Different ERL Applications

CAS
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Outline of the lecture

1.) Introduction to „different applications“
2.) ERL with fixed target experiments
3.) ERL based Linac-Ring Colliders
4.) Spin-Polarisation for ERLs

1 Introduction

When does it make sense to built a new type of accelerator? … taking into account risks of new concepts

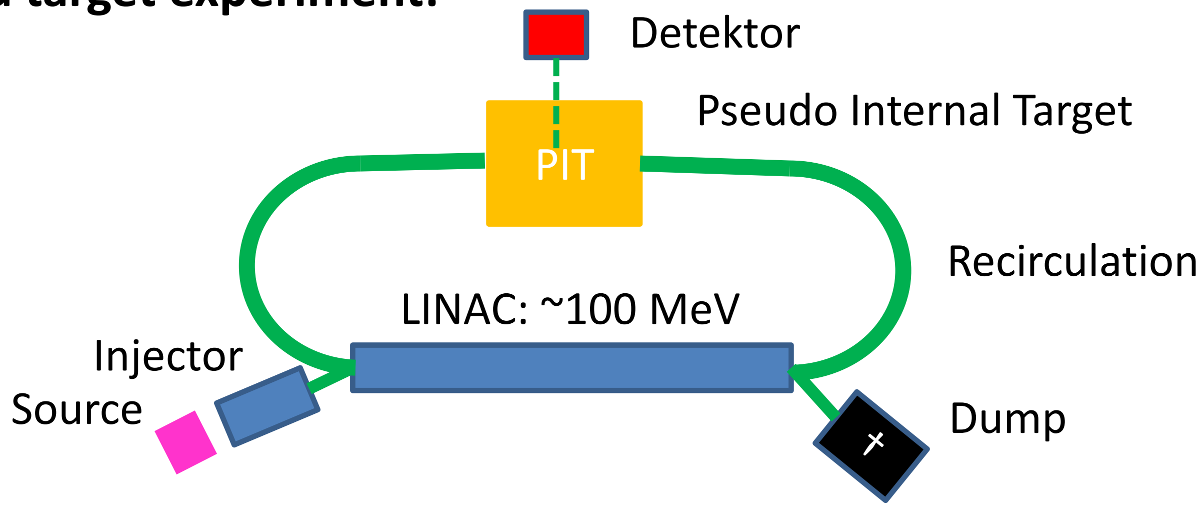
Introduction

When does it make sense to built a new type of accelerator?

One promise (argument):
If experiments become
possible that have not been possible before

Different applications: Scattering experiments for particle physics

Type 1: Fixed target experiment:



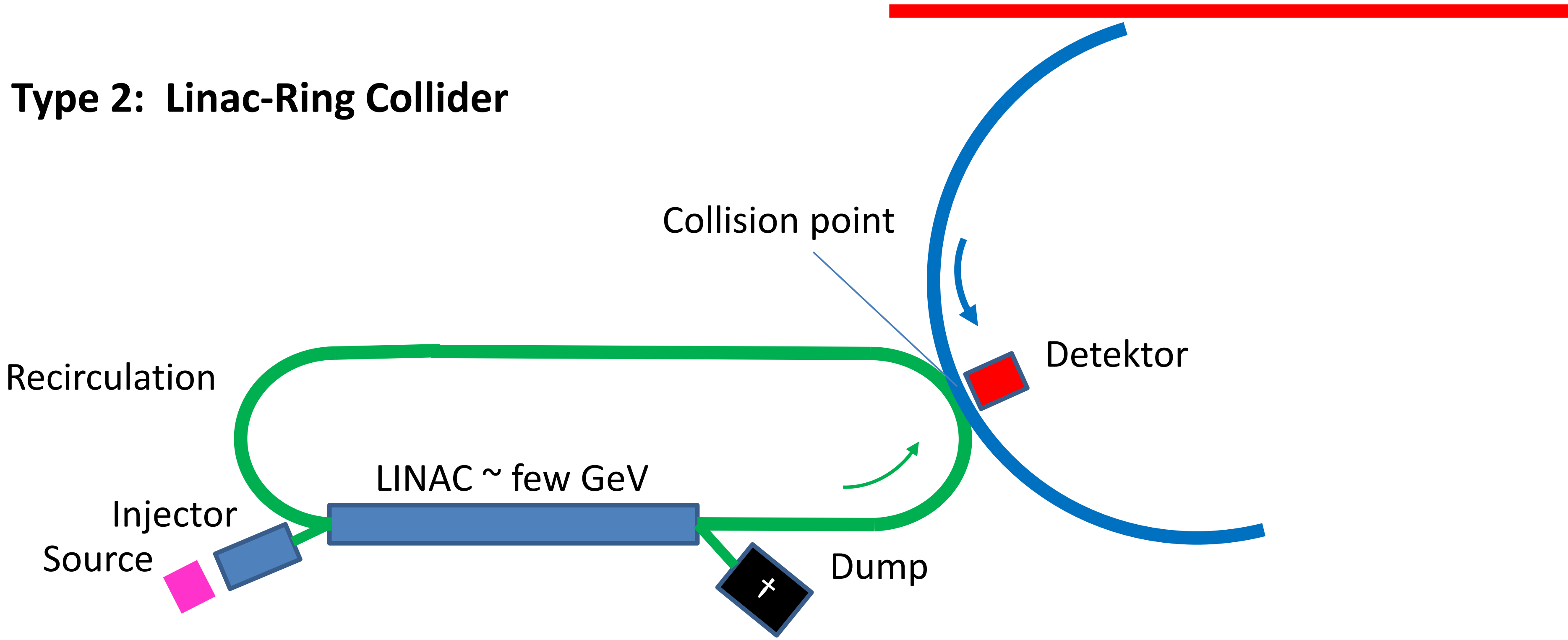
Promises:

