„ULTIMATE“ PRECISION POLARIMETRY FOR FUTURE PVES EXPERIMENTS

Precision tests with neutral current coherent interactios with nuclei

Workshop at the Mainz institute for theoretical physics

2022, May 24

An approach by Kurt Aulenbacher

Precision polarimeters - overview

Process for analyzing power S	Target	Exp. Complexity/ ONLINE?	Main error source	Typical Energy/ Beam Current	ΔP/P [%] Ultimate??
Double Mott scattering (DSMP)	2*Gold	High NO	Instrumental asymmetry	0.1 MeV < 10nA	0.6 [1] <0.3 ??
Single Mott scattering	Gold	Low-medium NO	Theory	<10MeV 0.01-100muA	0.61 [2] <0.5 ??
„Iron“-Möller scattering	Solid Iron	High NO	Levchuk, Target pol	>100 MeV 1muA	0.5 [3]
„Hydro“-Möller (proposed - [4])	trapped Hydrogen-Atoms	Very high YES	Ion/Plasma-Contamination (?)	>100 MeV >100muA	<0.3 ??
Laser-Compton	Laser beam	High YES	Calibration, circular polarization	>1000 MeV	0.5 [5]

[1]A. Gellrich and J. Kessler, *Phys. Rev. A* **43** (1991) 204, doi:10.1103/PhysRevA. 43.204. [2] J. M. Grames, et al. Phys. Rev. C 102, 015501
[3] M. Hauger *et al.*, *Nucl. Instrum. Methods A* **462** (2001) 382, arXiv:nucl-ex/9910013 [nucl-ex], doi:10.1016/S0168-9002(01)00197-8.
[4] E. Chudakov and V. Luppov, *Eur. Phys. J.* **24** (2005) 123, doi:10.1140/epjad/s2005- 04-028-8.
[5] SLD Collab. (K. Abe *et al.*), *Phys. Rev. Lett.* **84** (2000) 5945, arXiv:hep-ex/0004026 [hep-ex], doi:10.1103/PhysRevLett.84.5945.

Precision polarimeters- for MESA

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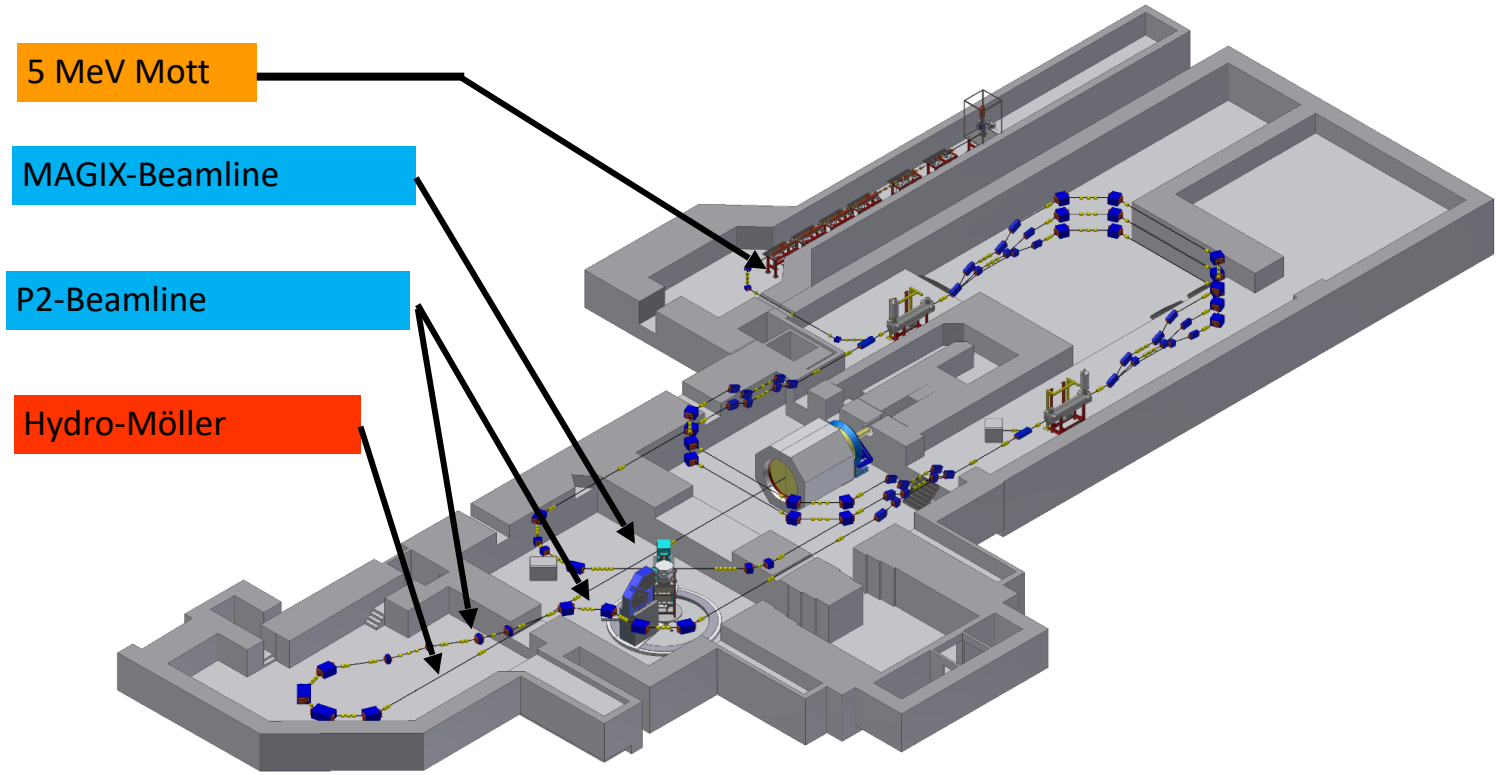
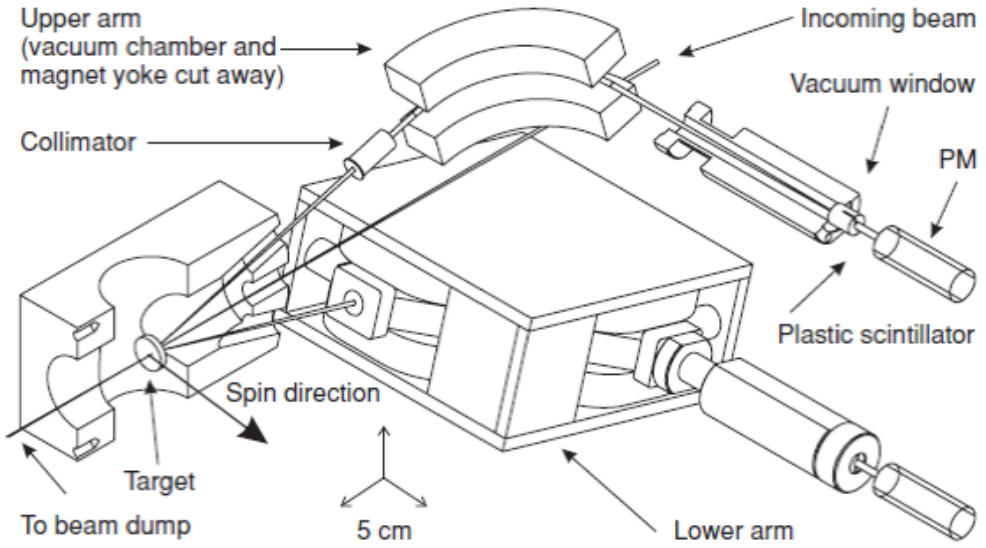
Polarimeters for P2

