CRC1044
The Low-Energy Frontier of the Standard Model

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MAINZER MIKROTRON

Polarized-beams and -projects at MAMI/MESA

POSIPOL workshop Zeuthen, 04.09. 2012

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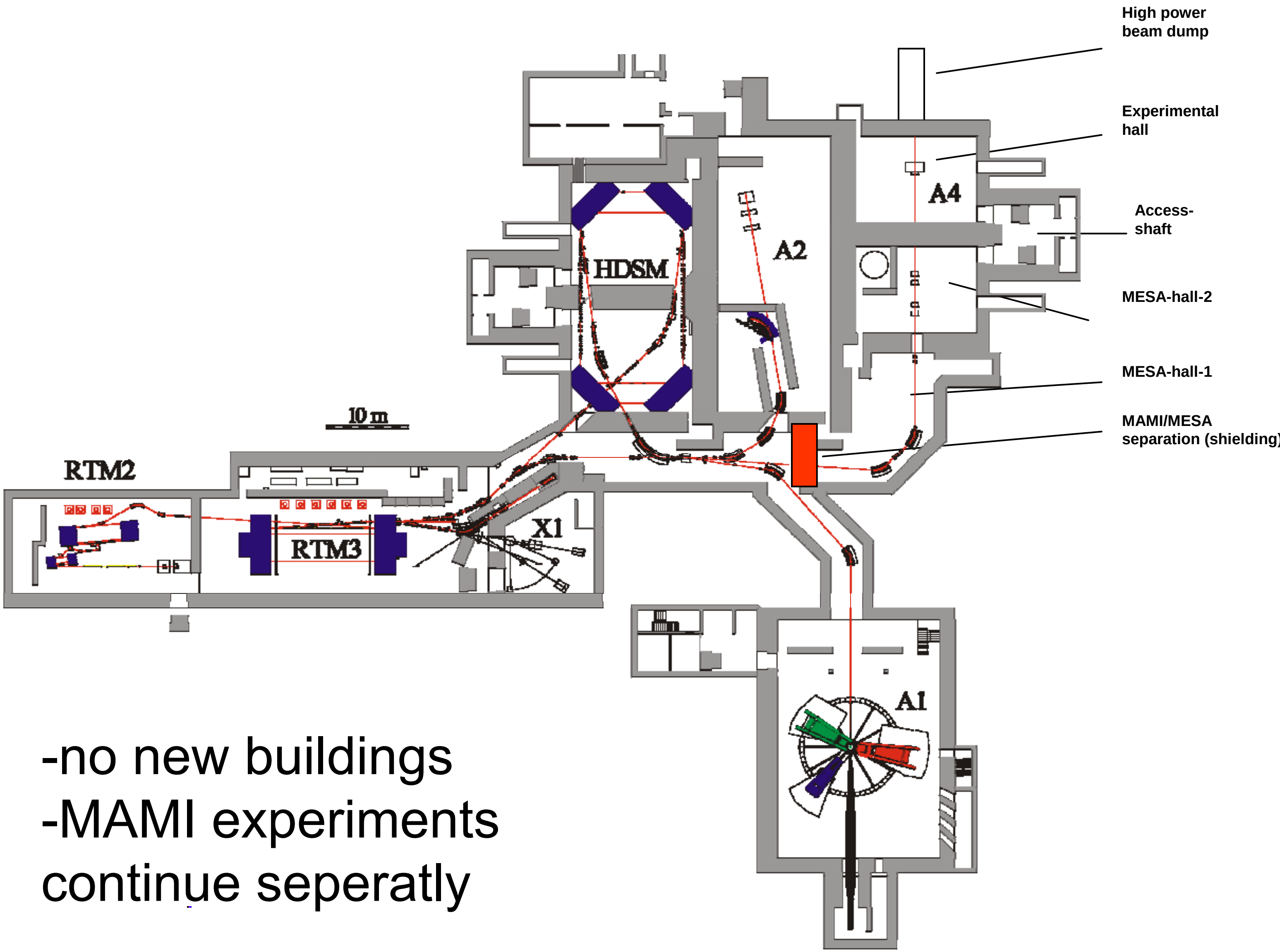
PRISMA

Outline

- The MAMI/MESA complex at Mainz
- Positrons at Mainz?: A pragmatic aproach
- Precision polarimetry

MESA at IKP Mainz



-no new buildings
-MAMI experiments continue seperatly

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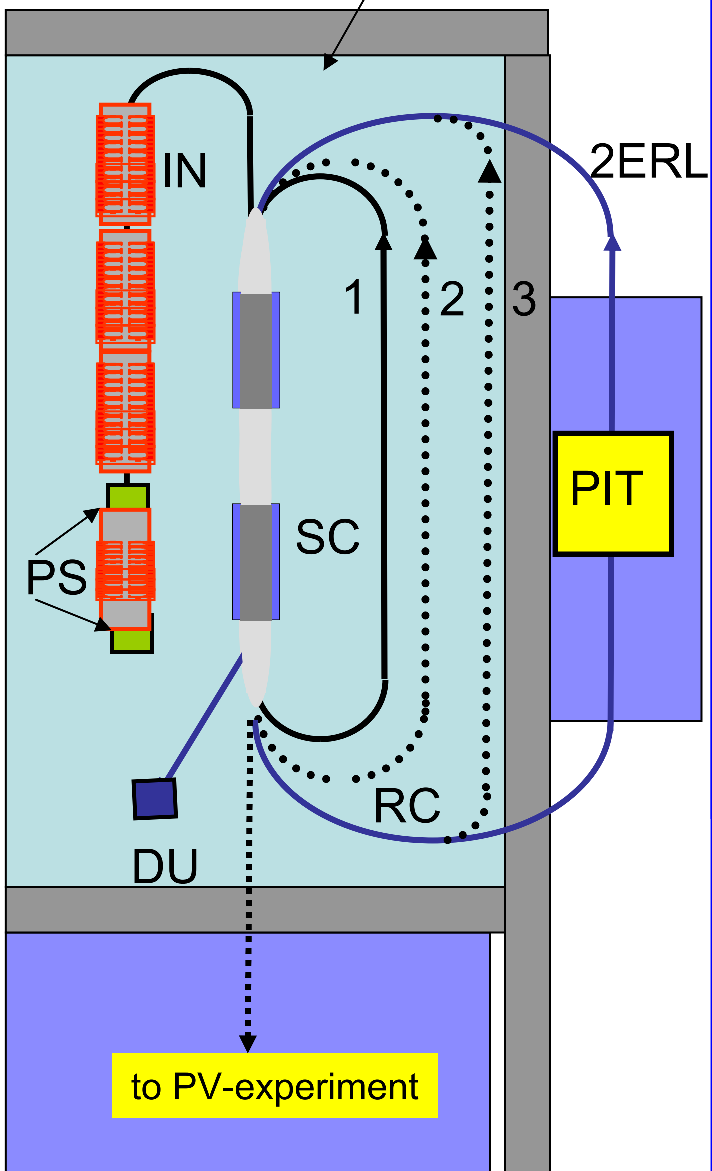
MESA-Scheme

MESA-LAYOUT



KEY:

PS: Photosources: 100keV polarized (EB, ERL (low charge)), 500keV unpolarized (ERL, high charge)

IN: 5 MeV – NC injector

SC: 4 Superconducting cavities Energy gain 50 MeV per pass.