- Stationary beam conditions even at very low energies due to Pseudo internal target (PIT)
- Reasonable reaction rates even without **any** target enclosure
- Superior for reactions searching for rare events („Dark particles“)
- All types of reactions investigating **low** momentum transfer

Planned Experiments: Dark light (JLAB) / MAGIX (MESA)

Different applications: Scattering experiments for particle physics

Type 2: Linac-Ring Collider

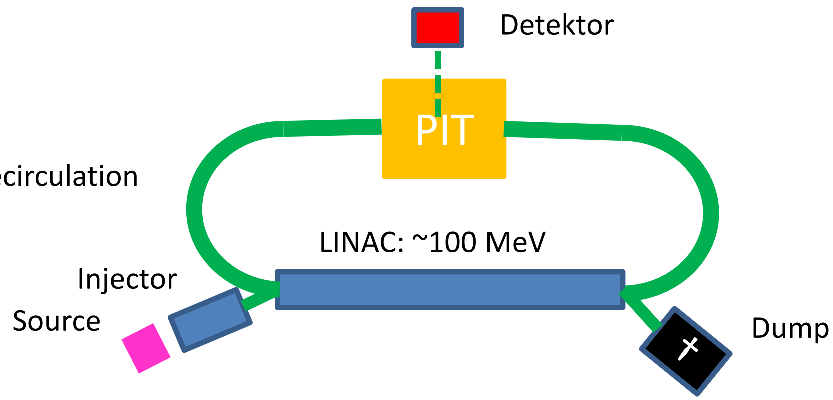


<u>Promises</u>: - strong beam beam tuneshift for lepton beam possible
- spin polarization of electron beam easier to manage than in ring/ring designs
- multiturn designs feasible (typically 3-6 turns)

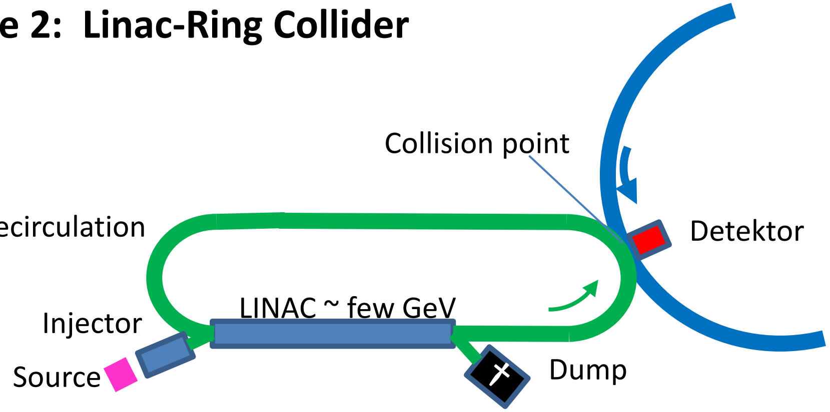
Planned set-ups: LHeC (CERN) eRHIC (Brookhaven National Loboratory ;BNL)

Conclusion of introduction

Type 1: Fixed target experiment:



