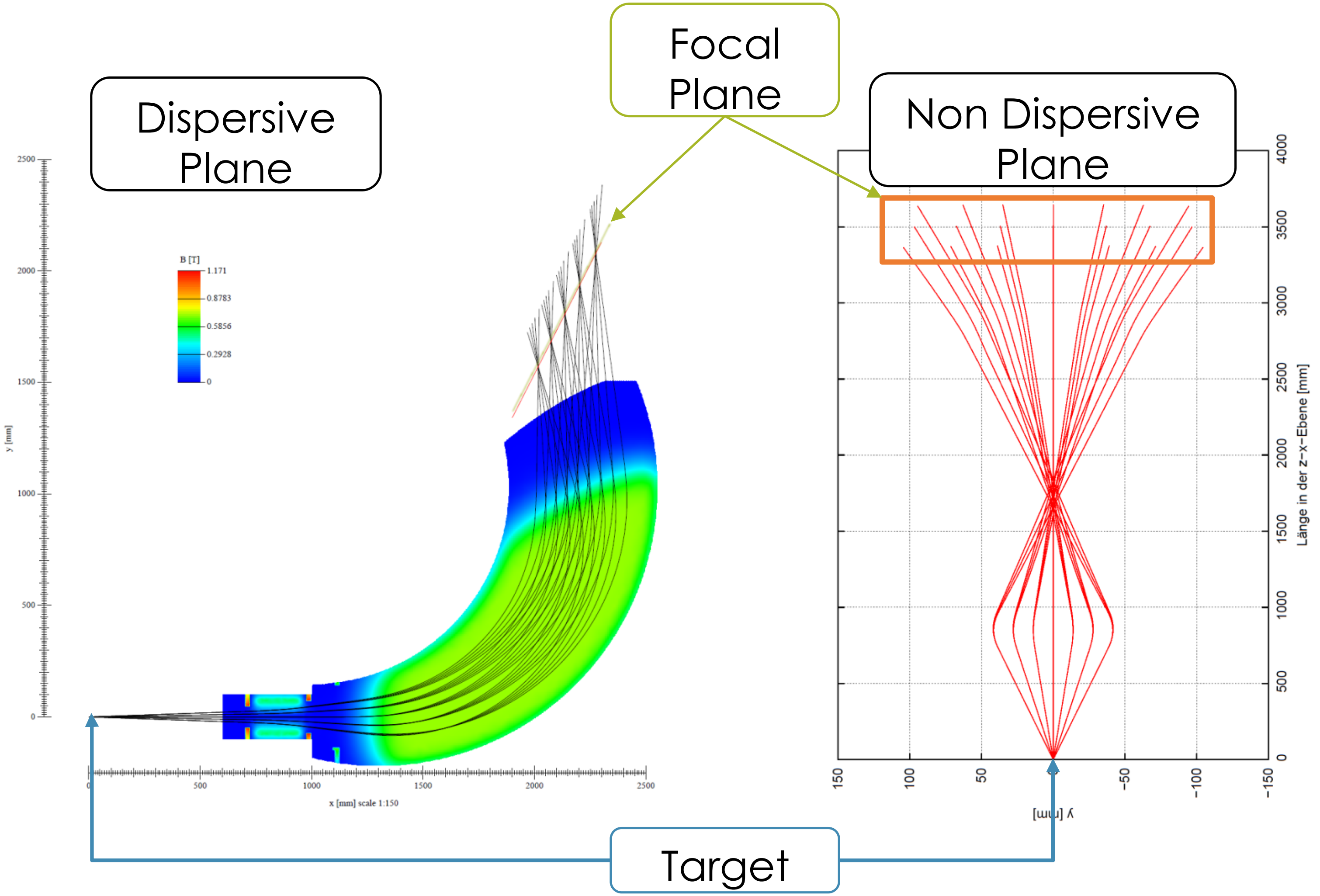
THE SPECTROMETER CONCEPT

Focus particles of different momenta at different positions

- Dipole field for momentum dispersion
- Quadrupole field for angular focusing

Point to parallel focus in the non-dispersive plane

- Measure the angle by the distance from the medial plane



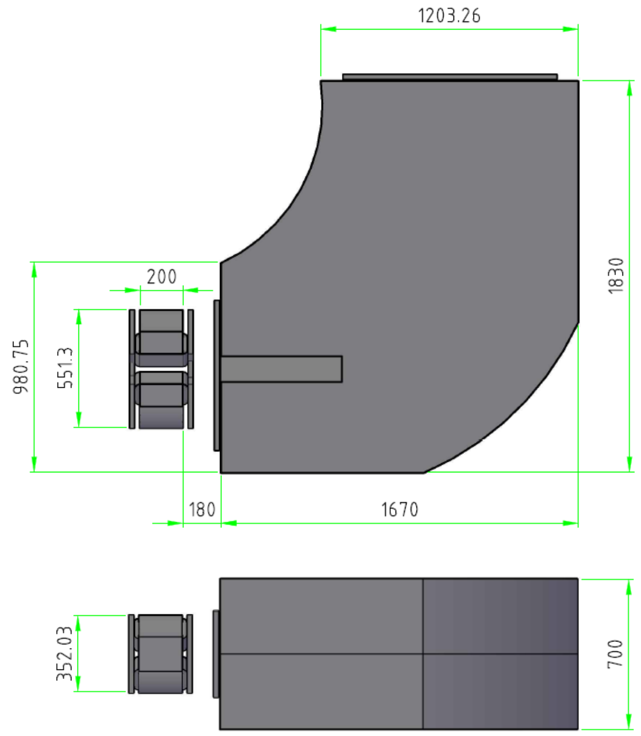
SPECTROMETER GEOMETRY

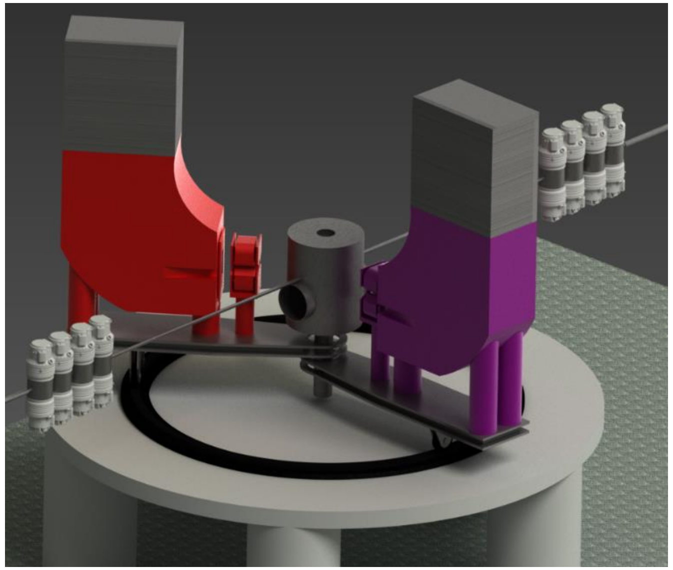
Size

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

Spectrometer rotation

- Air track platform
- 14° minimum rotation angle





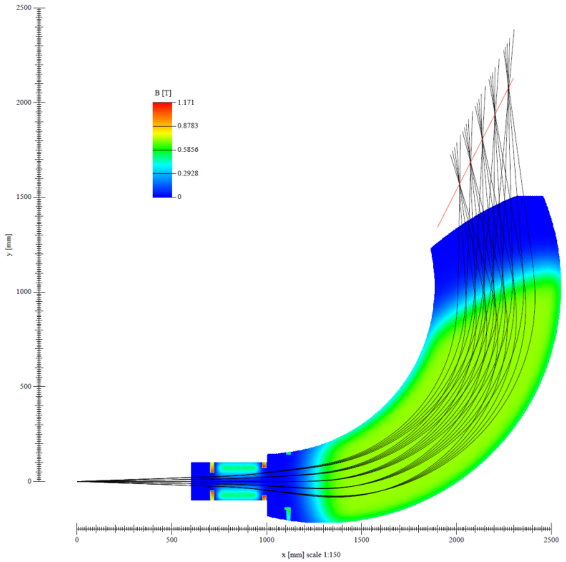
MAGNET OPTICS