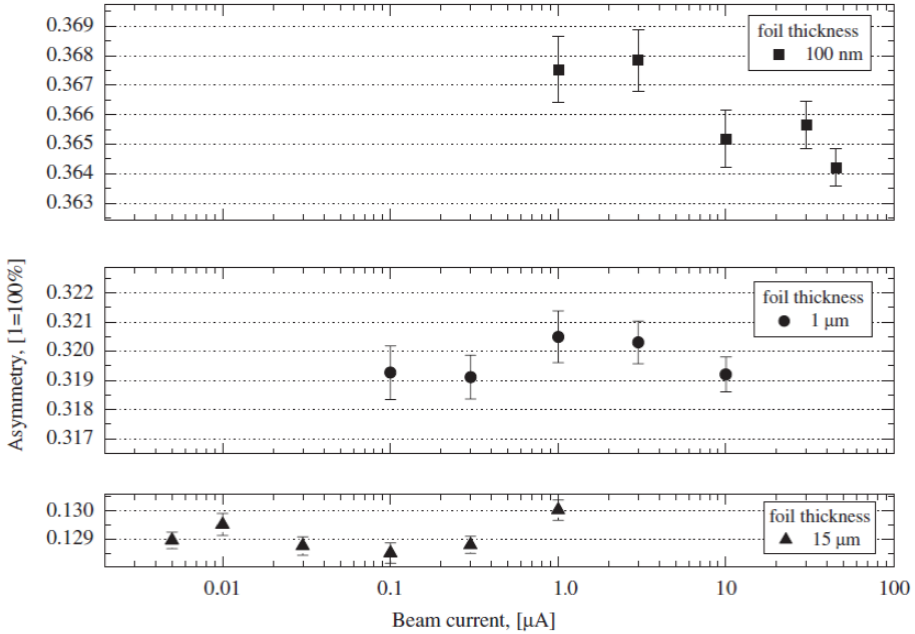


- In 2025 we will have at least one polarimeter which will achieve $\Delta P/P < 1\%$ and could realize "quasi" online measurement. Team: R. Thapa (MPA), V. Tioukine, Chr. Matejcek
- The Hydro-Möller may achieve $\Delta P/P < 0.5\%$ and could provide a real online measurement
- The Hydro Möller is delayed because of technological, budgetary and, meanwhile, also political problems