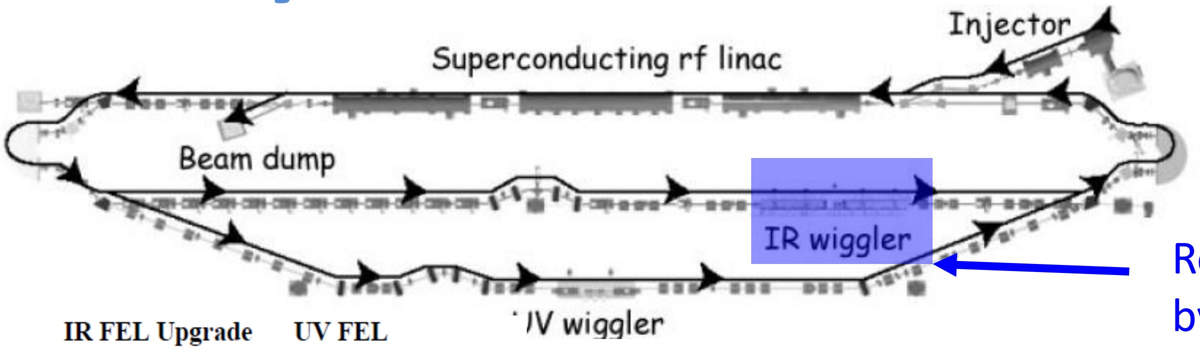
Type 2: Linac-Ring Collider



- The requirements are somewhat relaxed wrt to radiation generation: in general longer bunches
  → less coherent radiation problems
  → less problems with instabilities
- Additional tasks/challenges Type 1
  - Target/Detektor design
  - Halo Control/Collimation
- Additional tasks/challenges Type 2
  - multiturn desirable (→beam dynamics)
  - spin polarisaton/spin orientation required

2 ERL with fixed target experiment

2.0 Heinemayers observation



Replace wiggler by „Pseudo“ internal target

Parameter	IR FEL Upgrade	UV FEL
Beam energy at wiggler	80–210 MeV	200 MeV
Average beam current	10 mA	5 mA
Bunch charge	135 pC	135 pC
Bunch repetition rate	74.85 MHz	74.85 MHz
Normalized emittance (rms)	13 mm-mrad	5–10 mm-mrad
Bunch length at wiggler (rms)	200 fs	200 fs
Peak current	270 A	270 A
FEL extraction efficiency	1%	0.25%
$\delta p/p$ before wiggler (rms)	0.5%	0.125%
$\delta p/p$ after wiggler (full)	10%	5%
CW FEL power	>10 kW	>1 kW

L Merminga et al. Ann. Rev. Part. Sci 53 387 (2003)

JLAB ERL Laser output: 10kW
Beam Power in Wiggler: ~1MW
R.F power needed: ~100kW

The energy taken away by scattered particles in one passage of the target can be much smaller than the one extracted in the FEL
→ Experiments with „Pseudo“ internal targets could be attractive.
(Proposed for dark matter search by Heinemayer et al. (2007): arXiv:0705.4056v2)

2.1 PIT Primer

Event rate is beam current times target surface density times cross section

$$R = \underbrace{\frac{I_{beam}}{e}\rho_{\text{target}} d_{\text{target}}}_{\text{fixed target luminosity}} \frac{d\sigma}{d\Omega}$$

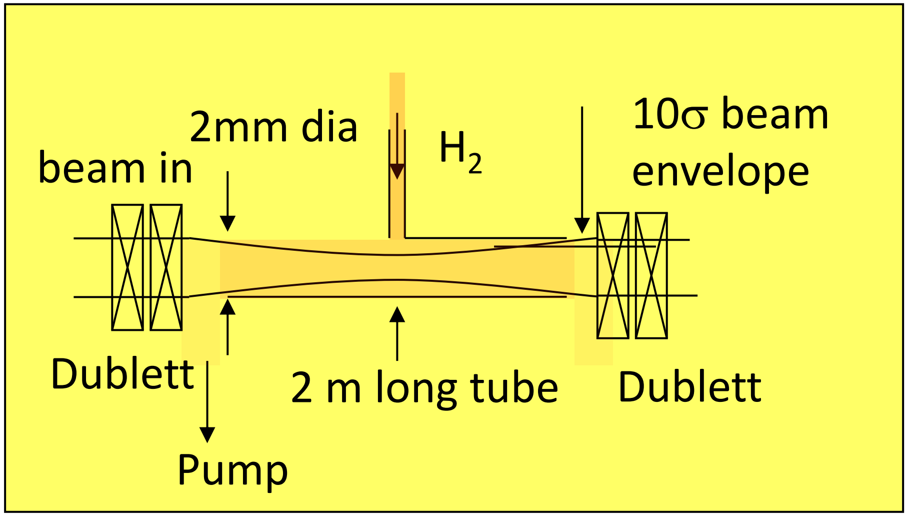
A measurement of the cross section requires suppression of background reactions

