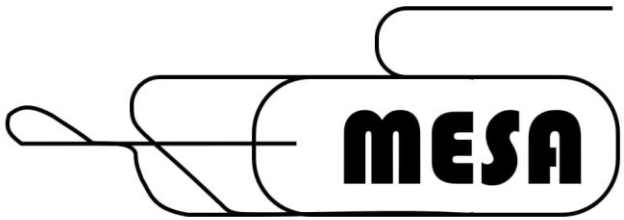
The Hydro-Möller at MESA

Status and work(s) in progress

SPIN2021,
the 24th International Spin Symposium
18. October 2021
Presented by Kurt Aulenbacher,
- work by Daniel Simon, Valery Tioukine and K.A. & MESA-team

Cluster of Excellence
PRISMA+



MESA-Project - introduction

- MESA: Manz Energy-recovering Superconducting Accelerator
- Main interest: low energy electron scattering experiments
- Energies below 200 MeV, CW spin-polarized beam,
- → low energy polarimeters

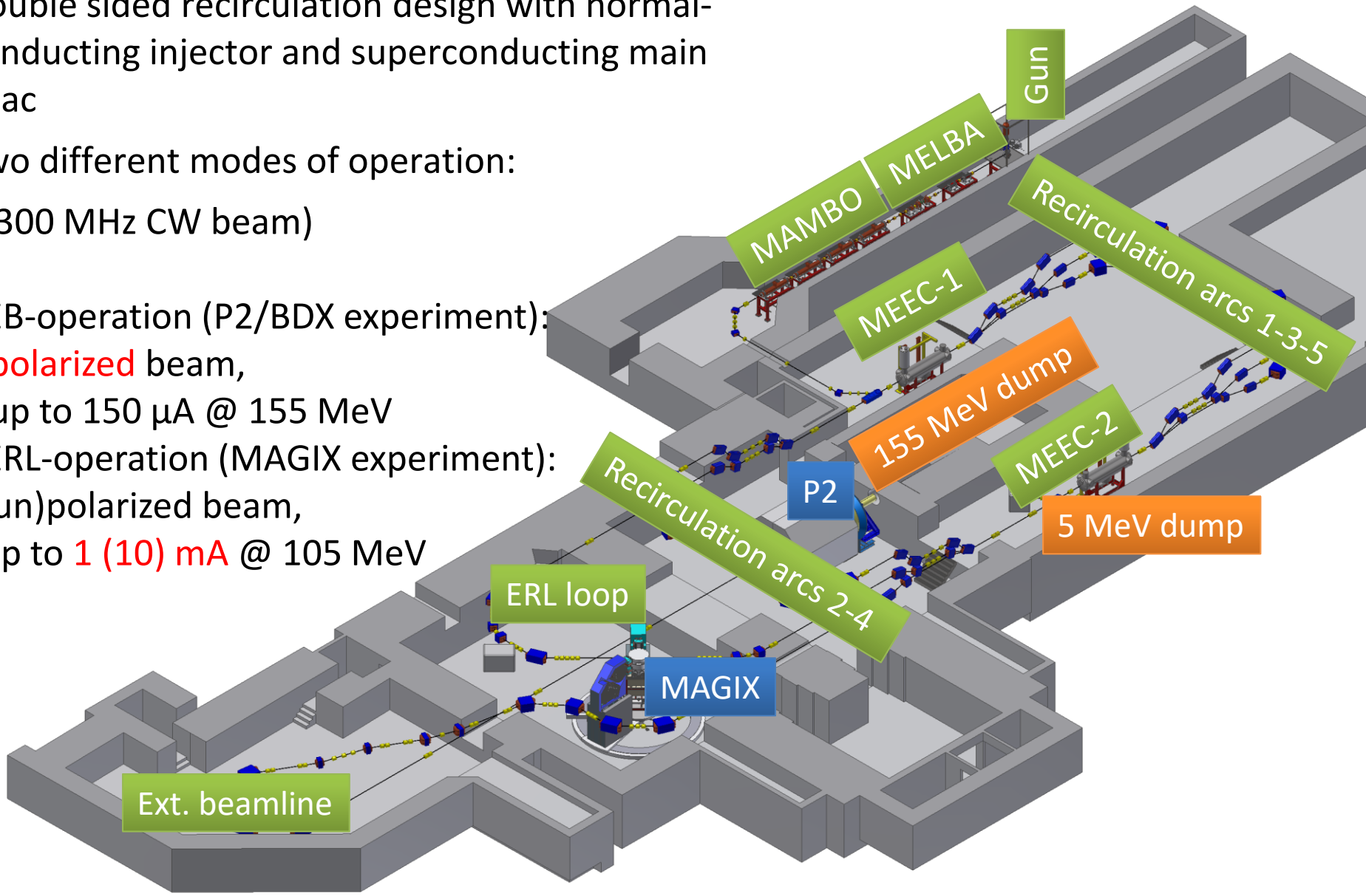
MESA Accelerator Layout

Double sided recirculation design with normal-conducting injector and superconducting main linac