Multi- MeV Mottpolarimeter



V. Tioukine et al. REVIEW OF SCIENTIFIC INSTRUMENTS **82**, 033303 (2011),

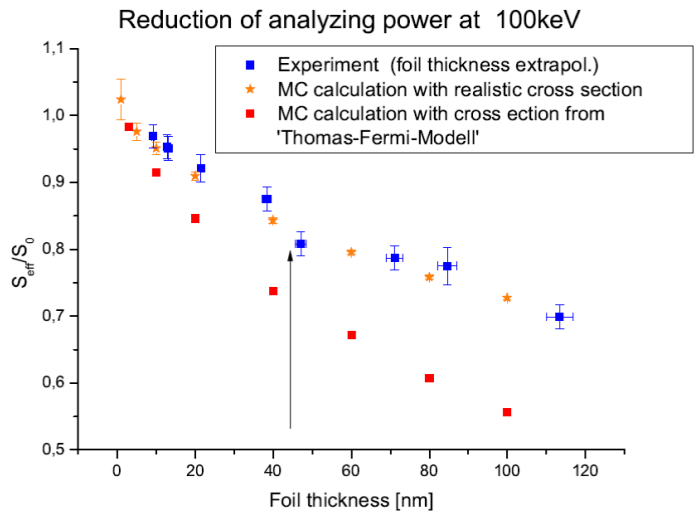


- PRISMA/P2 Team: R. Thapa/V. Tioukine: Explore Multiple scattering/Background
- Full P2 beam power capability expected, “quasi”- online capability being explored