- From target enclosure
- Multiple scattering
- Beam halo and collimation after target:

$$R_{Koll} = \int_{Acc(ERL)}^{Acc(Det)} \left(\frac{d\sigma}{d\Omega}\right)_{\text{all reactions}} d\vartheta$$

A windowless gas target eliminates the first aspect. A „thin“ gas target eliminates the second one.
→ In this case the beam current has to be increased correspondingly to keep the rate at the desired level. This motivates the use of ERL‘s for low energies

2.1.1Schematic PIT example



Assume Bunchcharge 7.7pC (10mA at 1300 MHz): $\varepsilon_{\text{norm}} \approx 1\mu m$

Beamdiameter :

$$r^2_{\text{beam}}(z) = \varepsilon_{Geo} * \beta(z)$$

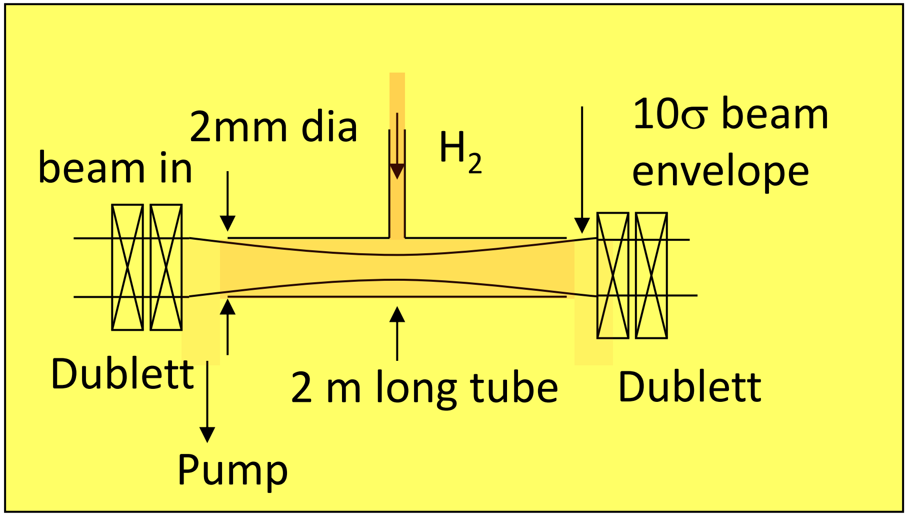
$$\text{with } \varepsilon_{\text{Geo}} = \frac{\varepsilon_{\text{Norm}}}{\sqrt{\gamma^2 - 1}} \quad \Rightarrow \varepsilon_{\text{Geo}}(100\text{MeV}) \sim 5\text{nm}.$$

In the region around center of target $z^* = 0$

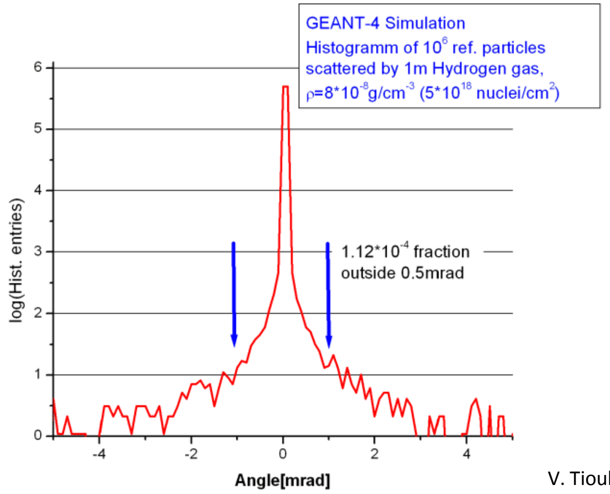
$$\beta(z) = \beta(z^*) + \frac{z^2}{\beta(z^*)} = \beta^*(1 + (z/\beta^*)^2) \text{ wähle}: \beta^* = 1m$$