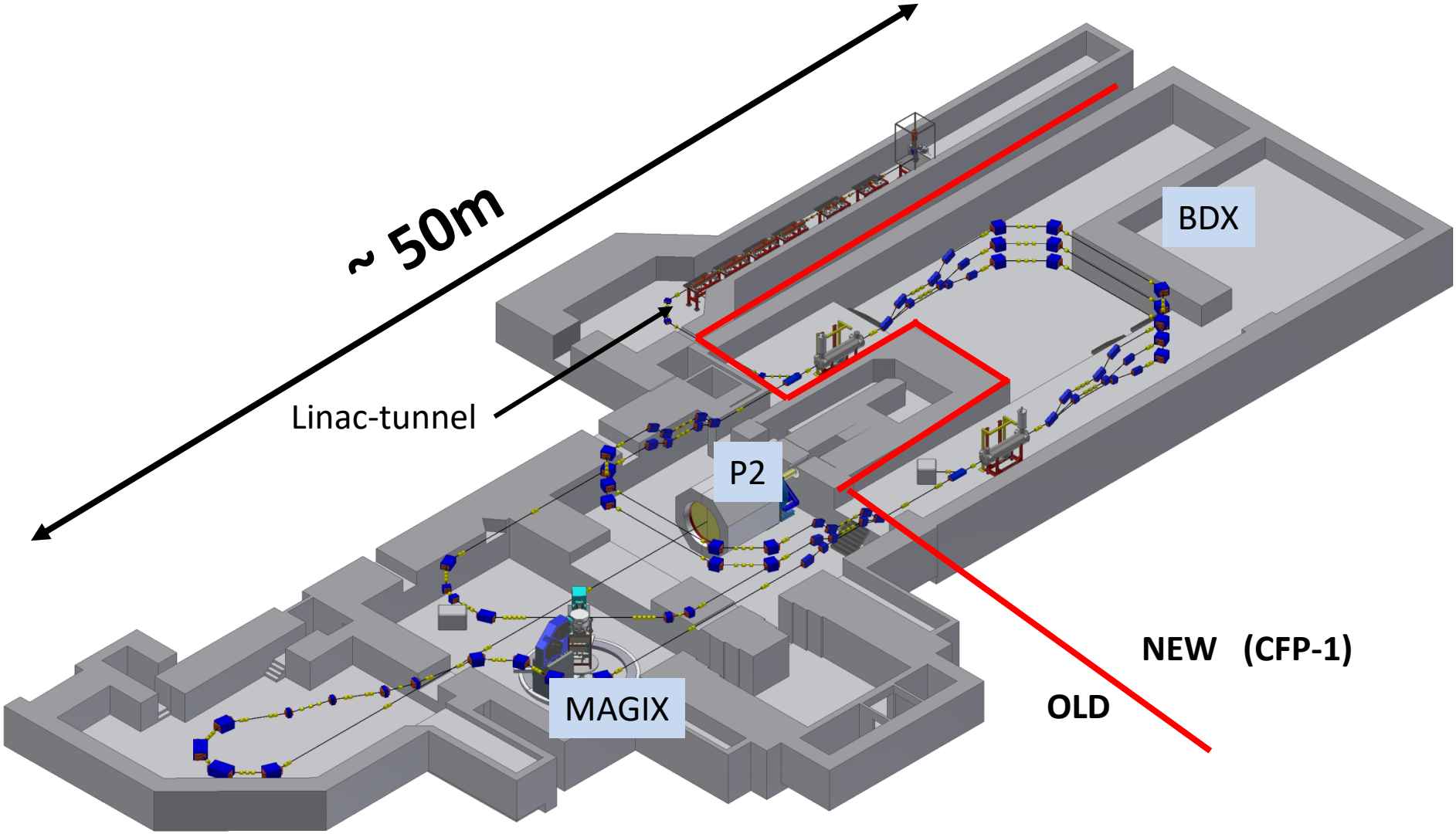
Two different modes of operation:

(1300 MHz CW beam)

- EB-operation (P2/BDX experiment):
  polarized beam,
  up to 150 µA @ 155 MeV
- ERL-operation (MAGIX experiment):
  (un)polarized beam,
  up to 1 (10) mA @ 105 MeV



New experimental halls
…for more and larger experiments

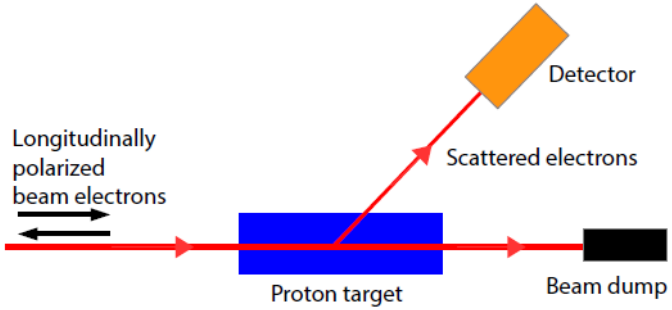


MESA Civil construction status September /2020

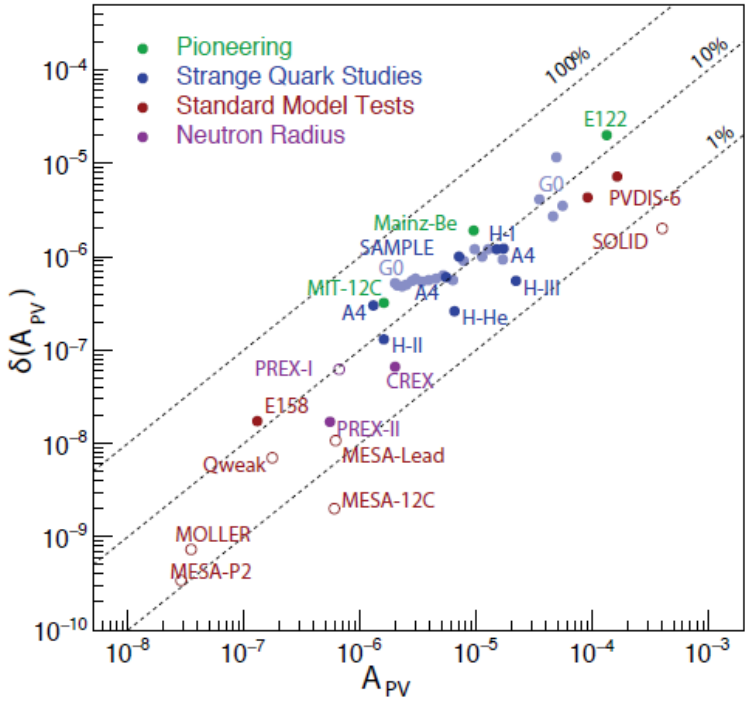
Main accelerator installation cannot begin before winter 22/23