→ Accuracy should be sufficient for P2-H , but not for P2-C

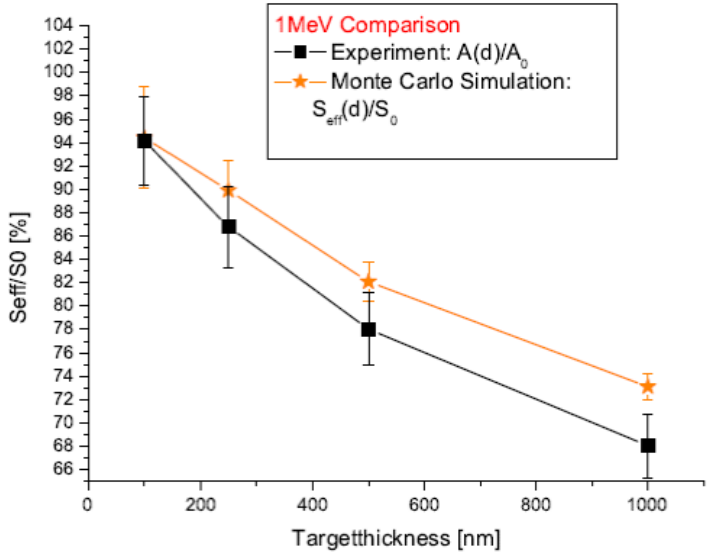
Spin diffusion and background

0.1 MeV



K. Aulenbacher and V. Tioukine proceedings PESP2008

1 MeV



2 MeV

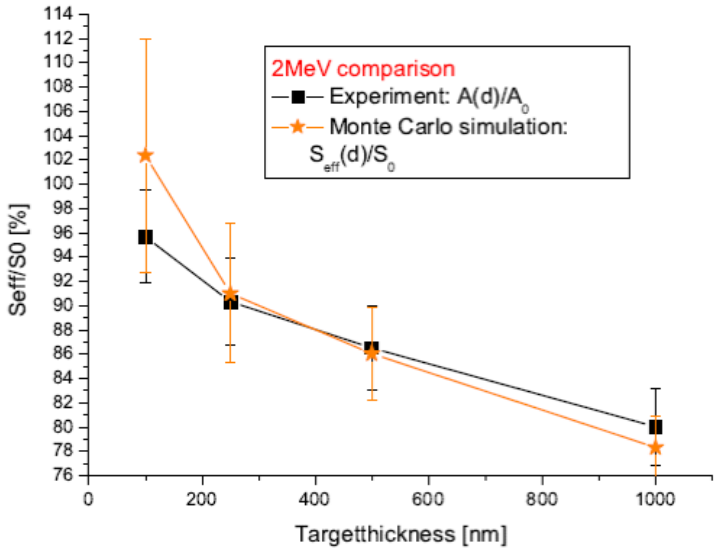


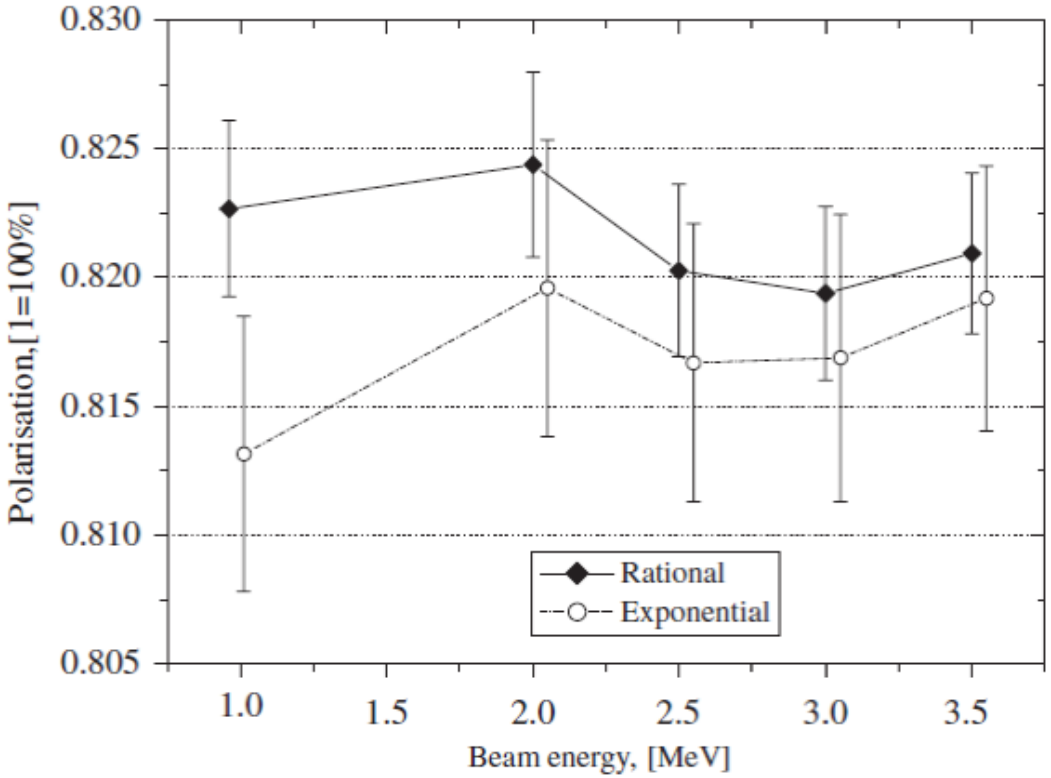
FIGURE 4. Decrease of analyzing power with target thickness for 1 and 2 MeV.

The MC simulation has in principle no parameters to „fit“ the data.

But the experimental data comprise (target induced) background from the beam dump !

→ Both effects can nowadays be simulated simultaneously! → error will be limited by theory

Mitigation of theory problem?



V. Tioukine et al. REVIEW OF SCIENTIFIC INSTRUMENTS **82**, 033303 (2011),

Difficult to calculate self-energy effect

X. Roca-Maza, EPL, **120** (2017) 33002 www.epljournal.org
doi: 10.1209/0295-5075/120/33002

Observation: The extracted value does not depend on energy at the 0.5% level. (based on solution of Dirac equation and no radiative corrections)
→ Could this indicate that radiative corrections are Not „so“ important

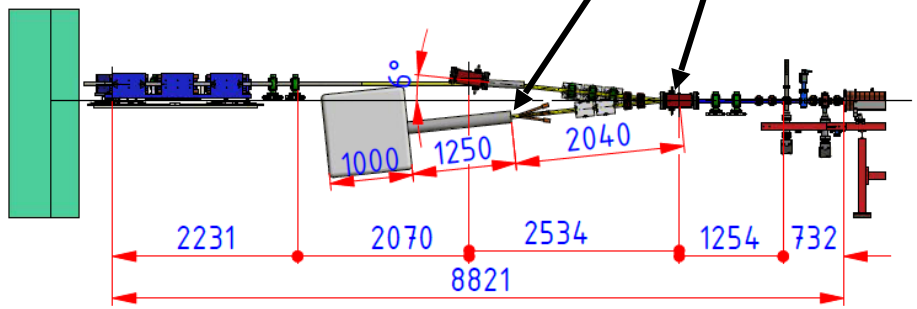
Other option: Different Z- targets

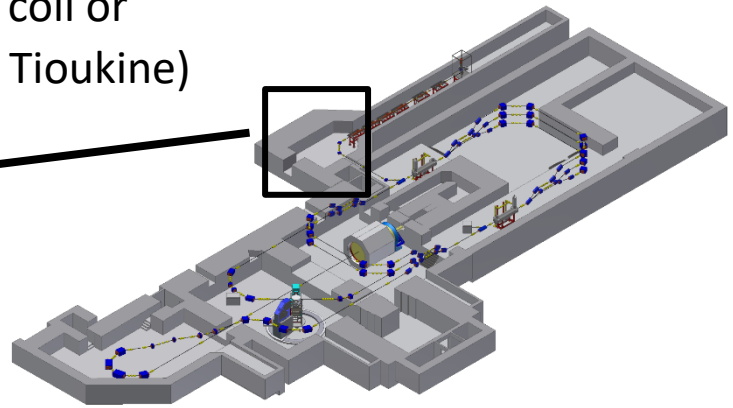
MESA-ARC-0 layout

Jefferson-Lab-type polarimeter/or magnetic spectrometer (MAMI-type) (under investigation by R.Thapa)