1-3 Beam recirculations for EB Orbit 1 common to ERL and EB, Orbit 2 could be separate for ERL and EB

PIT: Pseudo Internal target (ER-experiment)

PV: Parity violation experiment (EB-mode)

DU: 5 MeV beam dump in ERL-mode

Existing walls: 2-3m thick shielding

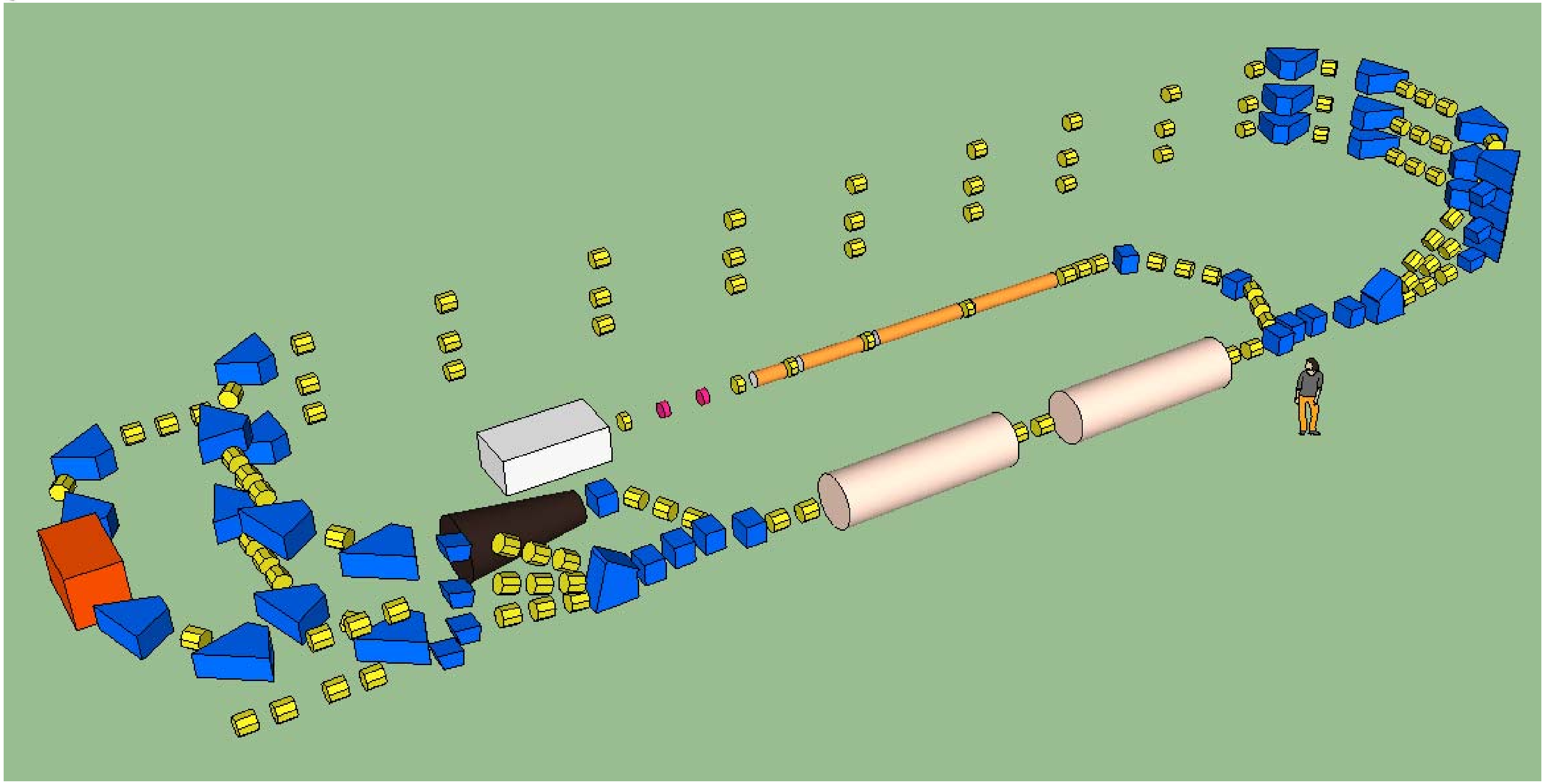
EXPERIMENTAL BEAM PARAMETERS:

1.3 GHz c.w.

EB-mode: 150 μA, 200 MeV polarized beam (liquid Hydrogen target $L \sim 10^{39}$)

ERL-mode: 10mA, 100 MeV unpolarized beam (Pseudo-Internal Hydrogen Gas target, $L \sim 10^{35}$)