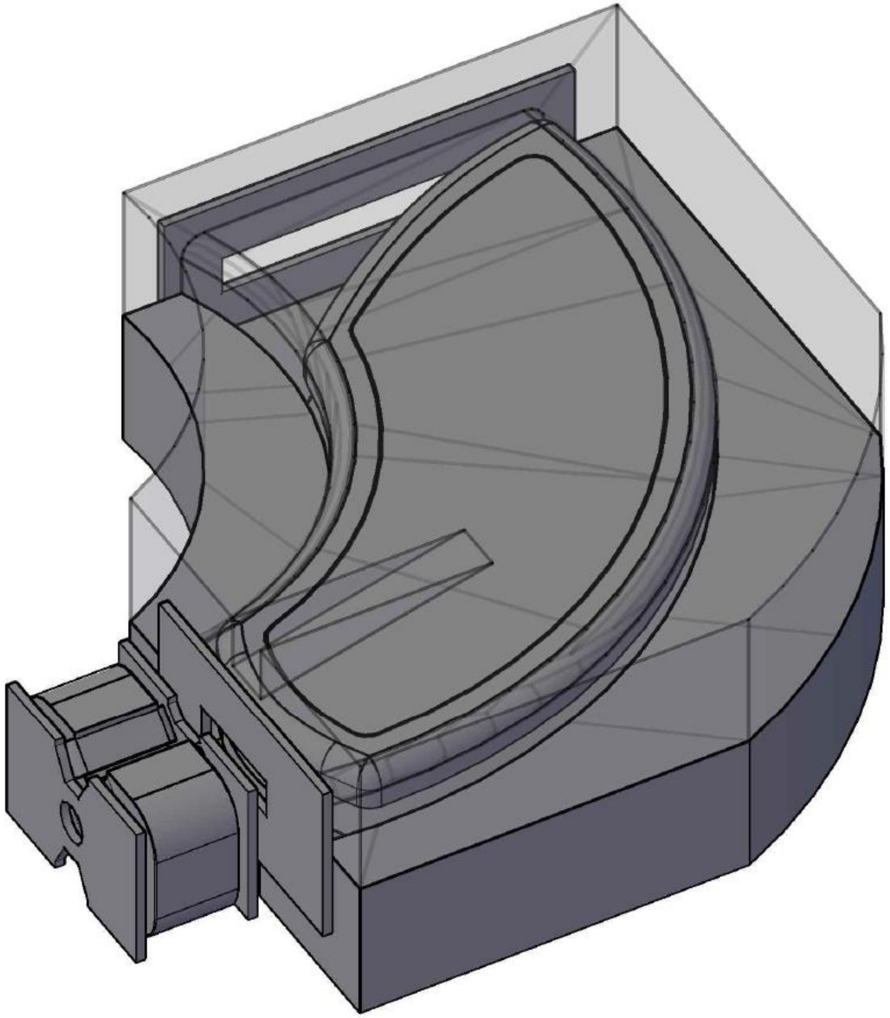
Quadrupole + Dipole

- 200 MeV maximum momentum
- 90 MeV momentum acceptance

Performance simulation

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





DETECTOR CHALLENGES

High resolution on low momentum electrons

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

Material reduction

- No window before the magnet
- Thin detector

Large sensitive surface

- $120 * 30\ cm^2$ focal plane surface

Good point resolution

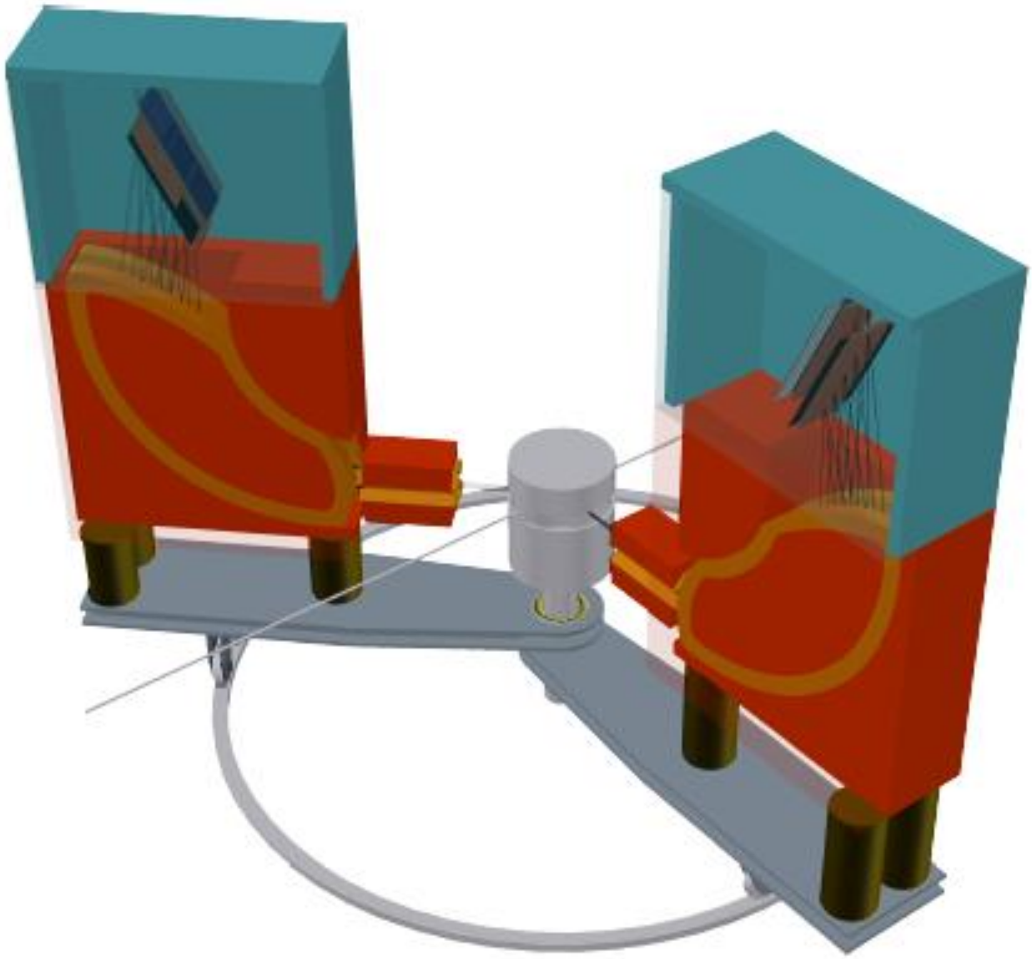
- $50\ \mu m$ point resolution along the in the dispersive plane

Multiple samples

- At least 2 points to reconstruct the full kinematics