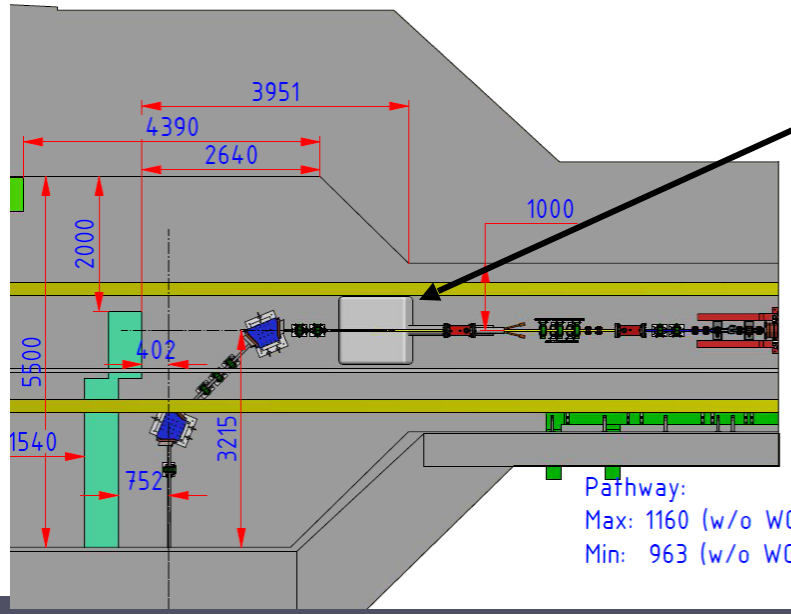
±6 degree deflection by „kicker“ (air coil or condensor plates, under design by V. Tioukine)