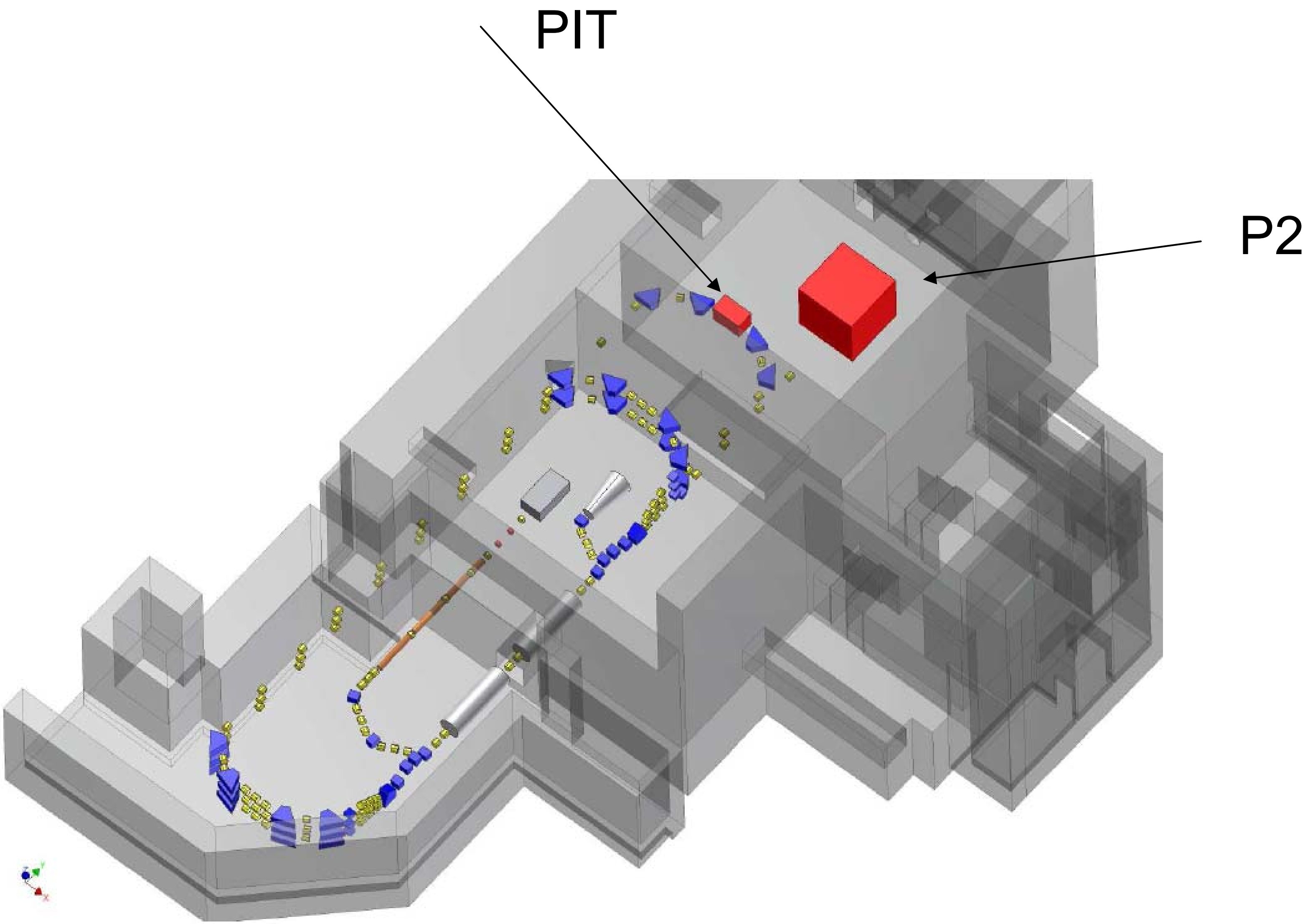
Accelerator Layout



Lattice by Ralf Eichhorn: Orbit footprint ~24*8 m)

PRISMA

Accelerator Layout

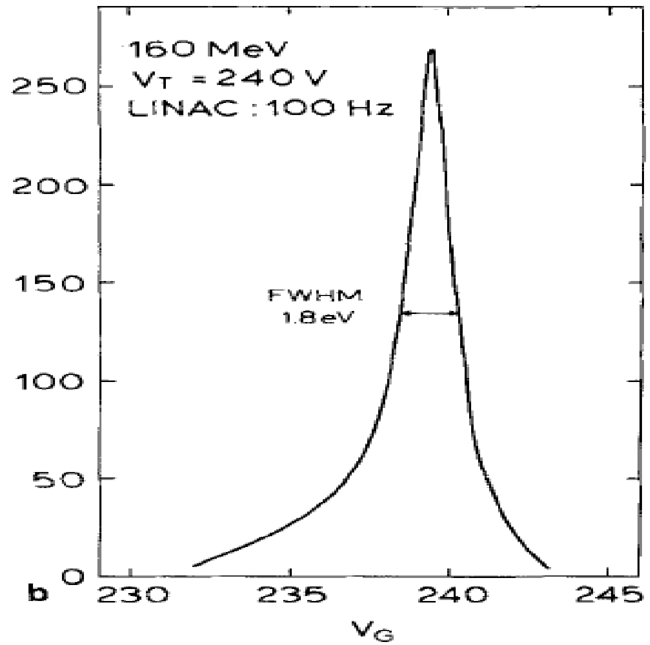


V. Bechthold/R. Heine

Positron-sources in Mainz?

- Being high power accelerators, MAMI/MESA could both create cold (polarized) positrons either by "ISOL" of (γ,n-) produced Isotopes (15-O)

or by moderation of pairs….



Old Mainz experiment:
G. Werth et al. :
Appl. Phys. A 33
59 (1984)

→MESA at 10kW beam power could produce
~10^9 positrons/s (pol :~10^7-8)
in a beam of <1cm diameter at 120eV
(to be injected and accelerated…)

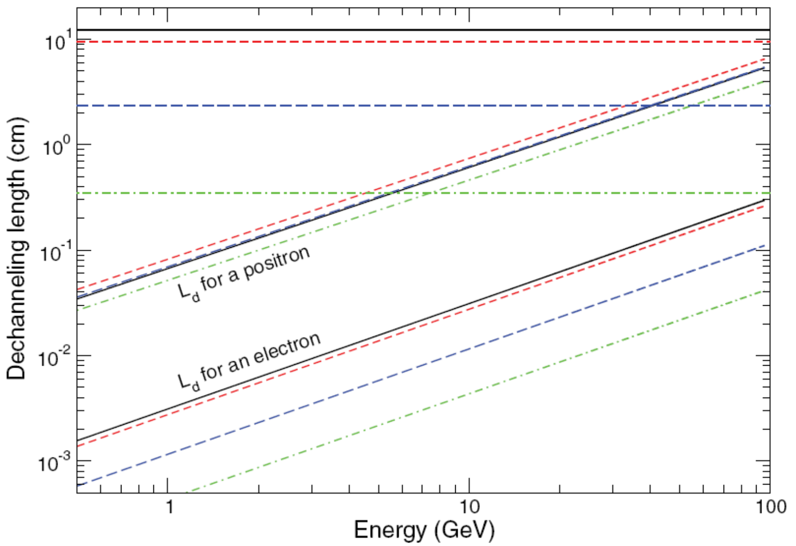
Given demanding conditions & investment:
promising application for c.w. external e+ beams required!

tried several, no success so far…. only one remains in discussion:

e+ undulator radiation in bent crystals

Basic research/proof of principle experiment – requires external c.w. positron beam