Polarization –accuracy requirements

P2@MESA: High accuracy measurement of (very small) parity violating asymmetry



$$A^{\mathrm{PV}} = \frac{-G_{\mathrm{F}}Q^2}{4\pi\alpha_{\mathrm{em}}\sqrt{2}}\left[Q_{\mathrm{W}}(\mathrm{p}) - F(E_{\mathrm{i}}, Q^2)\right],$$



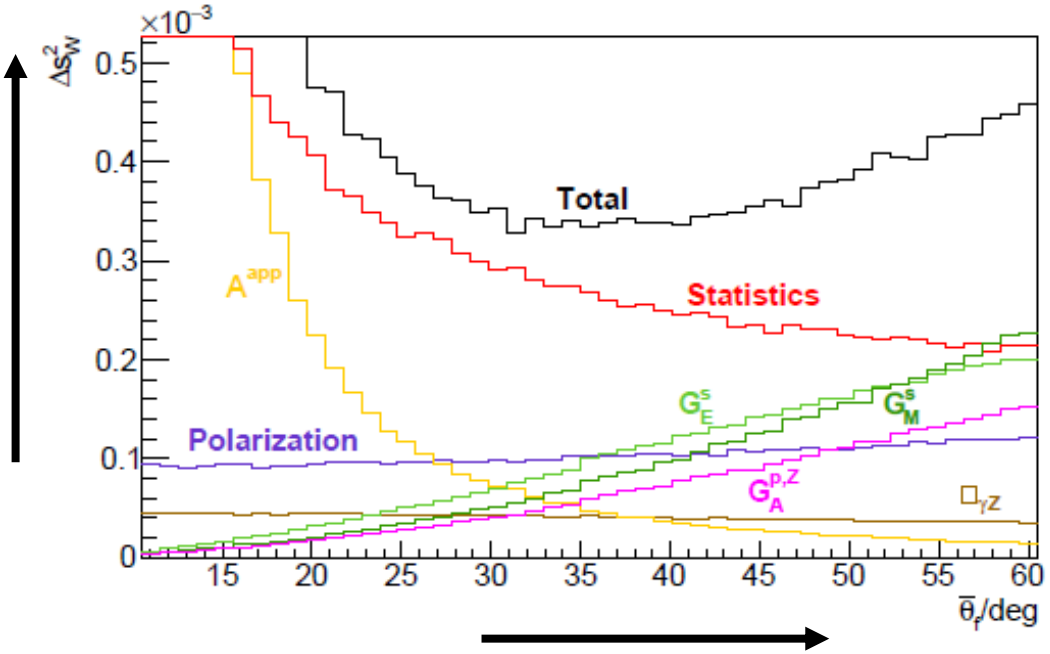
But: $A^{exp}=P*A^{PV}$

Figures from: D. Becker et al., Eur. Phys. J. A (2018) 54 : 208

P2@MESA:
Assumptions concerning error contributions

Statistics: Assuming 150 µA beam current on 55cm lq. Hydrogen for 10000 hours with P=0.85

Relative error on $\sin^2$ of weak mixing angle



Polarization error assumed as $\Delta P/P=0.5\%$!

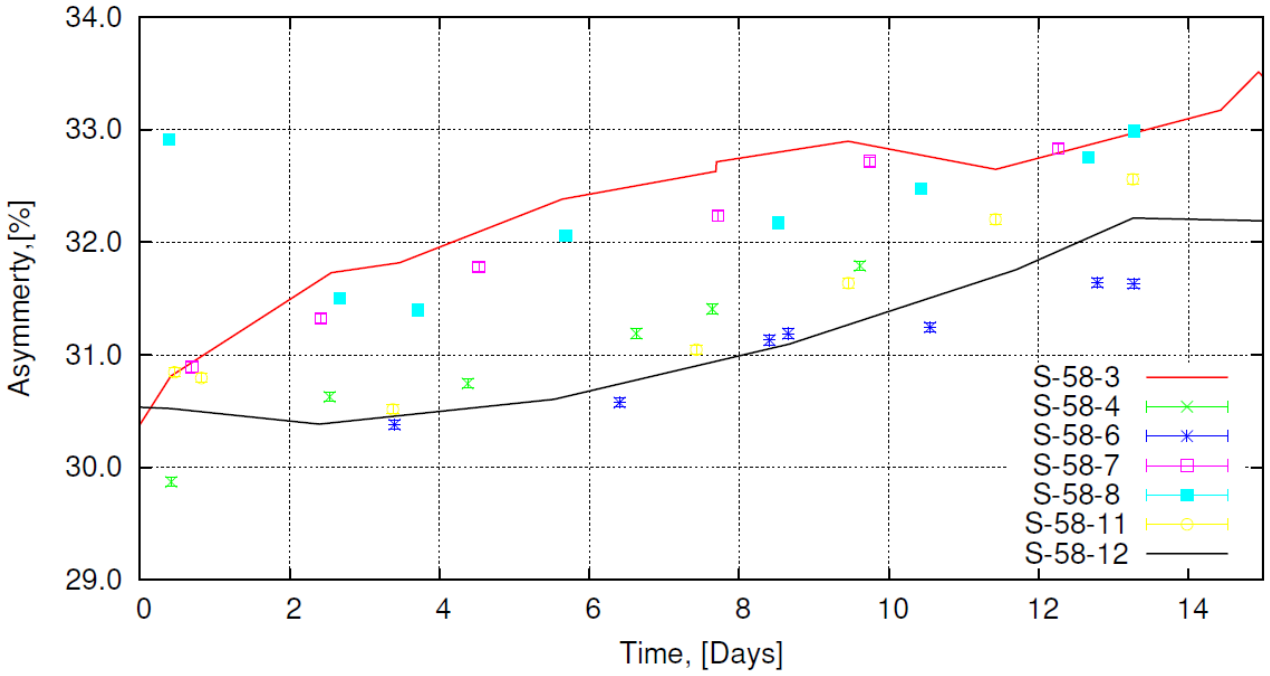
Average scattering angle at E_{beam}=155 MeV