MESA MARC-0
Side view

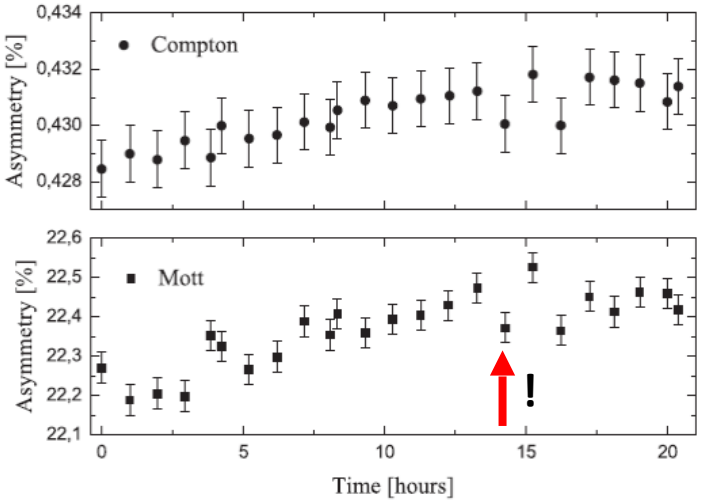




MESA MARC-0
Top view

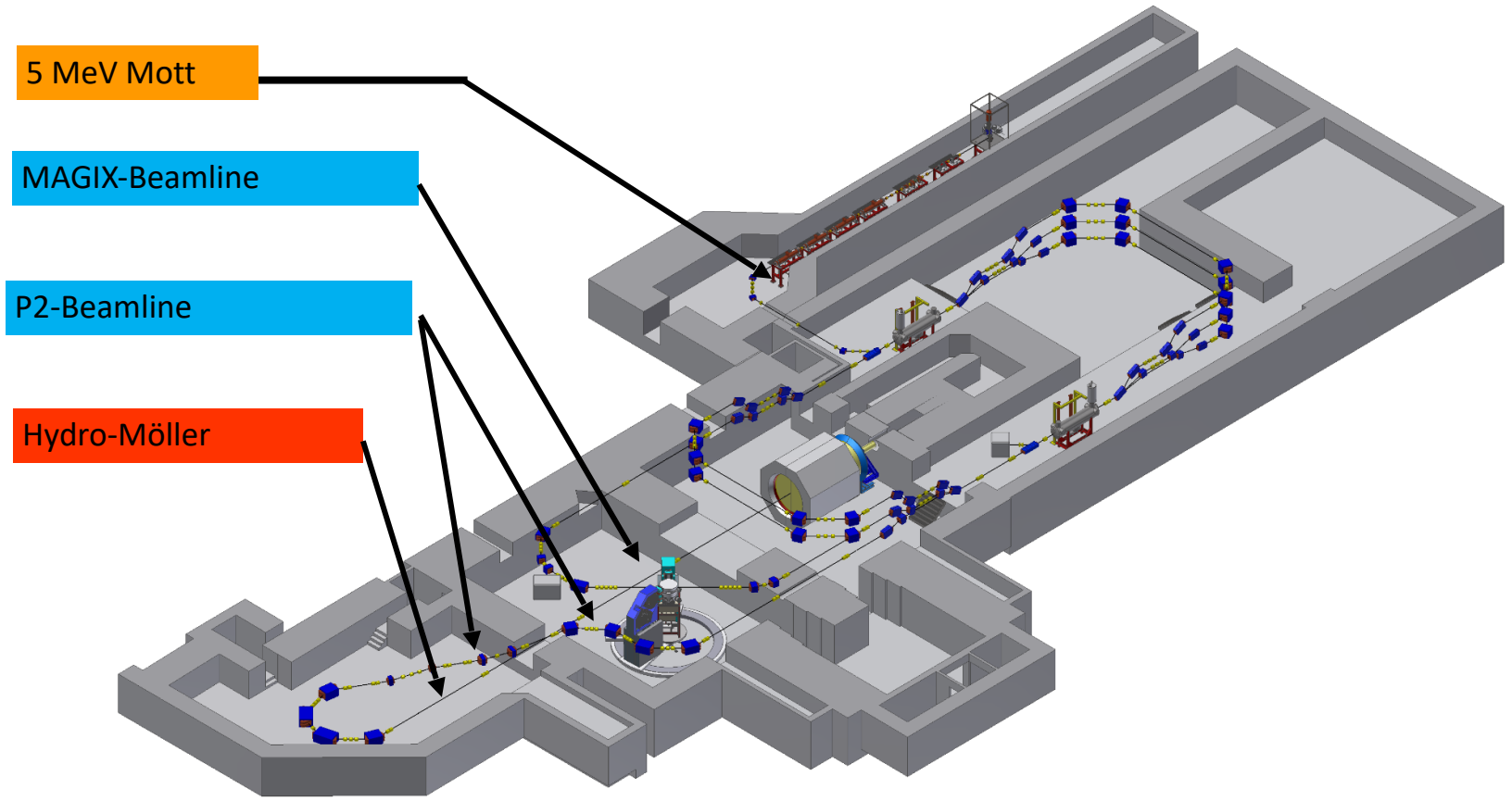


Beam dump with longitudinal Compton-Absorber
-allows pol control even at not completely transverse angles.
-independent check for drifts and jumps



R Barday *et al* 2011 *J. Phys.: Conf. Ser.* **298** 012022

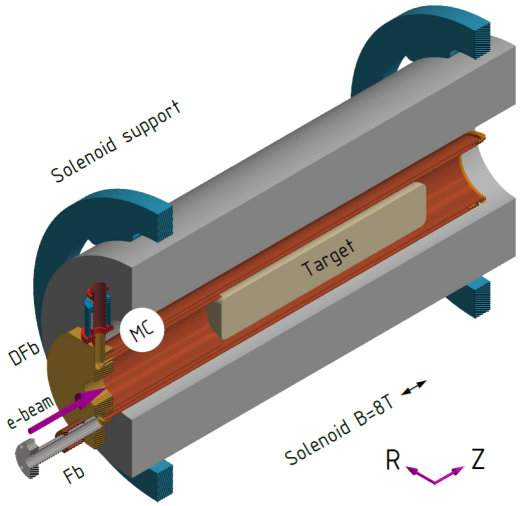
Hydro- möller @ MESA



[4] E. Chudakov and V. Luppov, *Eur. Phys. J.* **24** (2005) 123, doi:10.1140/epjad/s2005-04-028-8.

Hydro-Möller: Promise

- Areal density about 10^{15} electron 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
- → $\Delta P/P < 0.5\%$?



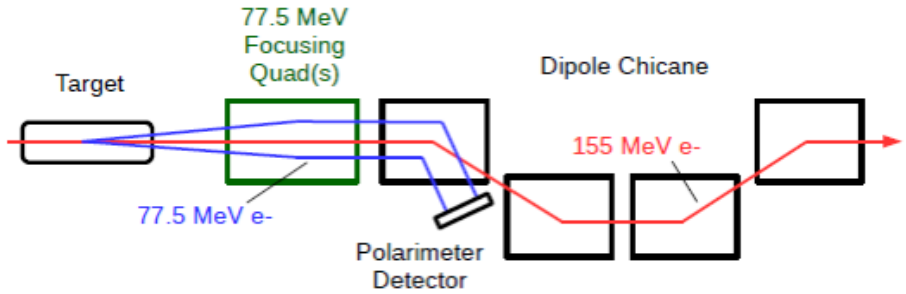


Figure from: D. Becker et al., Eur. Phys. J. A (2018) 54 : 208

Schematic of Hydro-Möller-Target, More: V. Tyukin et al. PSTP2019 (2020) 005 doi 10.22323/1.379.0005

Hydro-Möller: Challenges and status

- Powerful dilution refrigerator needed (50mW at 0.3K ????)
  → expensive (cooling power!)
- Cold electron spin polarized
  Hydrogen dissociator to be incorporated
  → new technology, to be tested at HIM
- Plasma effects – electron trapping?
  → further investigations needed

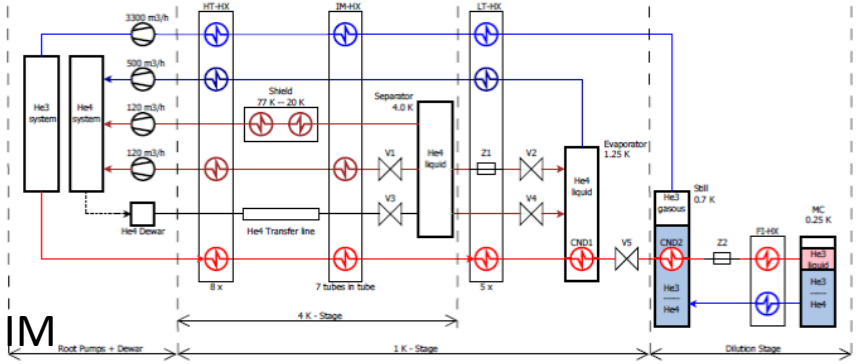


Figure 4: Refrigerator flow chart. HX=Heat exchanger. HT/IM/LT = high, medium and low temperature level of precooling circuit.