Positron and electron dechanneling lengths



M. Tabrizi, A. V. Korol, A.V. Solov'yov, W. Greiner
Phys. Rev. Letters 98, 164801 (2007)

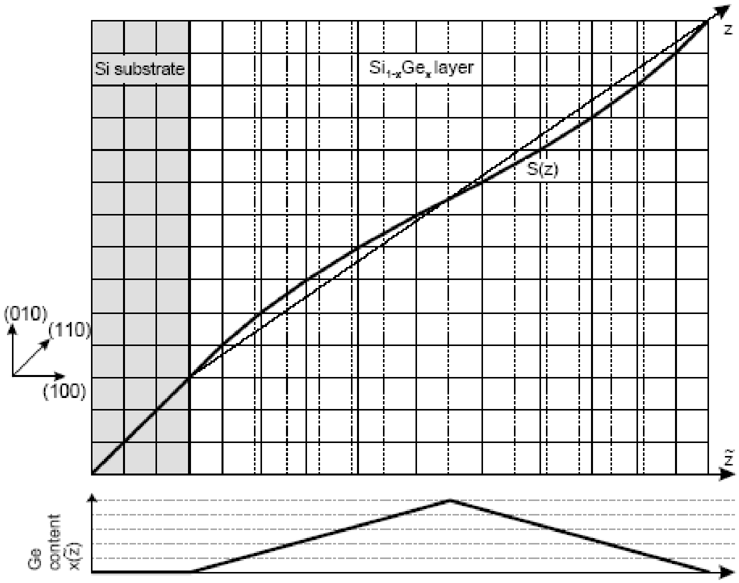
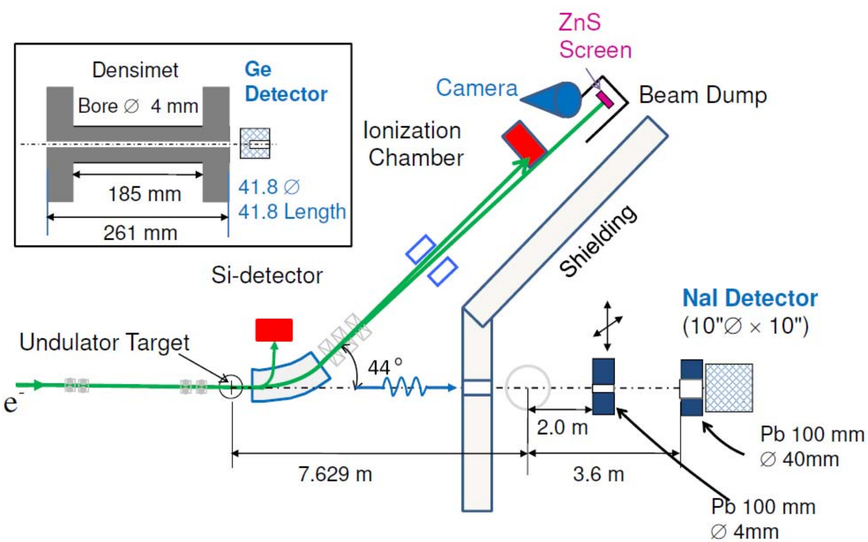


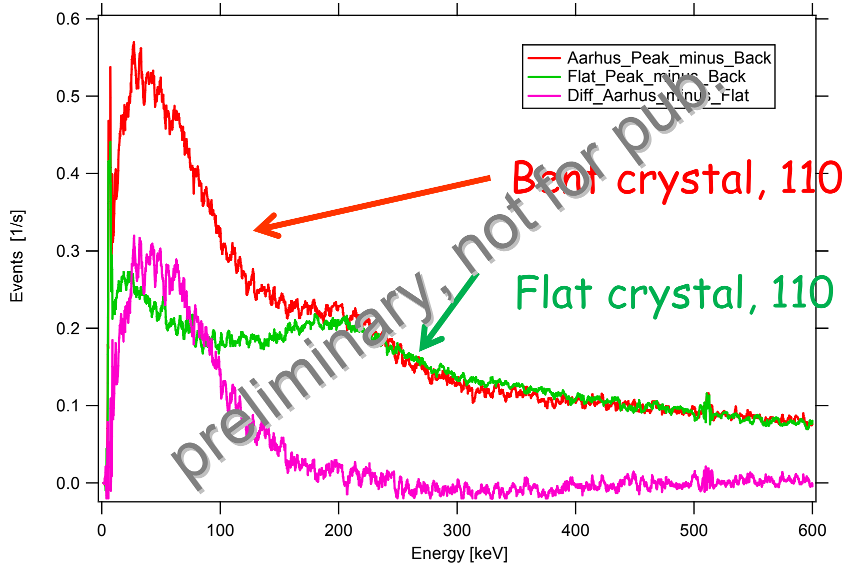
Figure taken from W. Krause, A.V. Korol, A.V. Solov'yov, W. Greiner: Nucl. Instr. Meth. In Phys. Res. **A 483** (2002) 455

Channeling in deformed crystal exposes particle to undulator of extremely short period (μm)→ full coherent radiation at Energy O(MeV)??
(sounds like science fiction, but…)

Chr. Bent undulator Experiment with electrons at MAMI



Spectra - Out of Plane subtracted
270 MeV, Ge 2"-Detector, 28 μm crystal, 110 Plane



Investigations call for low intensity, c.w. beam of positrons, with same beam quality as MAMI electron beam

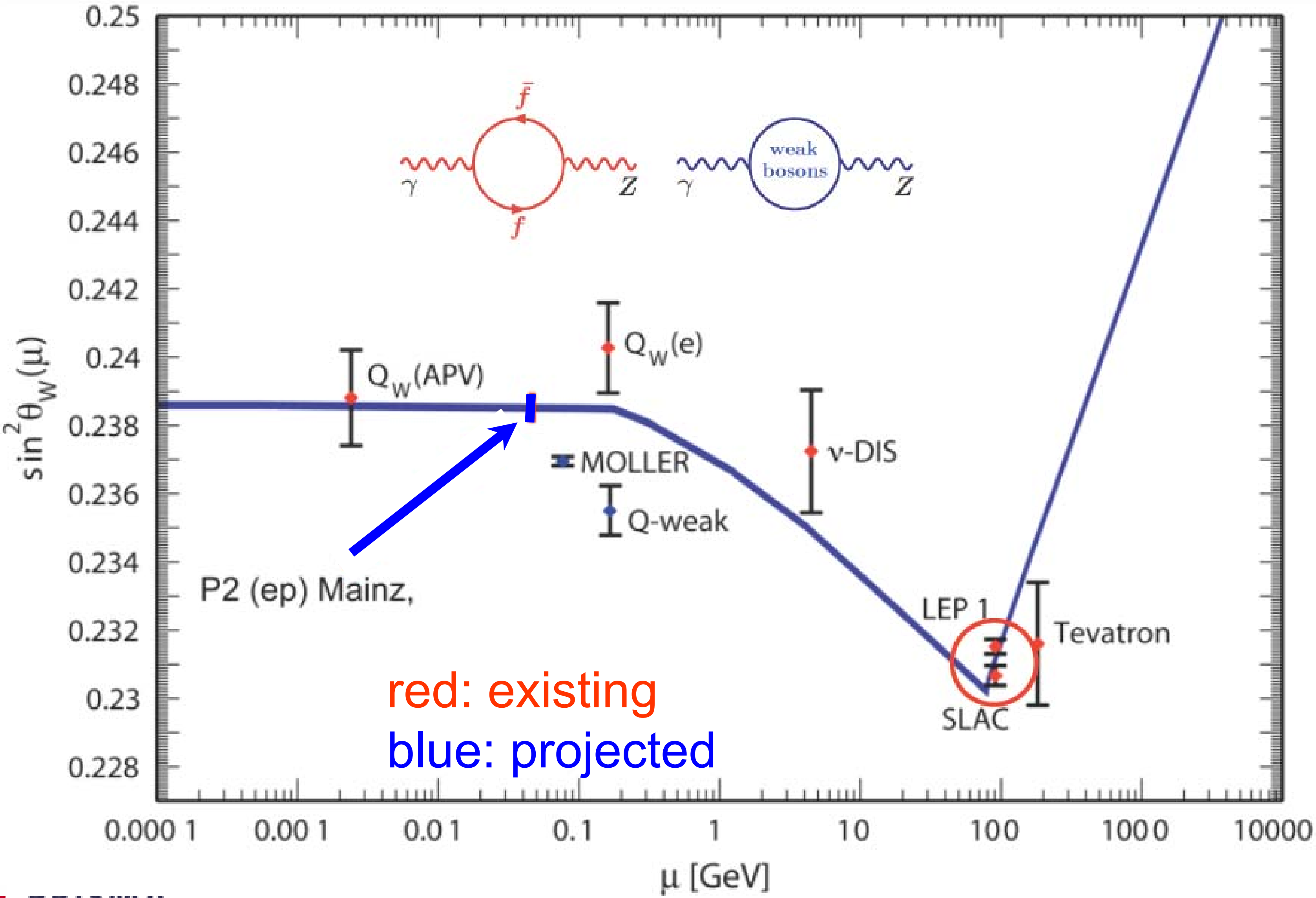
→ Could be the starting point of e+ program at MAMI