High rate capability

- With a CW operation rates up to $O(1\ MHz)$



FOCAL PLANE DETECTORS

Gas detectors

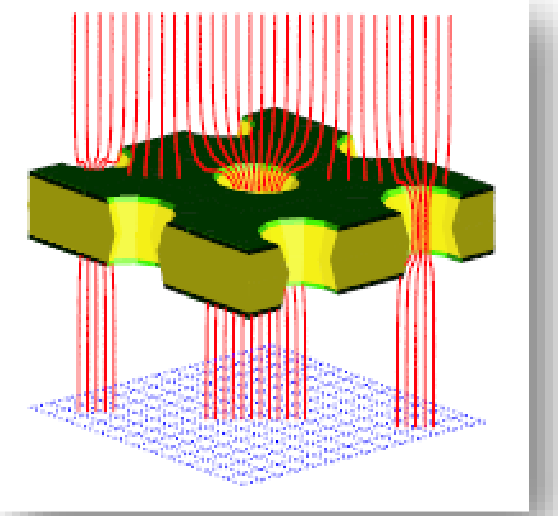
- Low material budget
- Low cost for large area coverage

Micro Pattern Gas Detectors

- Modern gas amplification systems
- Resolutions of the order of 50 µm achieved routinely

Gas Electron Multiplier

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



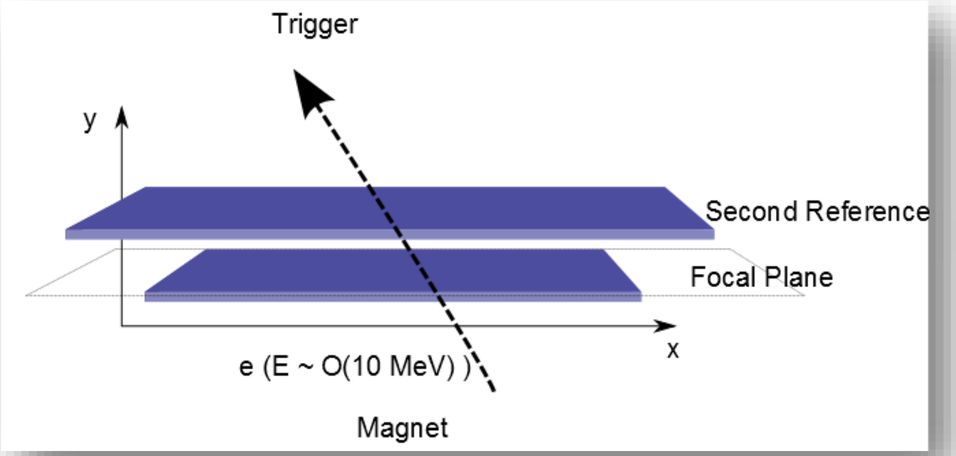
2 Layer Hodoscope

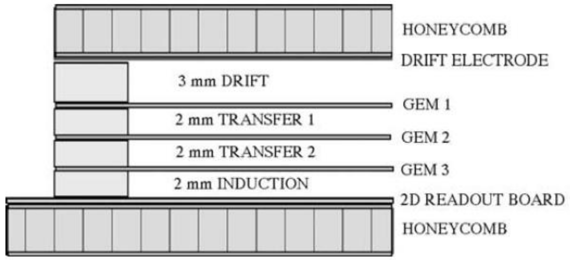
- Simple detector to built
- Uniform and high position resolution
- Moderate material thickness
- Only 2 reconstructed points