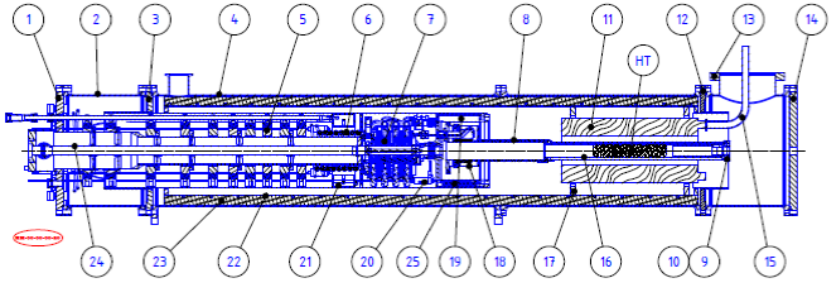
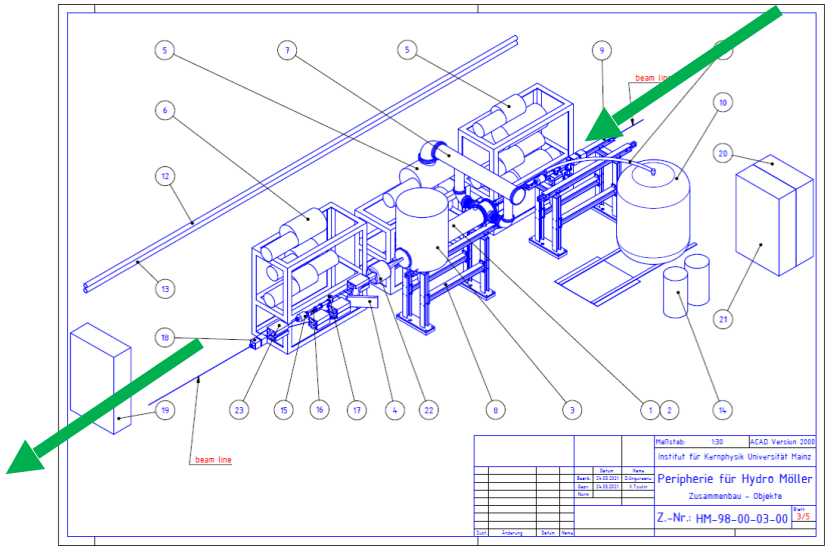


Figure 5: Schematic of the Hydro-Møller atomic trap. 1 - port flange , 2 - cross, 3 - connector flange cryostat, 4 - housing, 5 - high temperature HX, 6 - intermediate temperature HX , 7 - low temperature HX, 8 - final HX, 9 - one-sided film burner, 10 - double-sided film burner, 11 - super conducting 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

To P2



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

Political issue: Refrigerator parts…

KPH/Swagelock: German products

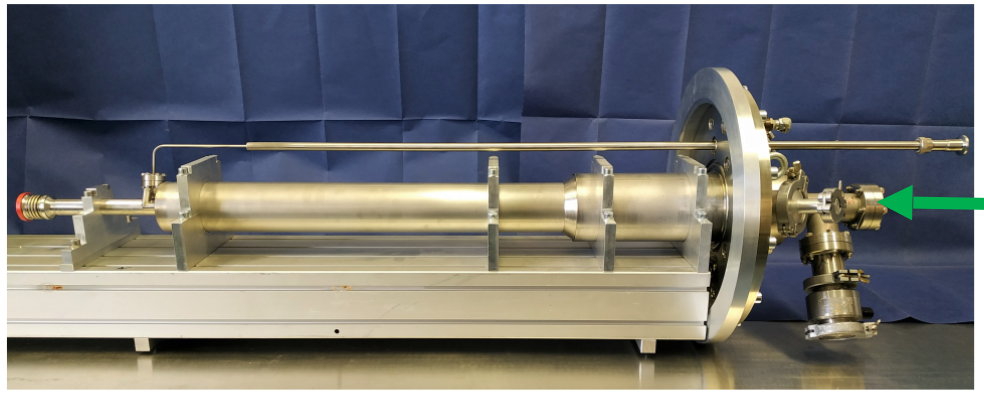


Figure 11: Base flange with pumping line surrounding the beam pipe. Developed by KPH-Mainz in coperation with several industrial suppliers.

Beam insert and
“Pumping line”

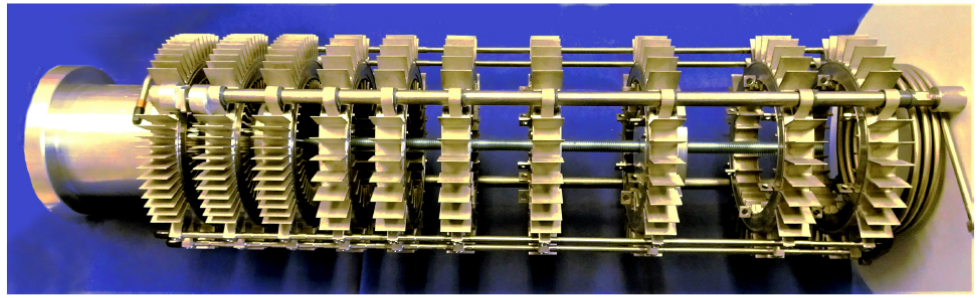
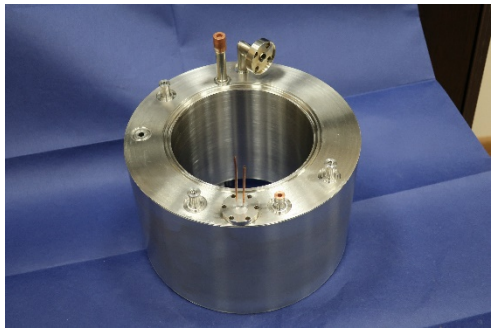