Content from: D. Becker et al., Eur. Phys. J. A (2018) 54 : 208

Concept of Polarimeter chain

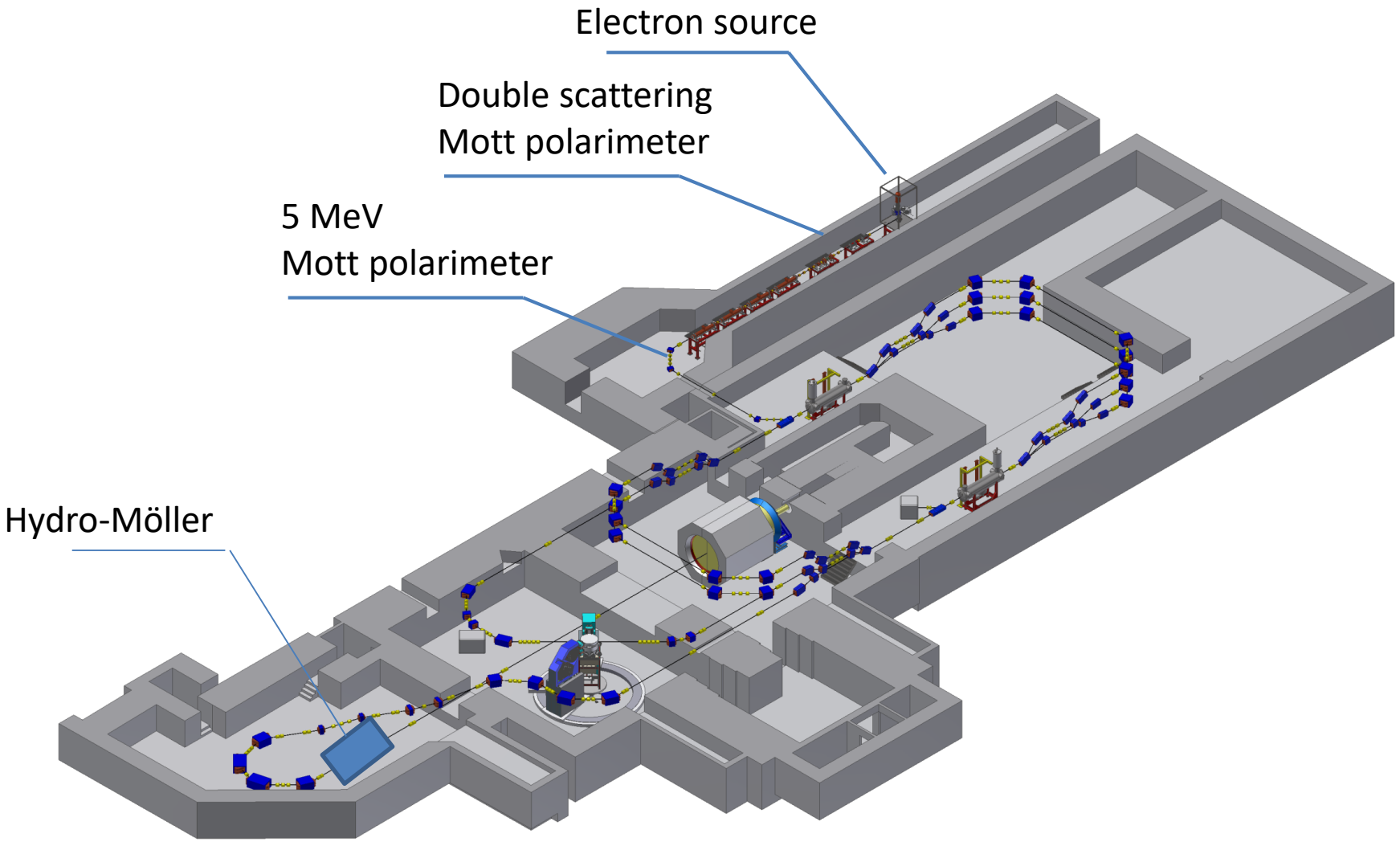
- Three independend polarimeters forming the chain
- Operating at 0.1; 5; and 155 MeV
- Each having sub-percent accuracy, (aiming at <0.5%)
- One of them operating online

Online requirement!



Observed drift of beam polarization during measurement
can reach 1%/day, and may depend on potocathode activation
Measurements by „conventional“ 3.5 MeV Mott-polarimeter at MAMI