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 layer

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

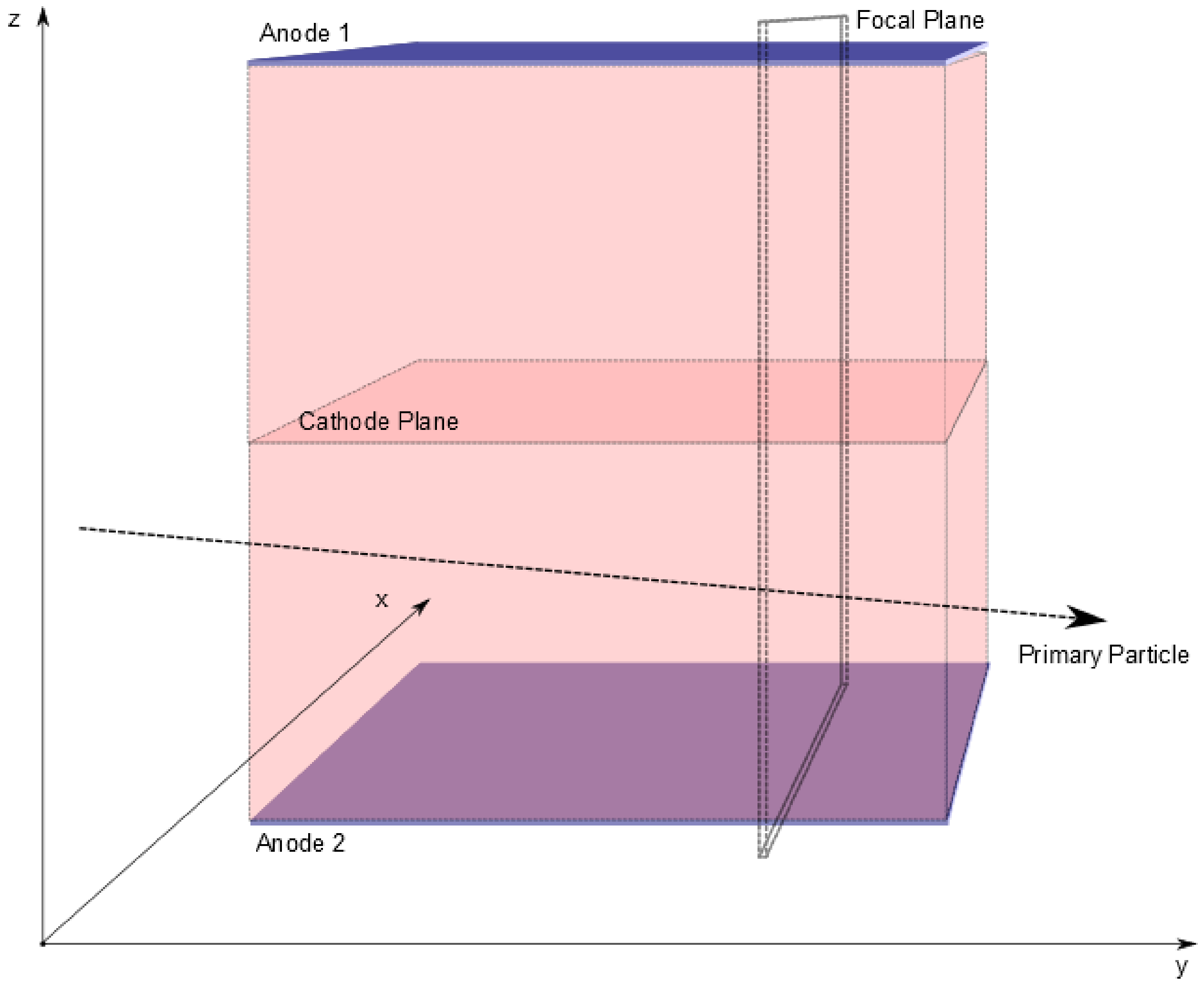
Reliable design

- 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?

THE PHYSICS

DARK PHOTONS

What is a dark photon

- Gauge boson of additional U(1) symmetry
- No tree level interaction with SM particles

Kinematic mixing

- Massive fermionic loops mix the two U(1) bosons
- The hidden photon interacts with the SM particles
- Small effective coupling