$\Rightarrow$ Maximum beam diameter (10 sigma) $\leq$ 4mm ($z = \pm 1$m)

2.1.1Schematic PIT example



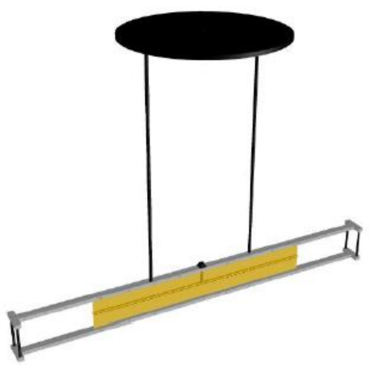
Target-density N=2*10^{18} atoms/cm^{-2}
(3.2 µg/cm^2, 5*10^{-8} X_0)
→ I_0=10^{-2} A: L= 1.2*10^{35}cm^{-2}s^{-1}
→(average) Energyloss (Ionisation): ~ 17eV
→ RMS Scattering angle (multiple scattering): 10µrad
→ Single pass Beam quality reduction negligible

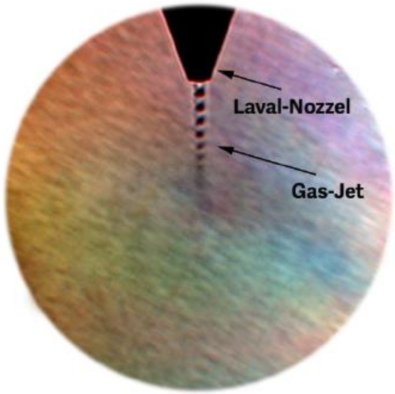


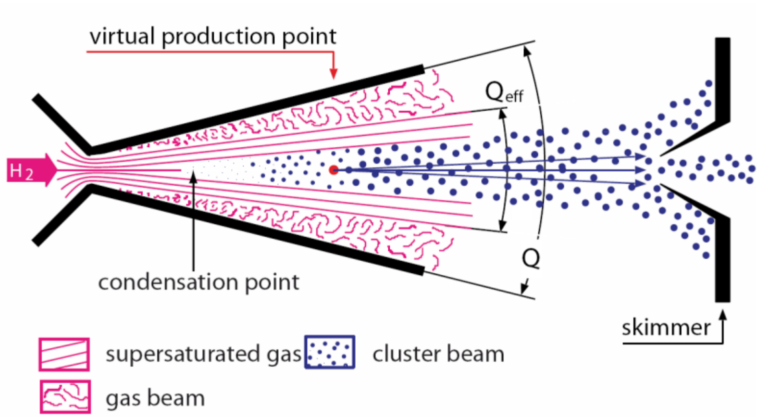
V. Tioukine

2.2 Internal targets: state of the art

Tube Target	Jet Target	Cluster-Jet Target
• Molecular Flow inside of a tube	• Gas Jet flows through the Chamber perpendicular to the beam	• Formation of clusters in the Jet