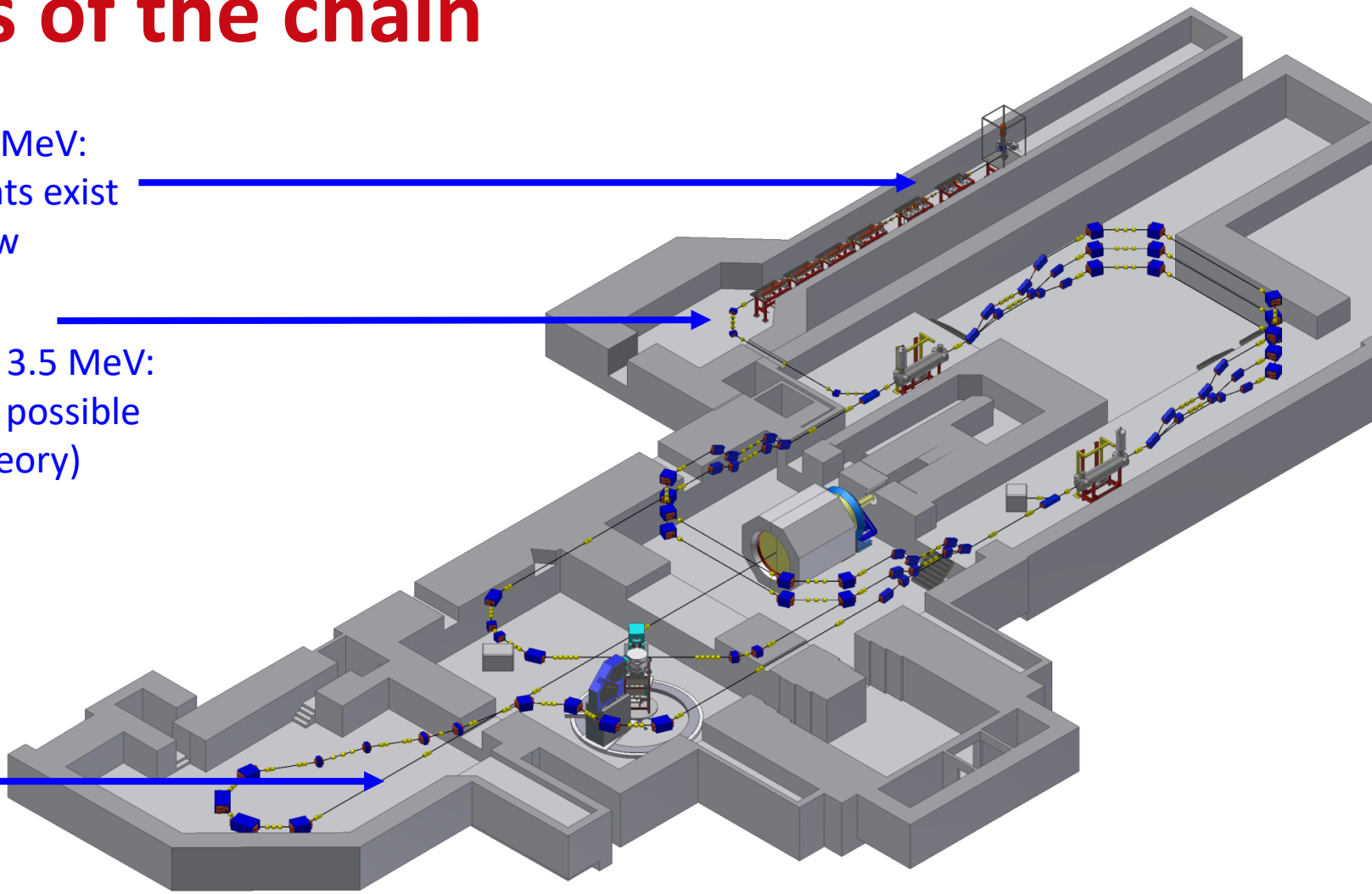
Positions in the chain



Status of the chain

DSMP @ 0.1 MeV:
Measurements exist
See tomorrow

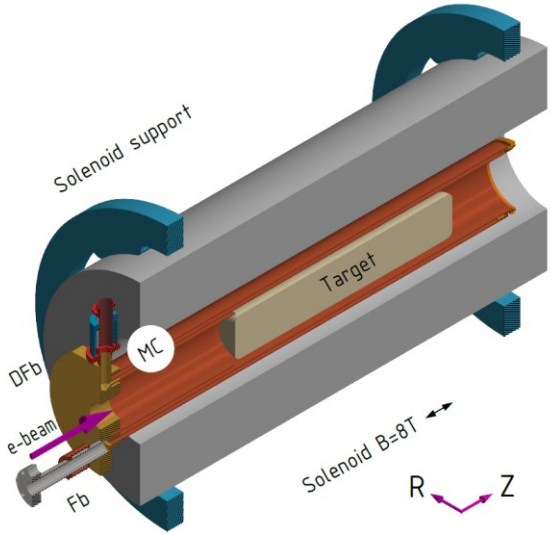
MP @ 5 MeV:
Experience at 3.5 MeV:
<1% accuracy possible
(limited by theory)



Möller scattering from completely spin polarized hydrogen target: technically demanding, cryostat under construction, detection system under discussion with US-groups. Online capability: see V. Tioukine et al. Proceedings PSTP 2019

Hydro-Möller:
A neutral Hydrogen Atomic trap

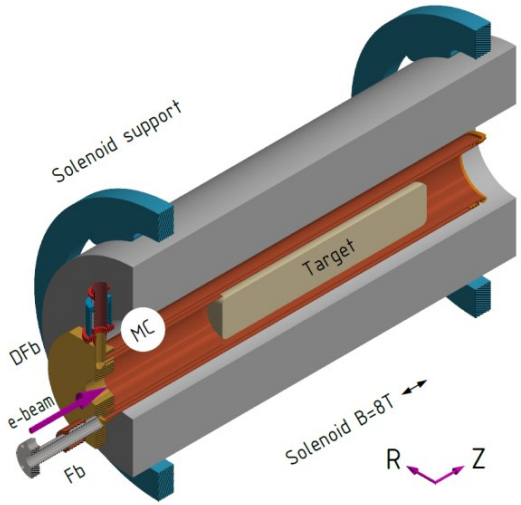
- Suggested by Chudakov and Luppov E. Chudakov and V. Luppov, Moller polarimetry with atomic hydrogen targets Nuclear Science, IEEE Transactions on 51 (2004) 1533.
- Trapping H-atoms at 0.3 K. Cooling by collisions with suparfluid helium
- Leads to axial trapping by solenoid and radial trapping by wall collisions
- Technology developed at BNL in the 1990ies, but never used in intense beam



Schematic of Hydro-Möller-Target, Dilution refrigerator provides cooling power of ~70mW at 0.3K at Mixing chamber (MC). From: V. Tioukine et al: Proceedings PSTP 2019

Hydro-Möller: Promise

- Areal density about 10^{16} spins/cm^2 → sufficiently low for online operation
- but reasonable statistical efficiency…
- Hydrogen Polarization 1-ε with $\varepsilon < 10^{-4}$ → suppression of error from target polarization
- No Levchuk effect
- → $\Delta P/P < 0.5\%$?