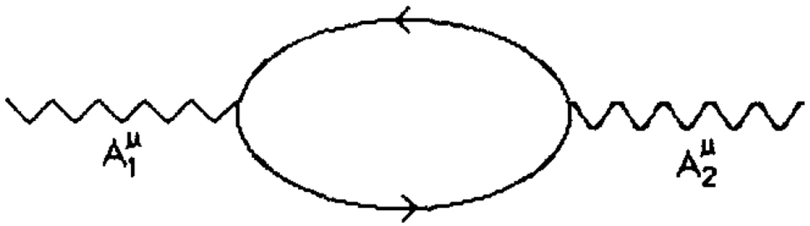
Search space parameters

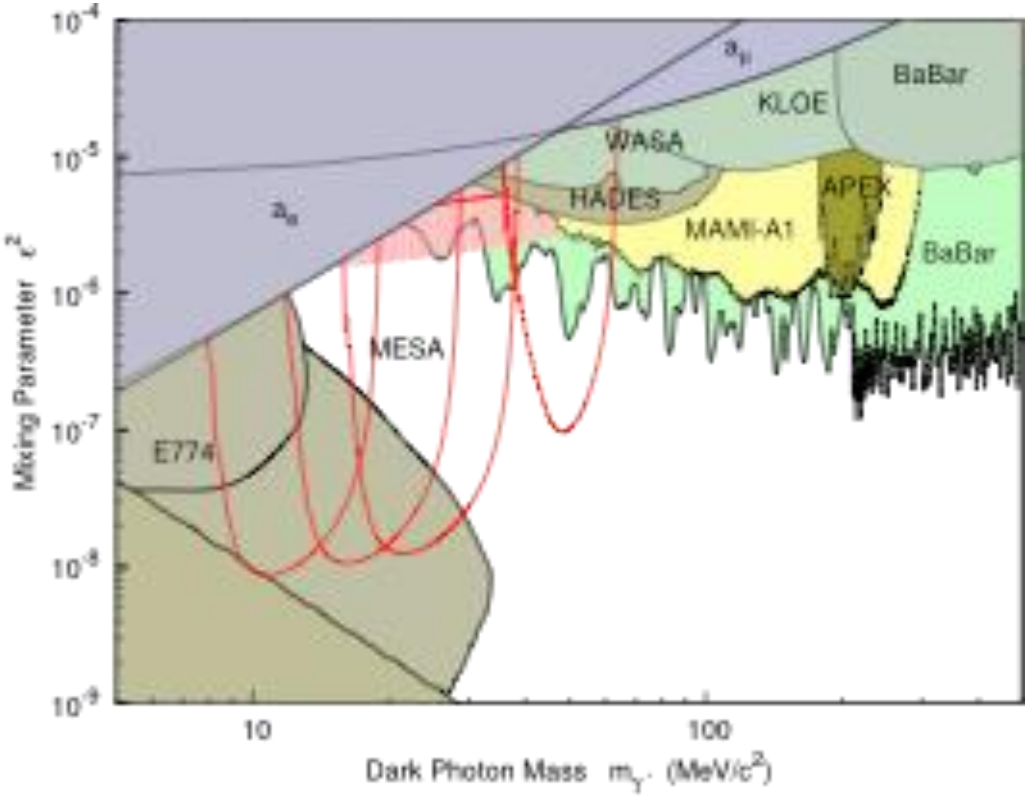
- ε : Effective coupling
- m : Dark Photon mass

Measurable effects

- The photon can oscillate to a dark photon
- Dark sector particles with a fractional QED charge
- Hidden sector contribution to SM diagrams

$$\varepsilon^2 = \frac{\alpha'}{\alpha}$$





ELECTRON SCATTERING SEARCHES

Parameter space coverage

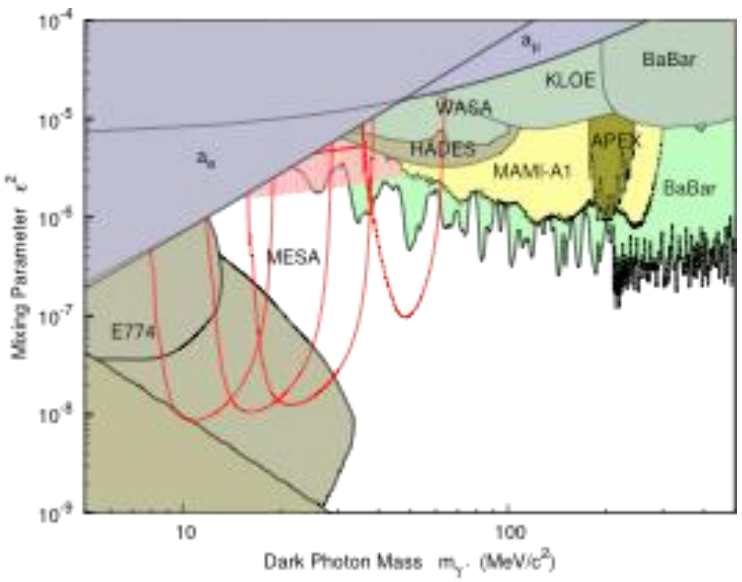
- Low dark photon mass
- Relatively high coupling
- Cover the area more promising to reconcile g-2

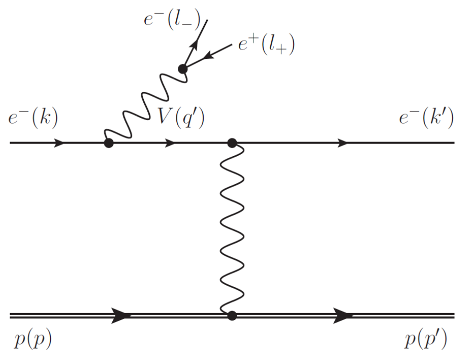
Measurement

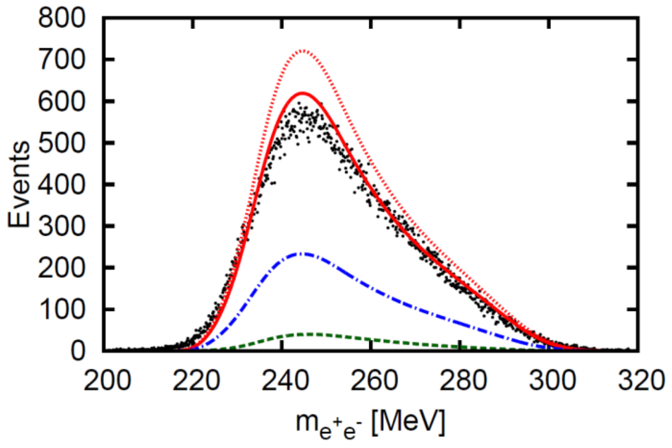
- Electron-nucleus scattering
- Measurement of the e^+e^- pair invariant mass
- Bump search on the continuous SM spectrum