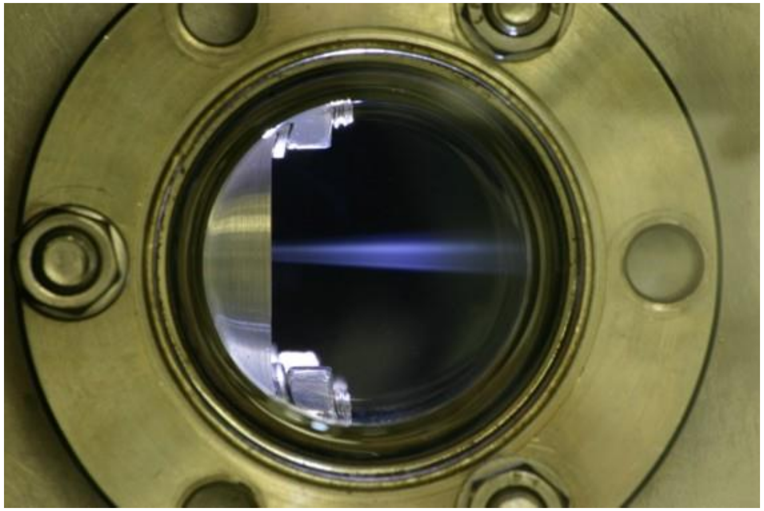




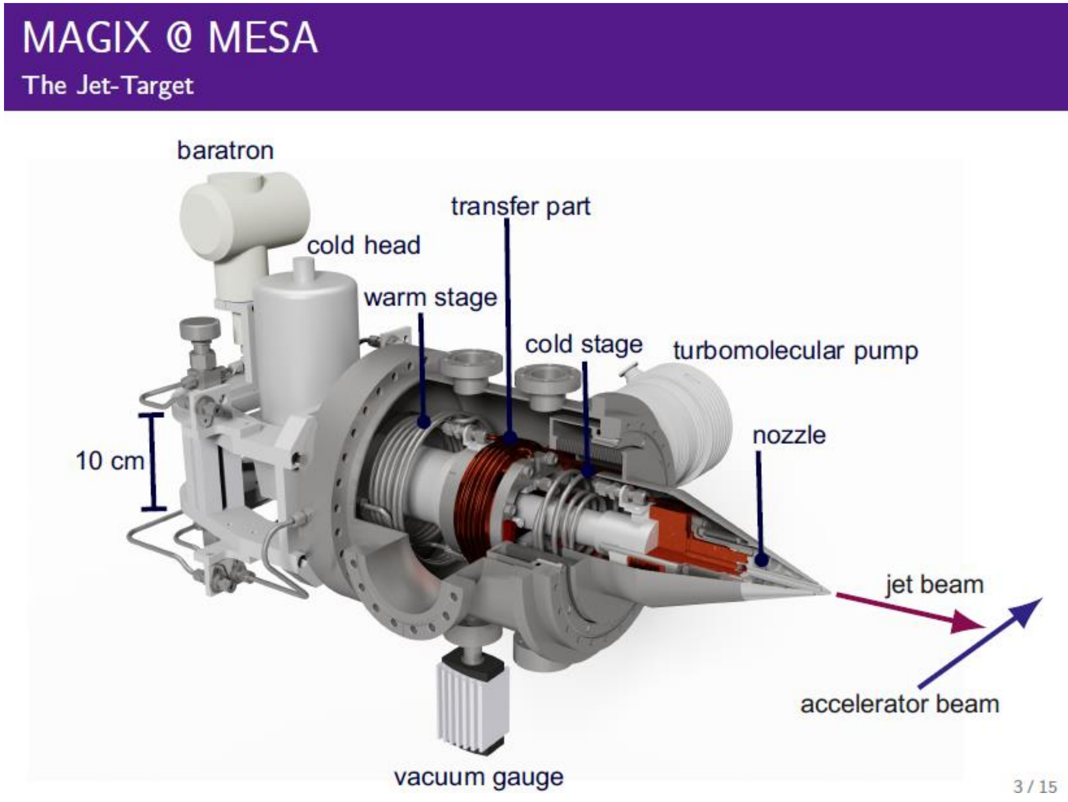
This is needed for POLARIZED Target (a la HERMES at HERA)!

S. Aulenbacher
https://indico.mitp.uni-mainz.de/event/66/session/5/contribution/48/material/slides/0.pdf

2.2 Internal targets: state of the art



Under development at Uni Münster
For MAGIX at MESA
Design Target density O(10^19 cm-2)