Schematic of Hydro-Möller-Target,

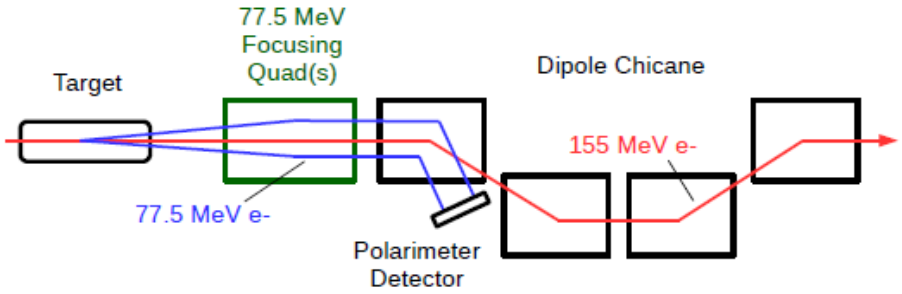


Figure from: D. Becker et al., Eur. Phys. J. A (2018) 54 : 208

Hydro-Möller: Technical Challenges and status

- Powerful dilation refrigerator needed (50mW at 0.3K)
- Components under construction at Mainz and at JINR-Dubna (group of Y. Usov)
- Cold electron spin polarized Hydrogen dissociator → long term operation?
- Plasma effects – electron trapping?
- Cryostat test begin in 2022
- MESA Beam available in 2024

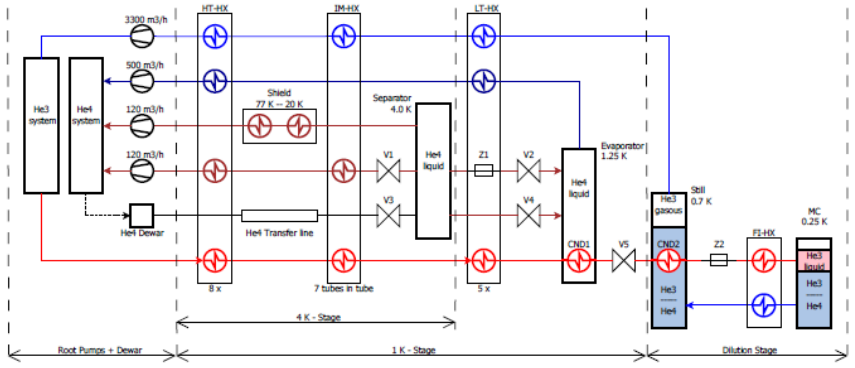


Figure 4: Refrigerator flow chart. HX=Heat exchanger. HT/IM/LT = high, medium and low temperature level of precooling circuit.

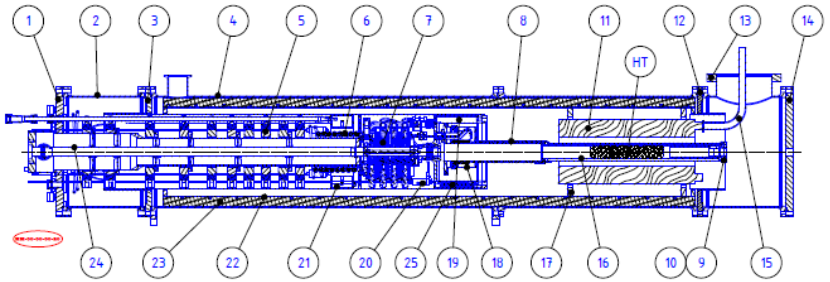
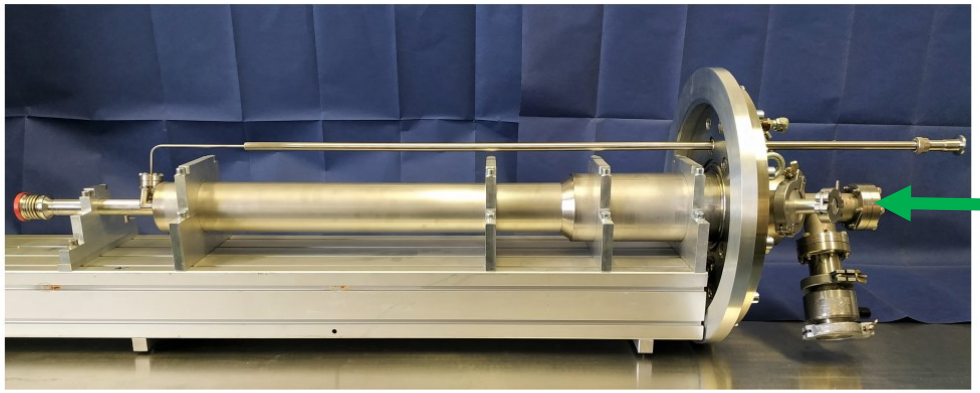


Figure 5: Schematic of the Hydro-Møller atomic trap. 1 - port flange , 2 - cross, 3 - connector flange cryostat, 4 - housing, 5 - high temperature HX, 6 - intermediate temperature HX , 7 - low temperature HX, 8 - final HX, 9 - one-sided film burner, 10 - double-sided film burner, 11 - super conducting solenoid, 12 - connector flange, 13 - tees, 14 - output flange, 15 - He4 - connections, 16 - mixing chamber, 17 - thermally insulated mounting, 18 - still, 19 - evaporator with 25-condenser, 20 - needle valves, 21 - separator, 22 - 77 K shield, 23 - multi layer insulation, 24 - evaporator pumping line