Requirements

- High luminosity
- High momentum resolution
- High efficiency at low electron momenta







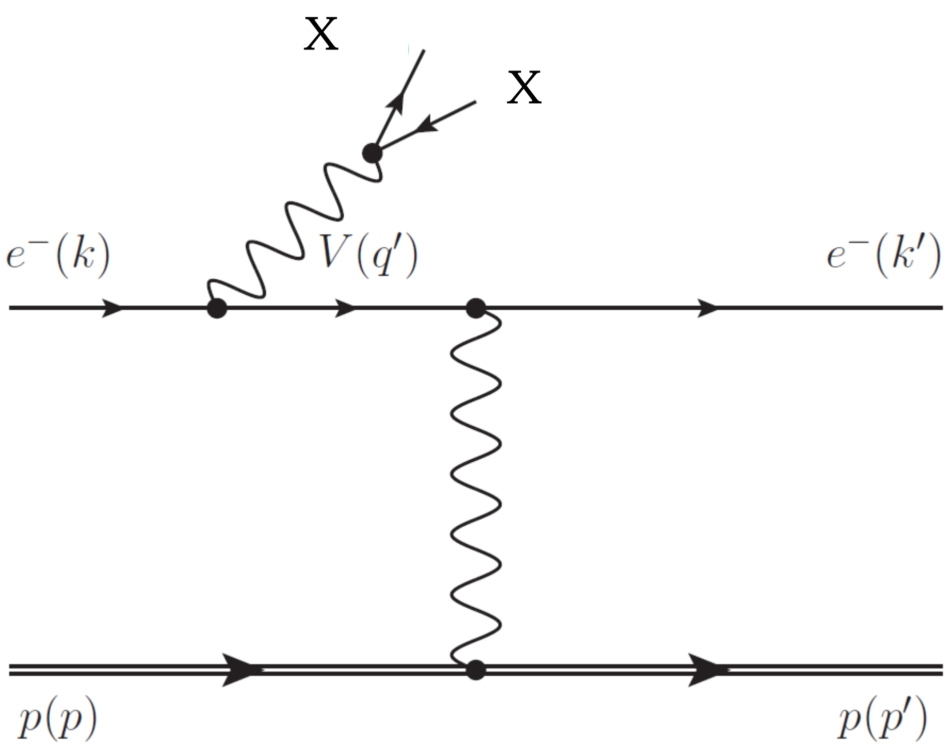
SEARCH FOR INVISIBLE DECAYS

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



PROTON RADIUS PUZZLE

Electronic measurements

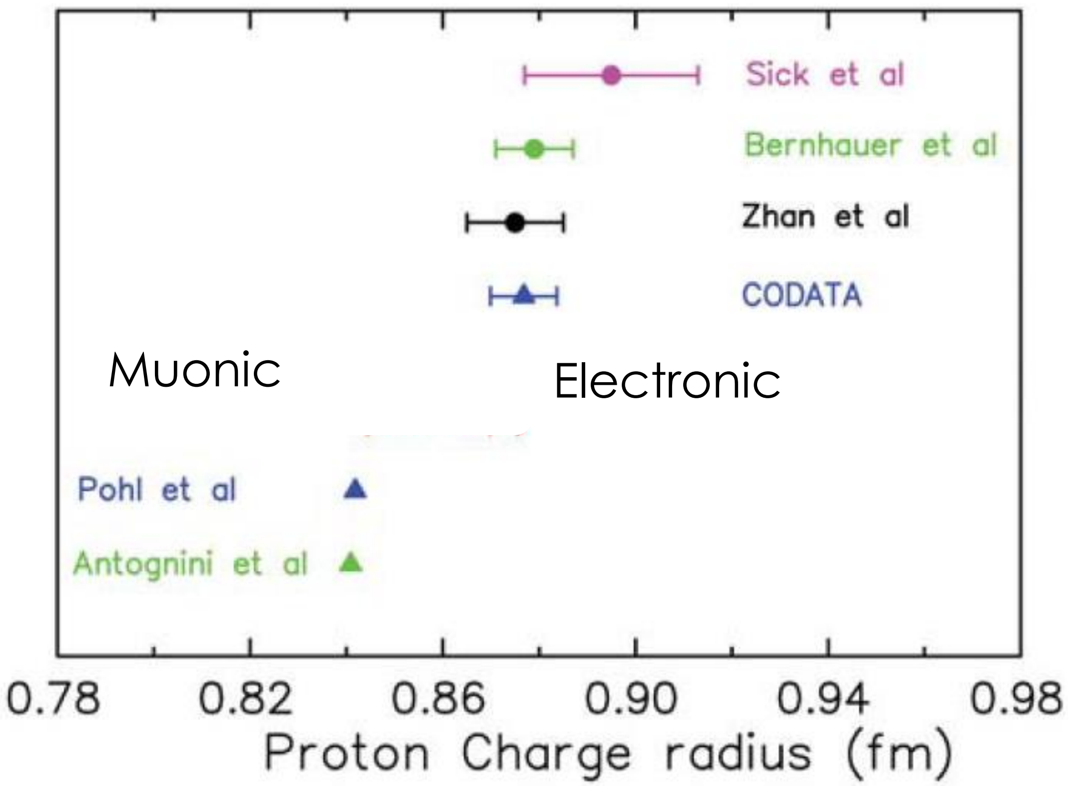
- Hydrogen hyperfine structure
- Electron scattering
- $r_e = 0.8775(51)$

Muonic measurements

- Lamb shit of a muonic hydrogen
- $r_\mu = 0.84087(39)$

7σ discrepancy of unknown origin

- Experimental mistakes?
- Neglected radiative correction?
- A dark photon again?
- Incorrect extrapolations at low Q^2?