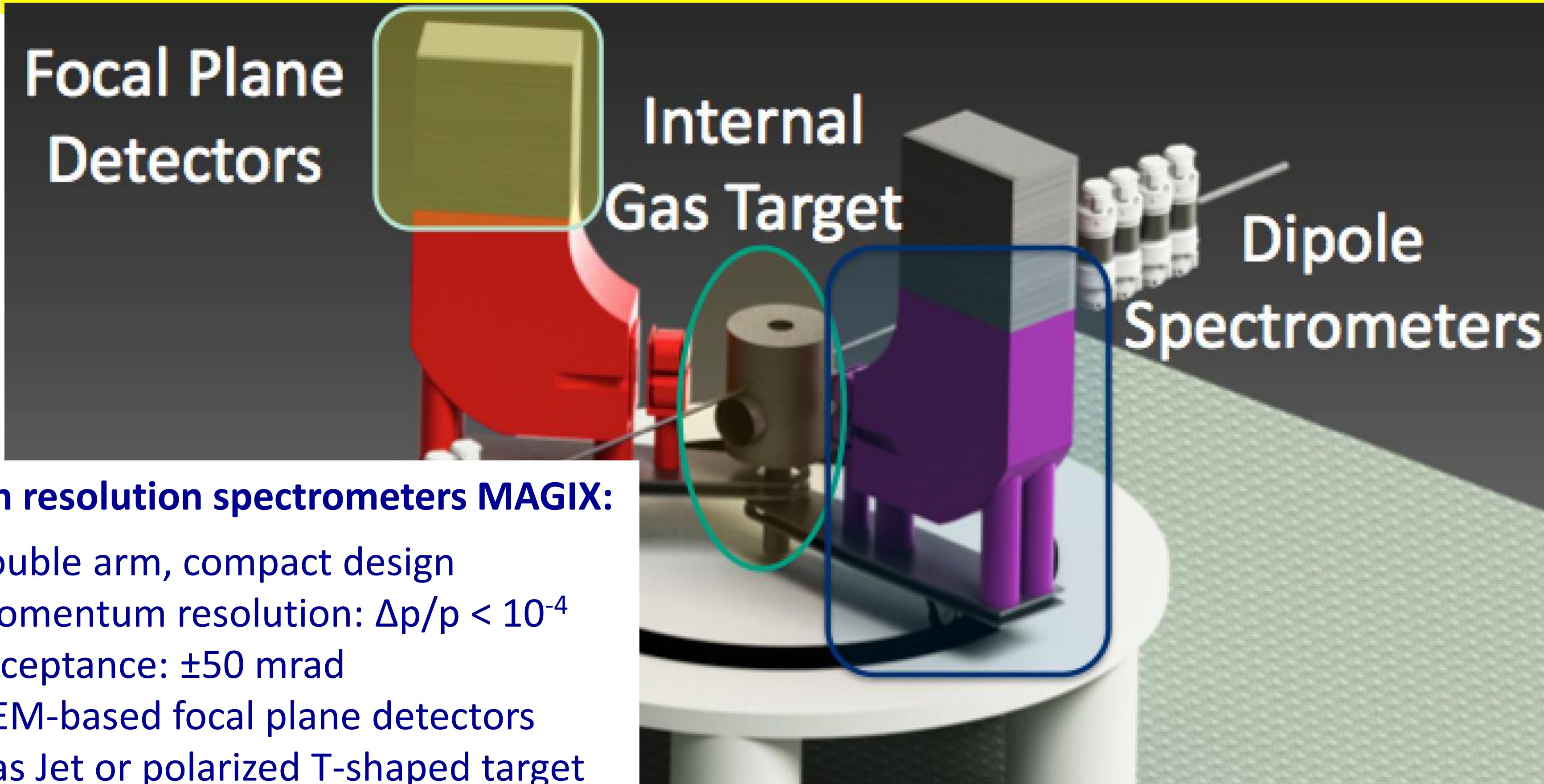


S. Grieser
https://indico.mitp.uni-mainz.de/event/66/session/5/contribution/27/material/slides/0.pd

2.3 Example: The „MAGIX“ experiment

Operation of a high-intensity (polarized) ERL beam
in conjunction with light internal target

→ **a novel technique in nuclear and particle physics**
→ **measurement of low momenta tracks with high accuracy**
→ **competitive luminosities**
→ **Small device if compared to GeV scale spectrometer set ups!**



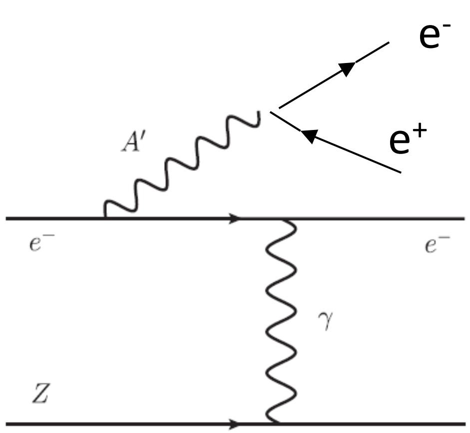
High resolution spectrometers MAGIX:

- double arm, compact design
- momentum resolution: $\Delta p/p < 10^{-4}$
- acceptance: ±50 mrad
- GEM-based focal plane detectors
- Gas Jet or polarized T-shaped target

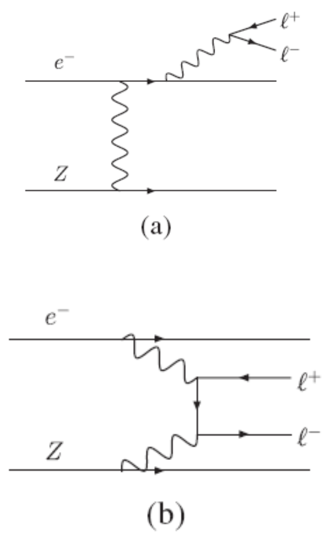
2.4 Physics with an ERL: Dark matter searches