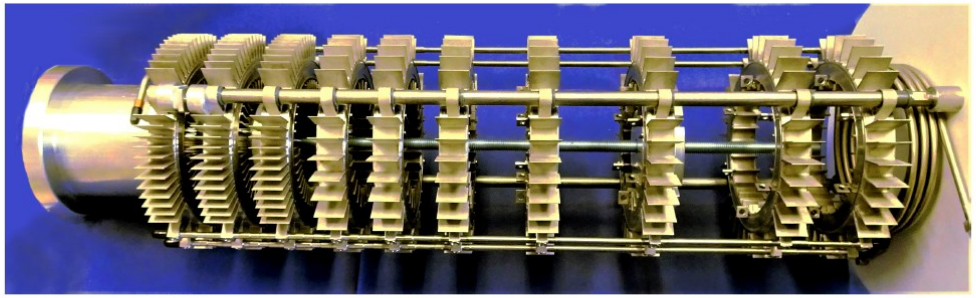
Upper frame: Schematic of Refrigerator
Lower frame: cross section of trap with refrigerator

“Robust” Refrigerator parts…



Beam insert and
“Pumping line”

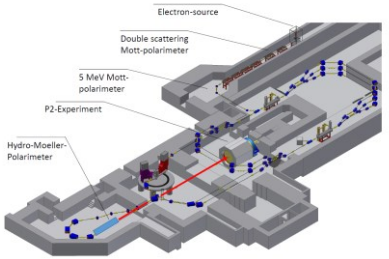
Figure 11: Base flange with pumping line surrounding the beam pipe. Developed by KPH-Mainz in coperation with several industrial suppliers.

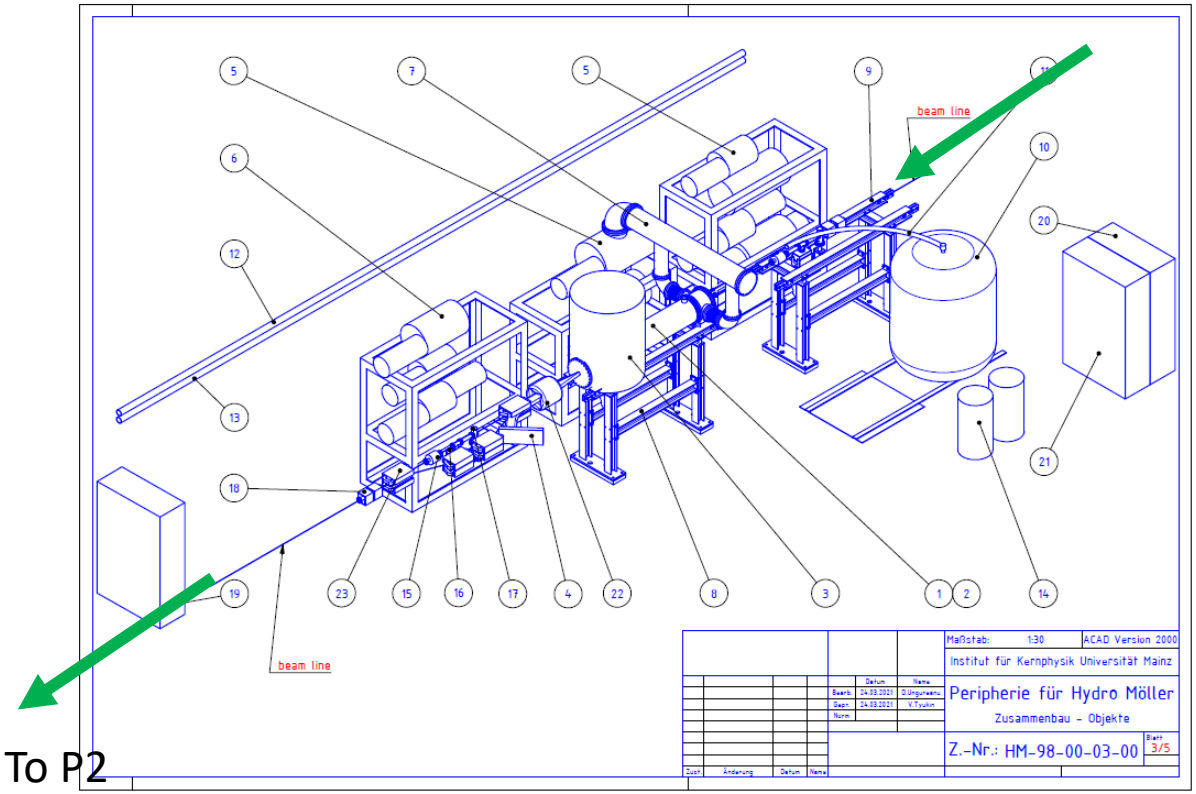


All welded
heat exchangers
For precooling stage

Figure 12: High temperature heat exchanger. Developed by KPH-Mainz in coperation with several industrial suppliers.