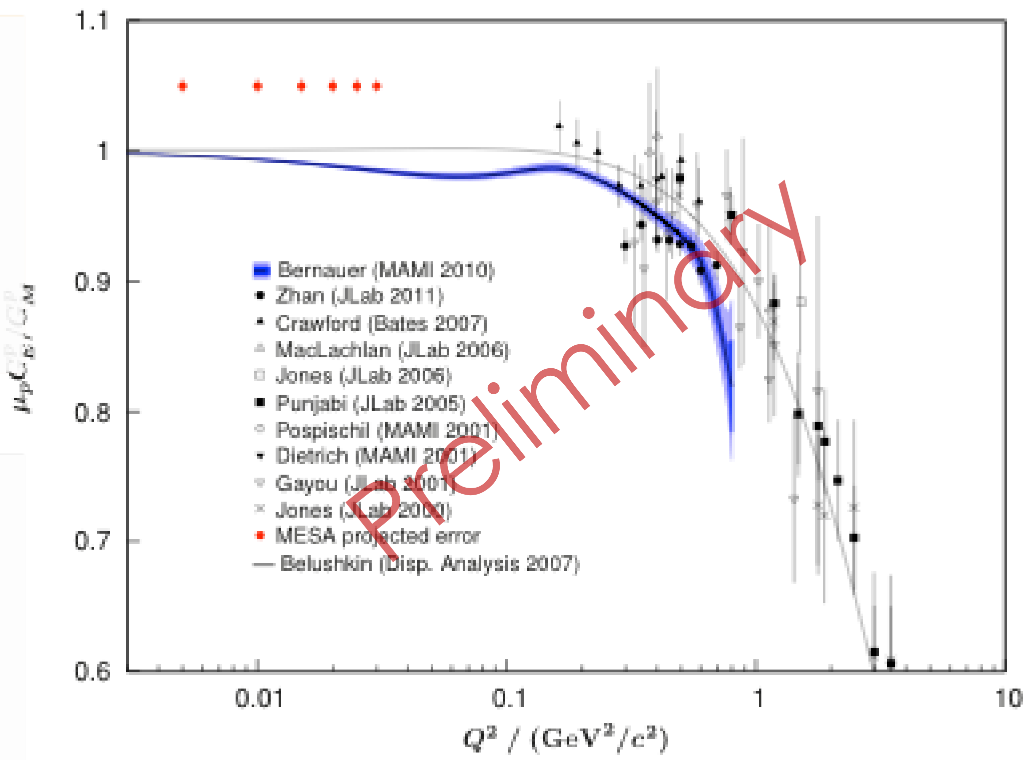
LOW Q^2 NUCLEAR FORM FACTORS

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



SOME MORE IDEAS

Test of chiral effective theories

- Test QCD calculations of light nuclei structure
- Flexible gas target design to inject different elements
- Electron polarization to enrich the measurements

Nuclear cross-section of astrophysical relevance

- The goal is to measure precisely cross-sections of processes like $^{12}C(\alpha,\gamma)^{16}O$
- Relevant cross section for stellar evolution calculations
- Relevant energy is of the order of tens of MeV
- Can be derived from the cross-section of the related process $^{16}O(e, e' \, ^{12}C) \alpha$

CONCLUSIONS

CONCLUSIONS

Interesting projects for low energy experiments

- Dark Photon Searches
- Dark Matter Searches
- Low energy nuclear spectroscopy
- Test of low energy effective theories
- Measurement of nuclear cross-sections

Low-energy, high-intensity accelerator

- The construction of MESA is starting
- 100-150 MeV electron accelerator
- Up to 10 mA current (0.15 mA with polarized beam)

MAGIX, a versatile, modern and efficient experiment

- Twin arm spectrometer on a thin gas target
- Very high momentum resolution at high rates
- Design of the system in progress

30 BACKUP

TARGET DEVELOPMENT

Fluid-dynamic simulation

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

Polarized gas injection

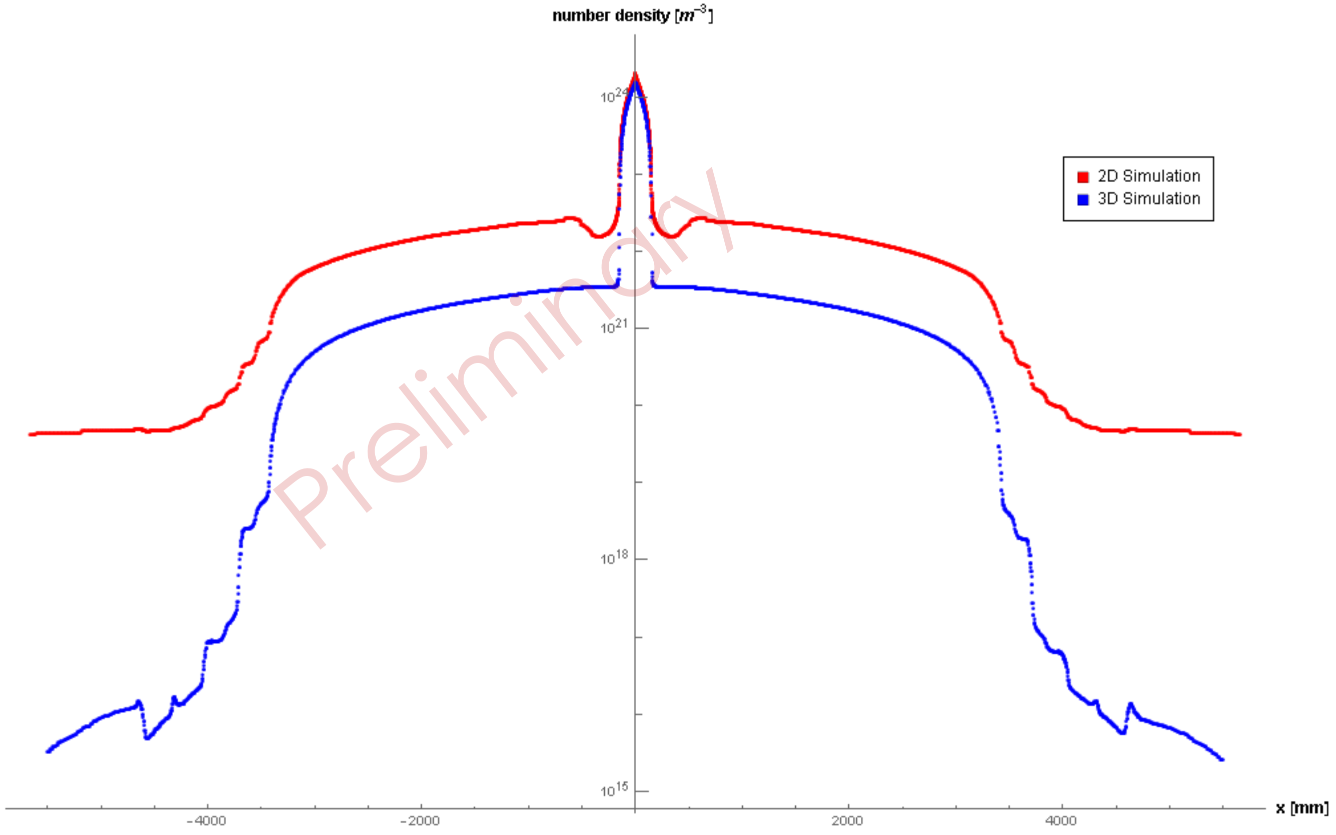
- Necessary for nuclear physics experiments