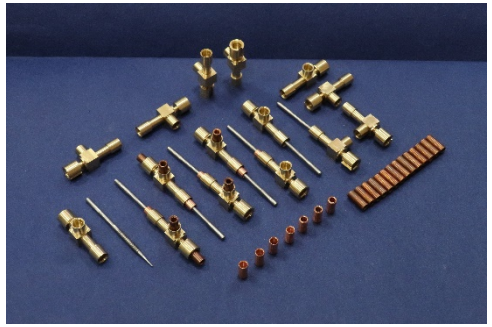
Figure 12: High temperature heat exchanger. Developed by KPH-Mainz in coperation with several industrial suppliers.

All welded
heat exchangers
For precooling stage

JINR - Russian products
(examples)



He-4 evaporator



Needle valves

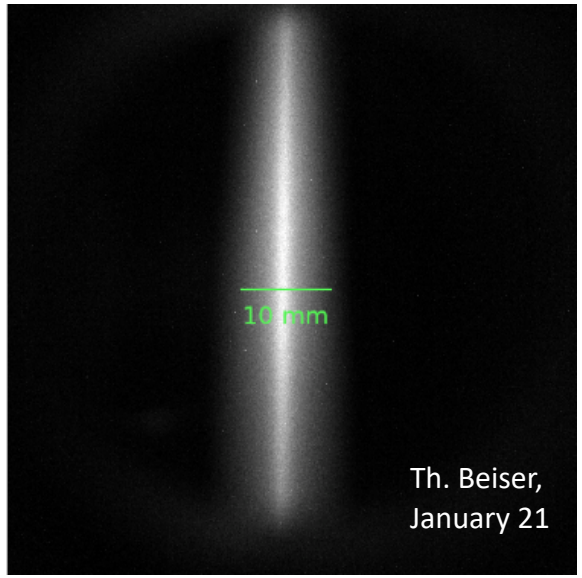
Unavailability of russian institution can be compensated by Mainz machine shops and industry from Rhein Main area.
(but at the expense of long delays due to learning curve and limited capacities.)

Hydro-Möller – unknown unknowns?

Effect of beam potential – example: trapping of ions in UHV

→ Thouroughly investigate plasma induced contaminations , magnetic bottle effects by field variations,….

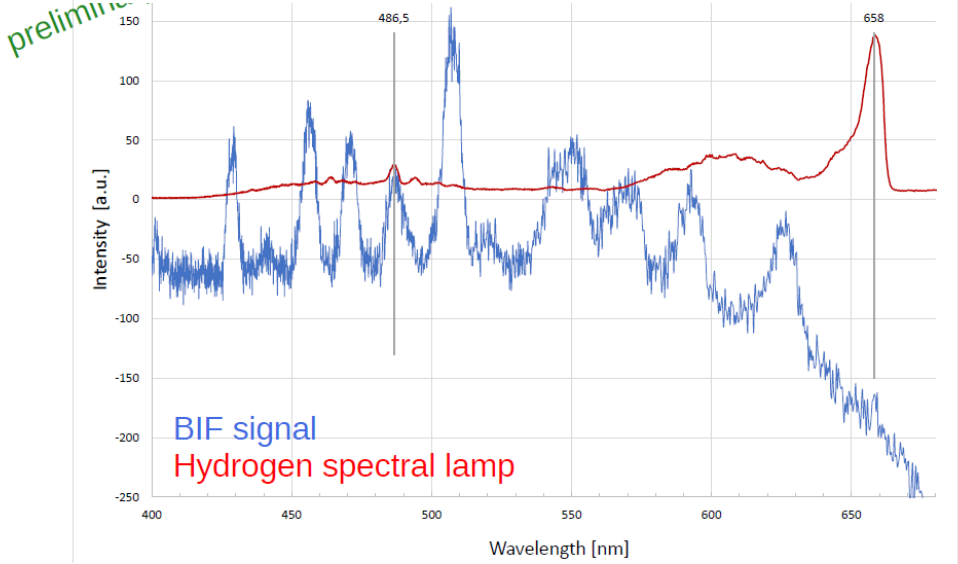
Sideview of 0.5A magnetized electron beam in vacuum of < 10^{-9} mbar



Spectrum of emitted radiation

H_2^+ recombination?

Space charge neutralization ??



Th. Beiser,
Talk at DPG
Spring meeting
March 22

Consequences

- Hydro Möller cannot be realized soon, but a conventional Möller could be done with 8T solenoid to be used later for the real thing.
- HIM offers good possibilitiy to test components in the future, in particular cold hydrogen dissociator.
- the present problems will be resolved by „local“ (or other) means but year long delays unavoidable.
- Goal: Optimized online performance and $\Delta P/P < 0.3\%$ for Carbon measurements at P2.

Thank you!