Precision Polarimetry

↕

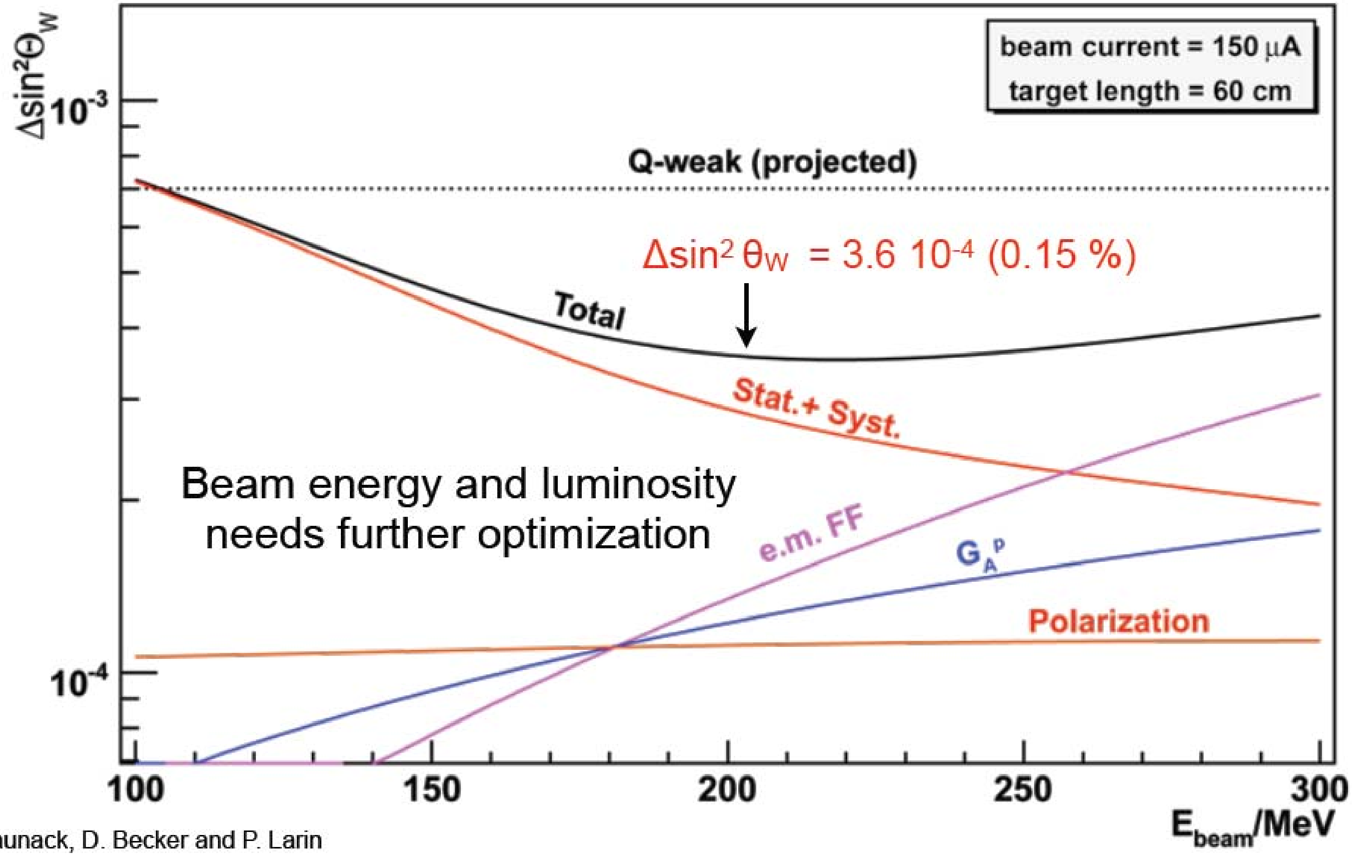
MESA-EB-experiments: Precision measurment of Weinberg angle

Why a precision measurement by PVES at low Q?