Target-machine integration

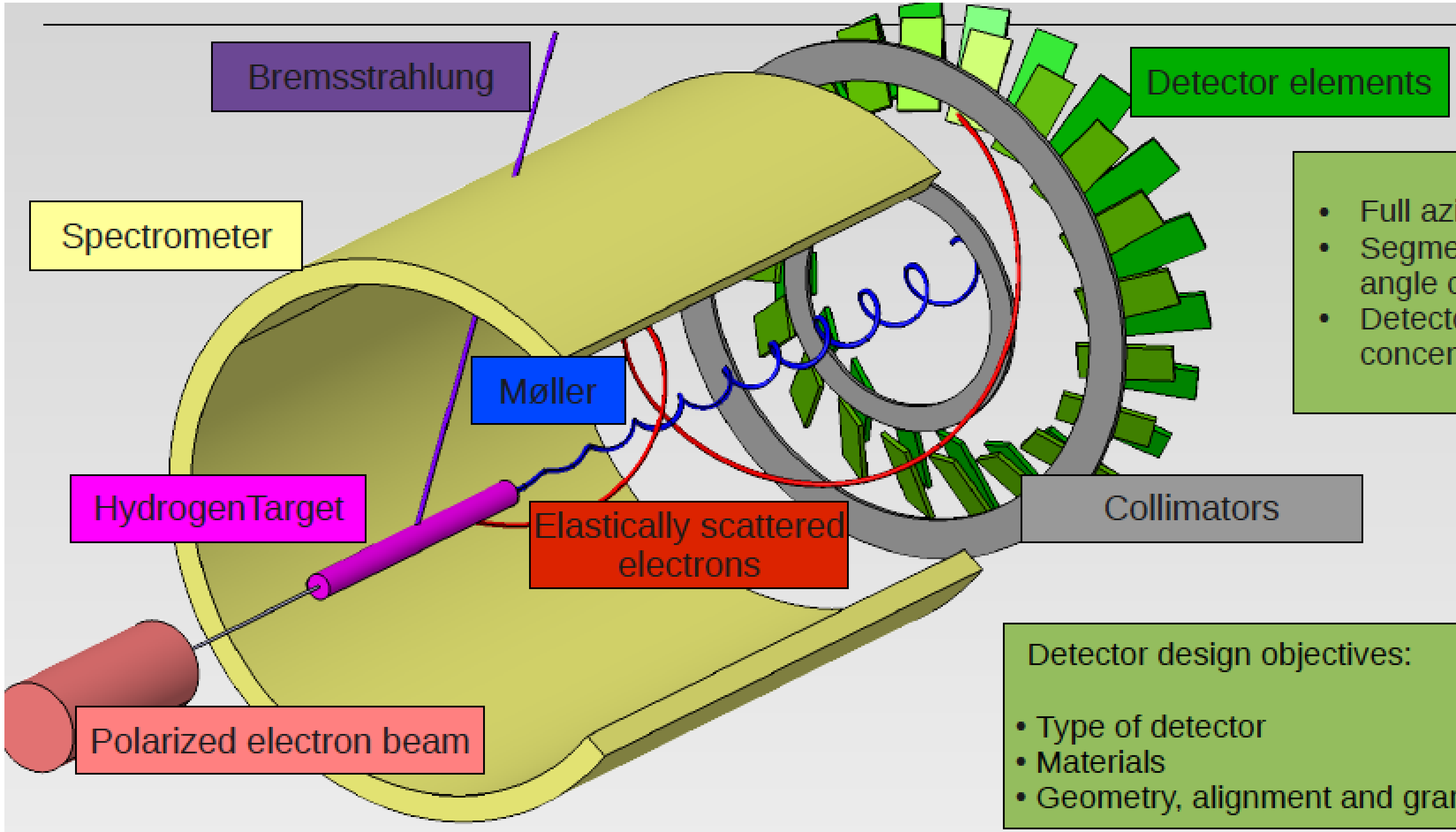
- Interactions with the beam-halo
- Target cooling
- Beam monitoring

Prototype testing

- Simulation validation
- On-beam test



P2 DETECTOR CONCEPT



- Full azimuthal coverage
- Segmented ~24°-44° polar angle coverage
- Detectors aligned in concentric circles

Detector design objectives:

- Type of detector
- Materials
- Geometry, alignment and granularity of modules