Hydro-Møller set up in hall

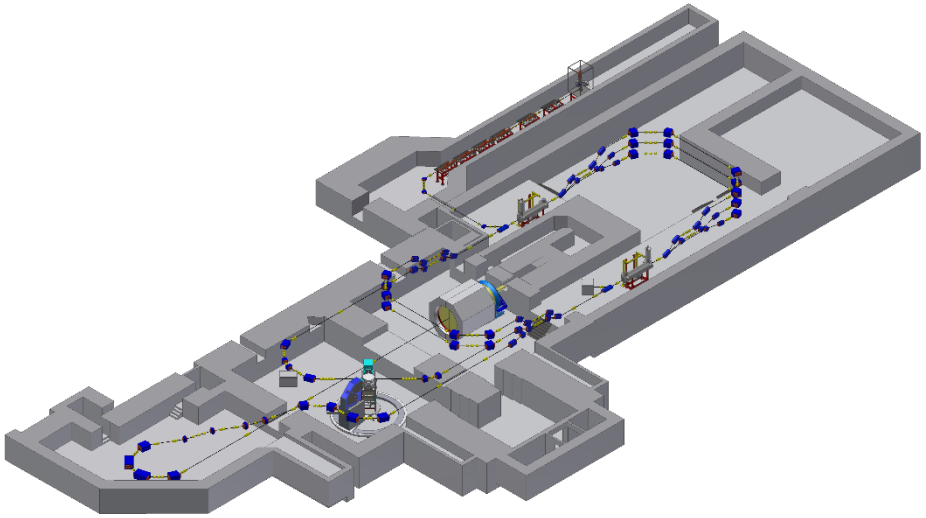


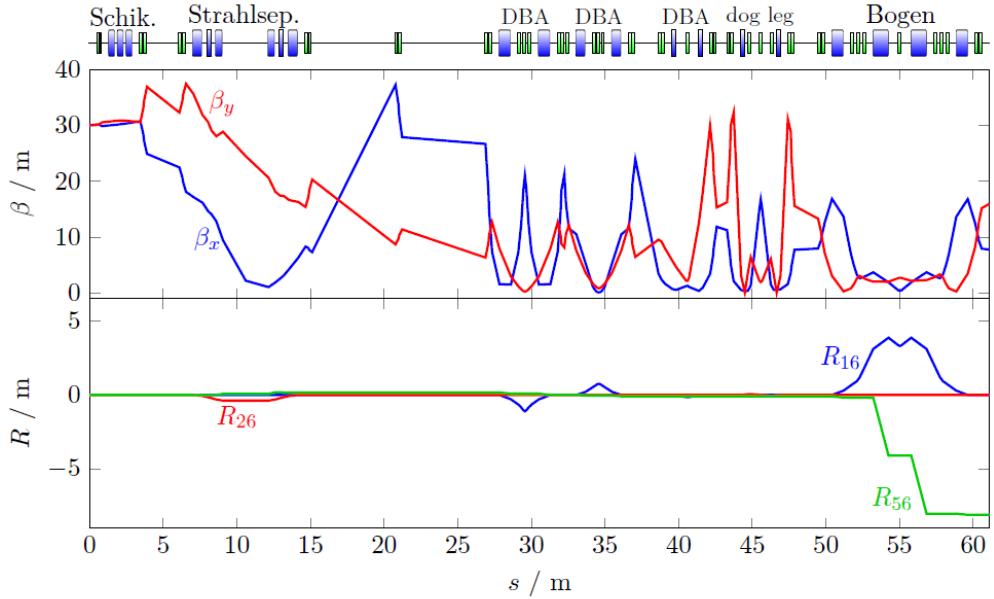


To P2

- Length of set up ~8m
- Two Helium circuits needed
- Estimated lq. Helim consumption <10l/h

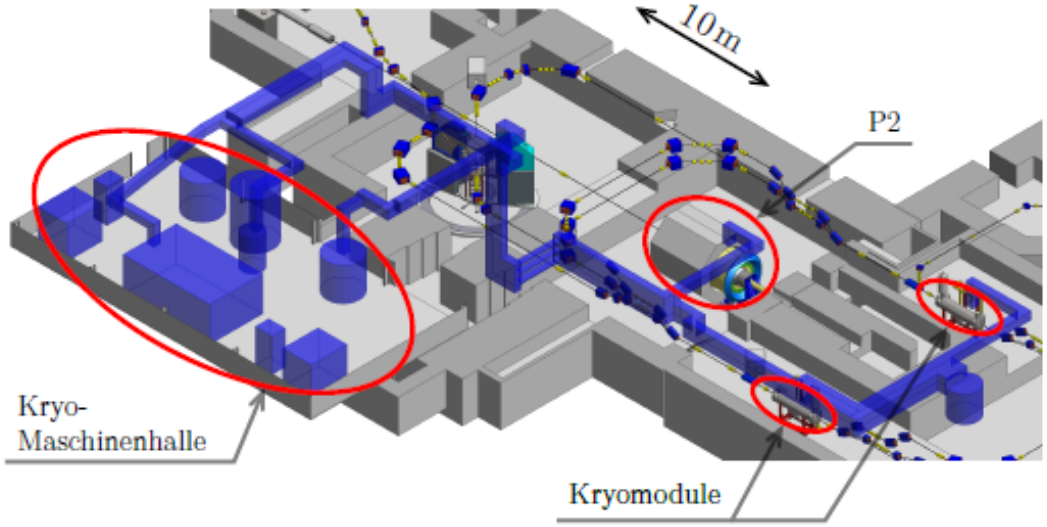
The beamline…

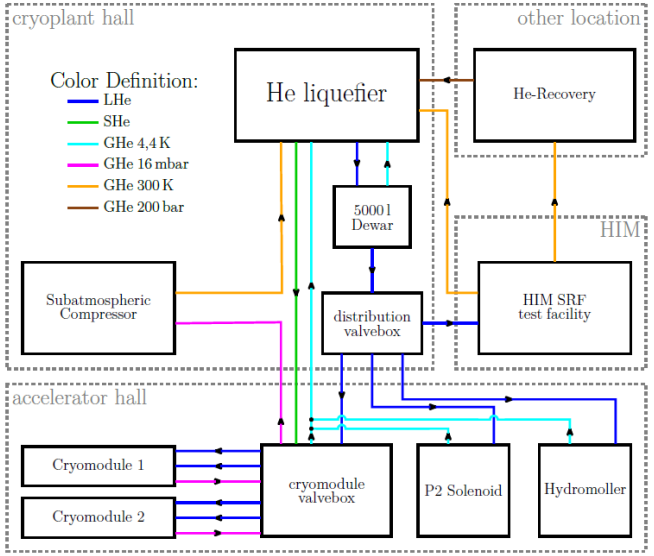




D. Simon Dissertation Thesis
http://doi.org/10.25358/openscience-5809

The cryogenic distribution





Outlook

- Cryostat under construction (JINR/Dubna and Mainz)
- Testing of trap will happen in 22/23
- Design work on detection system by other parts of P2 collaboration
- Beam at MESA available 2024

→ Lots of work, cooperation, collaboration or simply help would be greatly appreciated!

The Hydro Möller has the potential for sufficiently high accuracy ($\Delta P/P < 0.005$) for the P2-Hydrogen experiment

Once in operation it can be cross checked against the other polarimeters in the chain. For the P2-Carbon experiment ($\Delta P/P < 0.003$) is demanded

Thank you