MESA-EB-experiments: Precision measurment of Weinberg angle

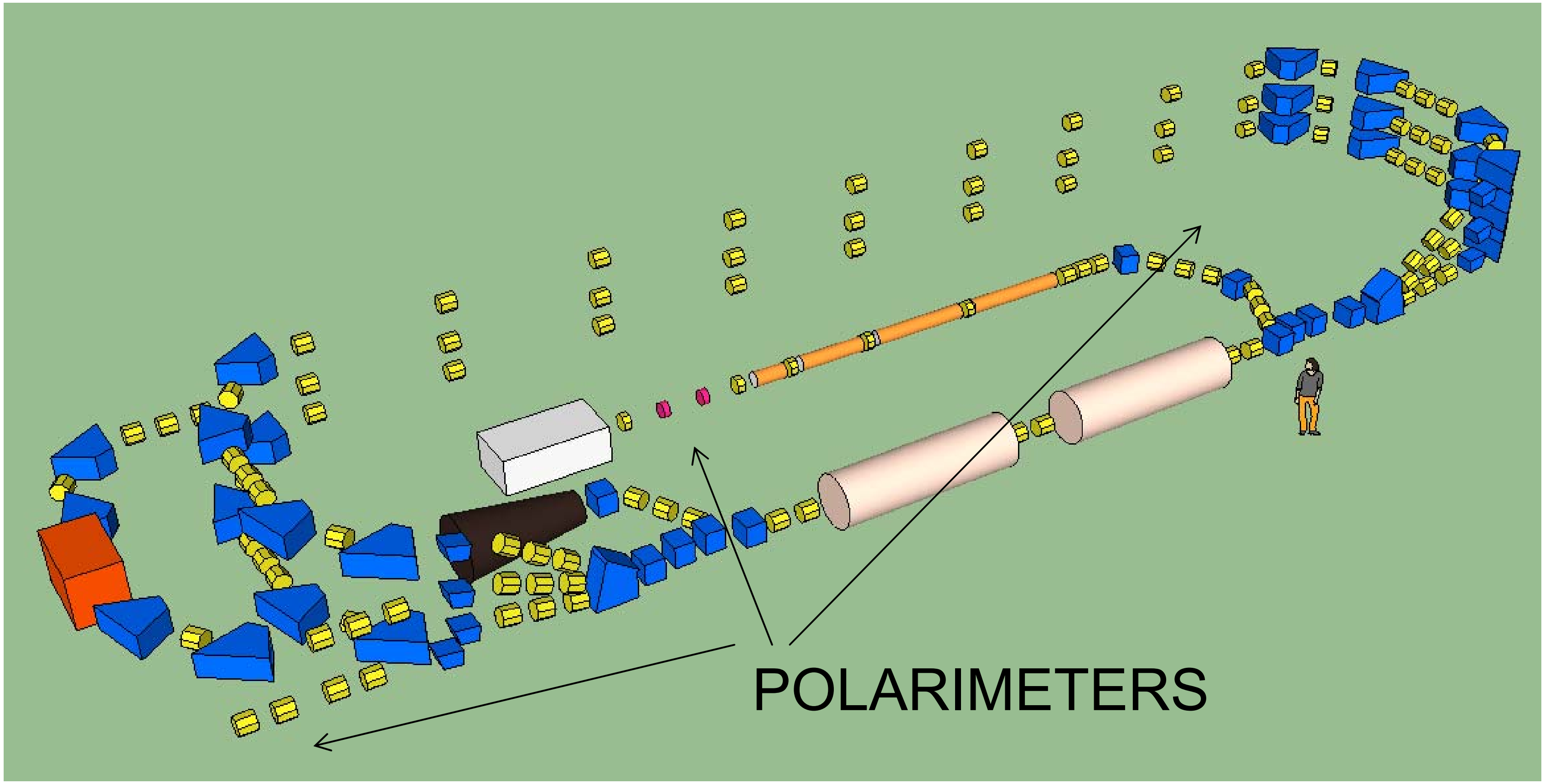
expected error for 10000 h data taking (est. 13-15000 h runtime)



S. Baunack, D. Becker and P. Larin

← 0.5% accuracy!

For MESA, a polarimeter "chain" is suggested to get a reliable ("unimpeachable") P measurement



•two independent polarimeters with ΔP/P <0.5% each. (LCP does not work!)

• source energy (0.1-0.2 MeV): double scattering polarimeter (invasive)

• experiment energy (200 MeV): Hydro Möller (non invasive)

• different beam intensities connected by " Mott & Compton absorber (lower absolute accuracy, but high reproducibility& dynamic range)

Some remarks on Polarization measurements

$$A_{\exp} = P_{beam} S_{eff}$$

$$S_{eff} = S_{0,y} F(p_1 \ldots p_n) \text{ (single spin polarimeter)}$$

$$S_{eff} = S_{0,x,y,z} P_{target} F(p_1 \ldots p_m) \text{(polarized target polarimter)}$$

$p_1 \ldots p_n$: Parameters such as

acceptance, background, analyzing power dilution, ….

Different concepts (‚paradigms') of measurements:

- „Hydro Möller": ‚double-polarization' : eliminate error of P_T (and provide „clean" environment for determination of F(p))

→accurate, but indirect determination of Seff

- Mott ‚double scattering': **<u>measure</u>** Seff directly (calibration)

→ use calibrated Seff for analyzing beam polarization

Double scattering

In **double** elastic scattering S_{eff} can be **measured**!

After scattering of unpolarized beam :

$$P_{sc} = S_{eff}$$

(Equality of polarizing and Analyzing Power :)

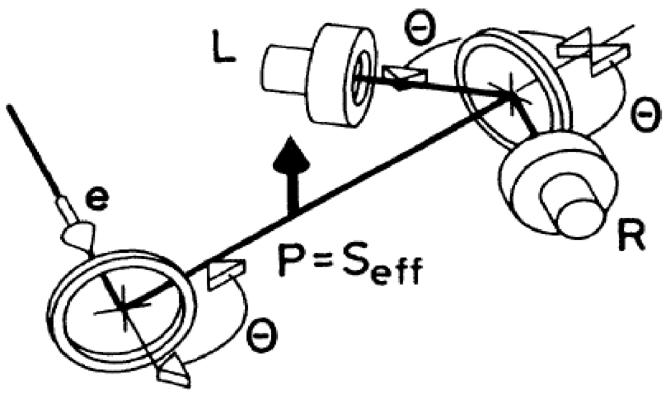
After second "identical" scattering process

$$A_{exp} = S^2_{eff}$$

with great effort to elliminate

apparative asymmetries and to provide 'identical' scattering)

the claimed accuracy in S_{eff} is < 0.3%!



A. Gellrich and J.Kessler
PRA 43 204 (1991)

Some remarks

- DSP works at ~100keV; (polarized source energy!)
- Targets **not** extremely thin (~100nm)
- Elimination of apparatus asymmetry depends critically on geometrical arrangement of normalization counters
- Apparatus calibrates S_{eff}, but does not allow to measure S_0
- Inelastic contributions do not jeopardize the accurac
- June 2012: Original Kessler apparatus set in operation at test source in Mainz
- potential issues
  → how to use with polarized beam?
  → What if the two targets are NOT identical?

Hopster&Abraham (1989):
In this case the first target may be treated as an auxiliary target and the availibility of (switchable) Polarization may be exploited for even better accuracy!

Kessler/HopsterAbraham/Kessler Method

1.) measurement : Pol beam on second target

$$A_1 = S_{eff} P_0$$

2.) with 'auxiliary target': $S_T ; + P_0$

$$A_2 = P_T S_{eff} = \frac{S_T + \alpha P_0}{1 + S_T P_0} S_{eff}$$

α = Depolarization factor for first Target

3.with 'auxiliary target': $S_T ; - P_0$

$$A_3 = P_T S_{eff} = \frac{S_T - \alpha P_0}{1 - S_T P_0} S_{eff}$$

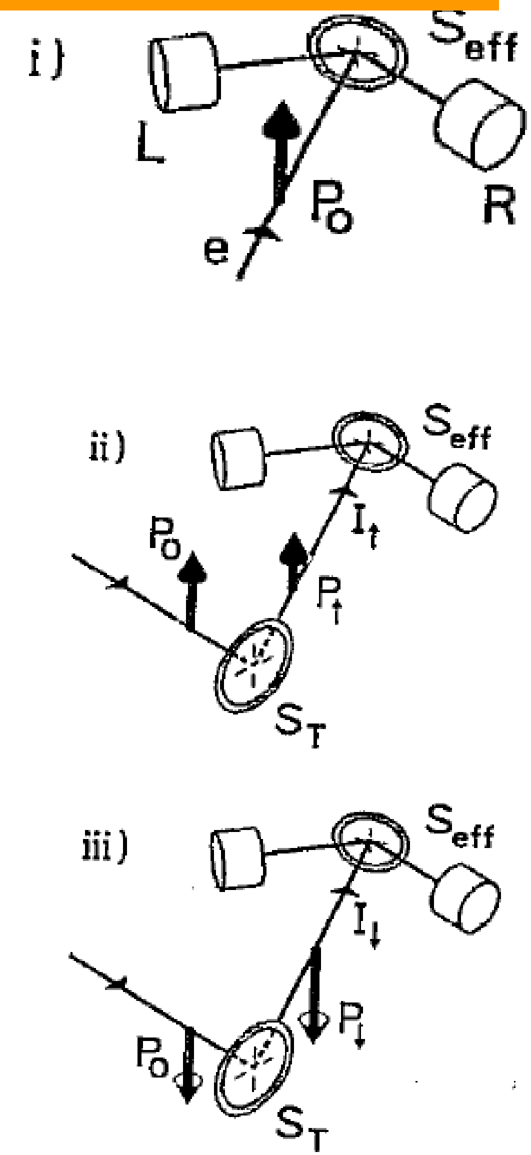
4. unpolarized beam on aux. target

$$A_4 = S_T S_{eff}$$

5. Scattering asymmetry from auxiliary target

$$A_5 = P_0 S_T$$

5 equations with 4 unknowns→
consistency check for apparative asymmetries!
→ Results achieved by Kessler were consistent <0.3%

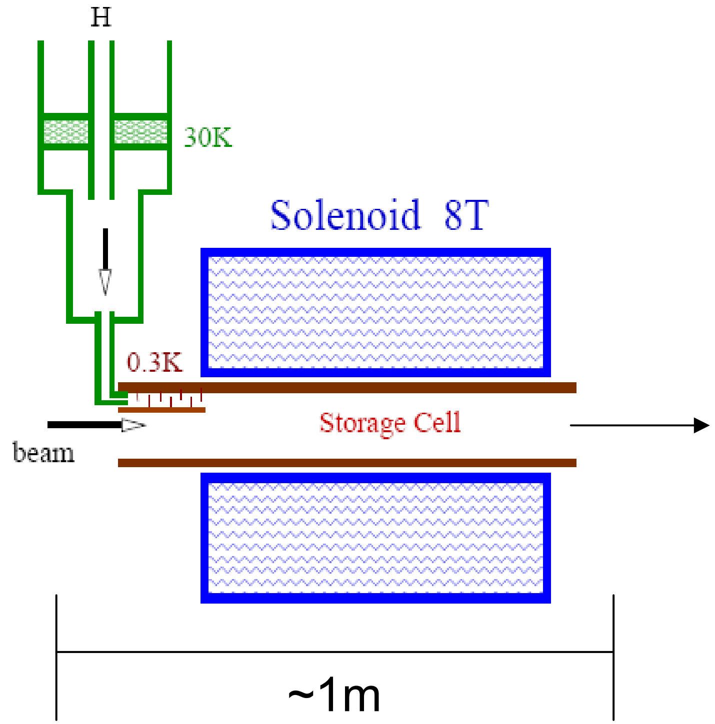


S. Mayer et al
Rev. Sci. Instrum. 64 952 (1993)

PRISMA

Hydro-Möller

Chudakov&Luppov, Proceedings IEEE Trans. Nucl. Sc. **51**, 1533 (2004):
Propose to use a device explored by A. Krisch et al. In the 1990‘s.....



+ measurement is non-invasive and
+ provides sufficient statistical accuracy at the beam current level of the PV experiment

Solenoid traps pure H↑ which has a long lifetime due to He-coating of storage cell. All other species are removed quickly from the trap.
→1-ε Polarization can be reasonably well estimated, but measurement difficult.

Target density ~10^{17} cm^{-2} !

Hydro-Möller in Mainz

Atomic trap given to U-Mainz by group of Don Crabb/ UVA

Design from University of Michigan

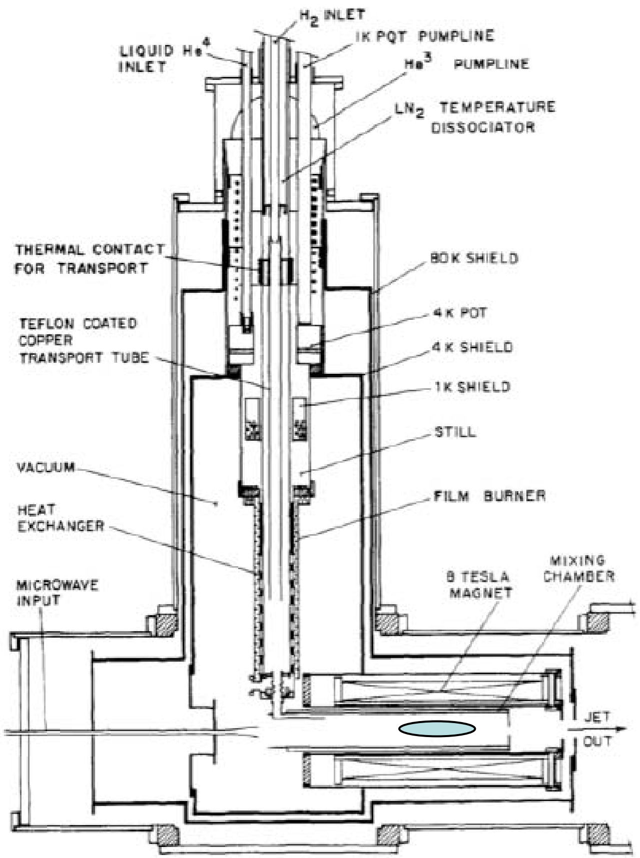


Fig. 4. Schematic diagram of the apparatus showing the vertical dilution refrigerator with the horizontal mixing chamber, the solenoid magnet, and the microwave and hydrogen feed.

Cold finger:
0.3W@0.4K
3He/4He Dilution cryostat

PRISMA

Hydro-Möller in Mainz

Design from University of Michigan

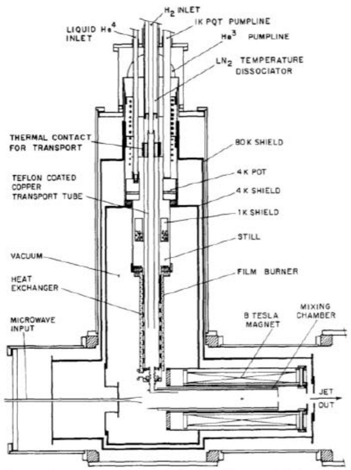


Fig. 4. Schematic diagram of the apparatus showing the vertical dilution refrigerator with the horizontal mixing chamber, the solenoid magnet, and the microwave and hydrogen feed.

- Dilution refrigerator and magnet shipped from UVA to Mainz
- Next steps:
  Setup and tests with beam

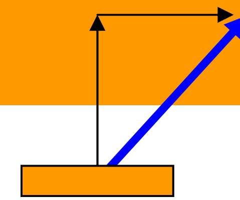
Future objectives:

- Make Cryostat operational (lot of work and investment!)
- Demonstrate trapping
- Demonstrate stability under high intensity e-beam

Some remarks

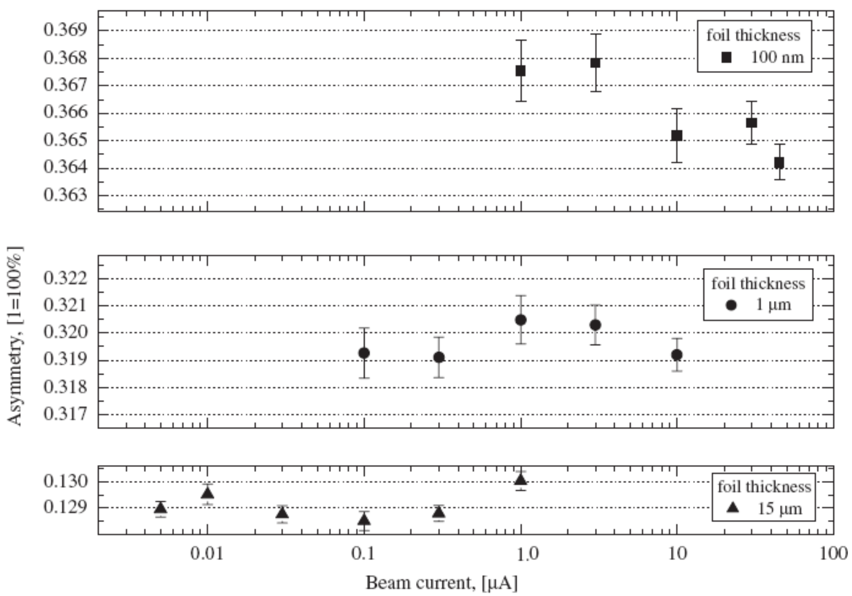
- Probably not feasible to operate DSP at > 100μA current level, requires ‚linking Polarimeter'
- Linking with high precision polarimeters to be installed at 5MeV (Mott/Compton-combination
- Mott/Compton combination invasive but extremely fast (O(seconds) <1% stat. accuracy), also control of spin angle

Linking capabilities



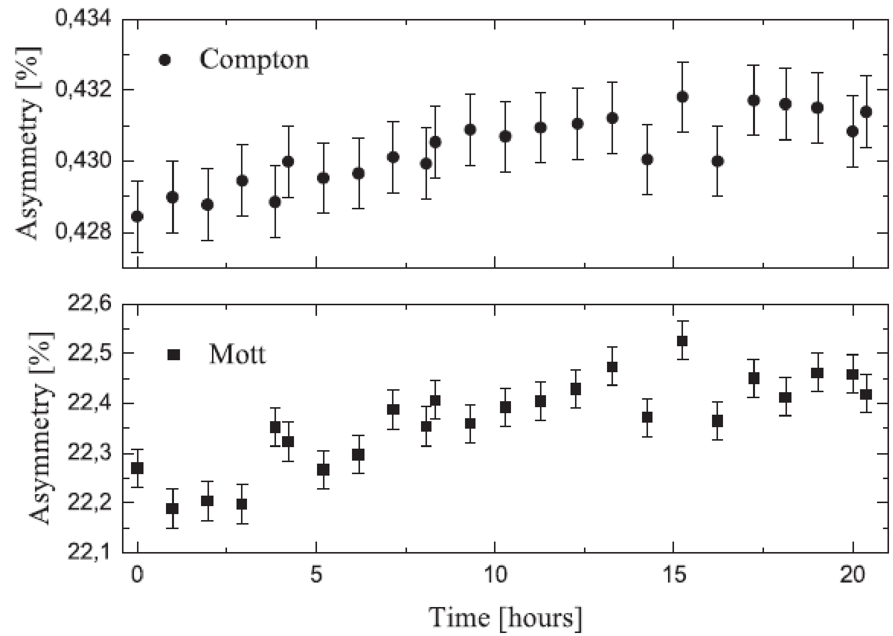
Dynamic Range:

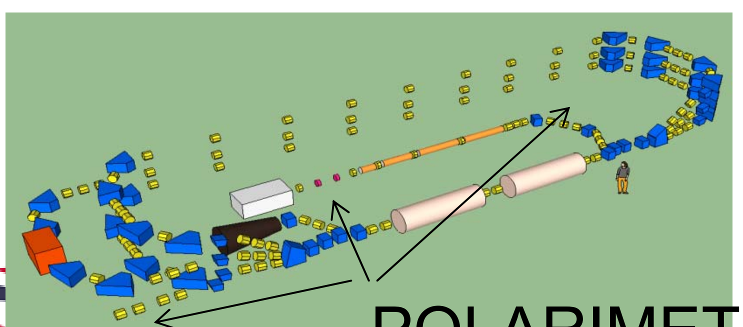
V. Tioukine et al. Rev. Sc. Instrum. **82** 033303 (2011)



Stability:

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





POLARIMETERS

Polarization Drift consistently observed in transverse AND longitudinal observable at the <0.5% level
(Measurement at 3.5 MeV, 35 μA)
Compton is an analogue, Mott a counting measurement

Conclusion/Perspectives

Polarimeter chain

- low and a high energy polarimeter cross-check: negl. depolarization due to low energy gain of MESA
- Monitoring, stability and cross calibration can be supported by extremely precise Mott/Compton combination.
- Hydro Möller + DSP may obtain $\Delta P/P < 0.5$ % each,

Positrons

- Investigation of elementary bremsstrahlung processes will go on
- The non invasive Hydro-M device could provide a useful device for a high intensity pol e+ source?