- Presently, there is no clear evidence if dark matter particles exist
- Searches for WIMPS so far not succesful
- Other possibility: New forces and force carriers: „ Dark Photons“ „ Dark Z“ „A‘“
- These are detectable by the so-called kinetic mixing effect

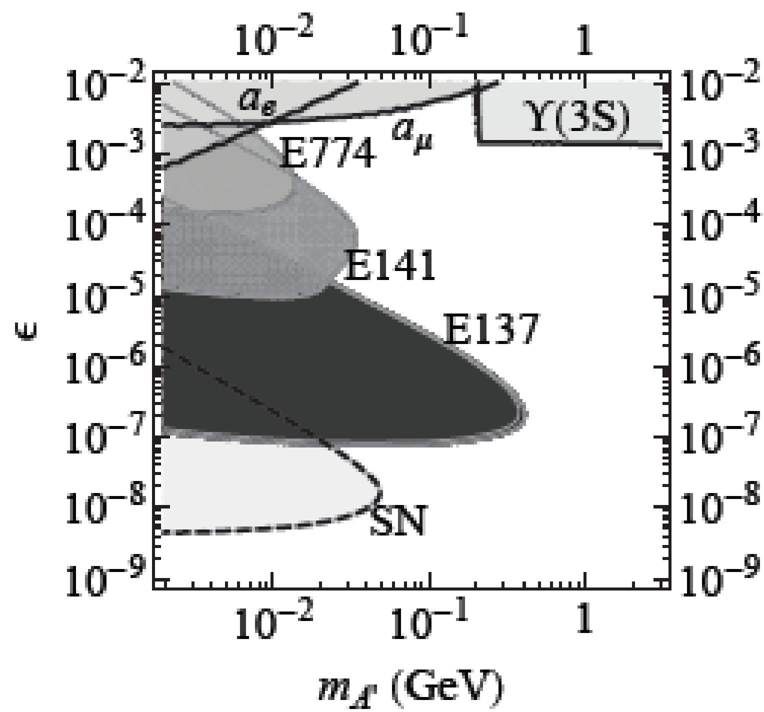
Signal :



QED Untergrund



A’ Status: Excluded areas in 2013



$\sigma(\varepsilon, m_{A'}) \approx 100\,pb(\varepsilon/10^{-4})^2(100MeV/m_{A'})^2$

$c\tau = 0.1mm(10^{-4}/\varepsilon)^2(100MeV/m_{A'})$

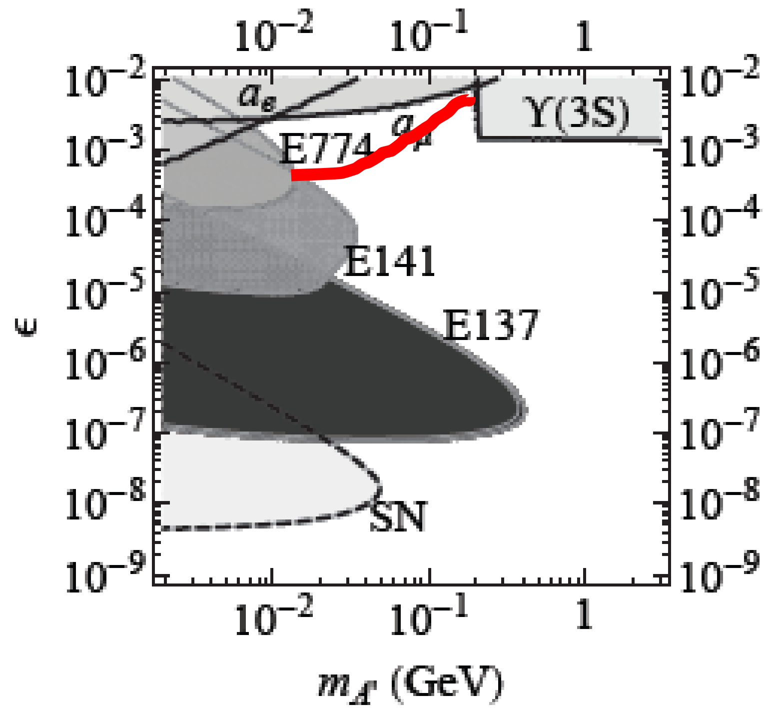
$\sigma_{QED} \approx 10^5\sigma(\varepsilon, m_{A'})$

$c\tau = 0$

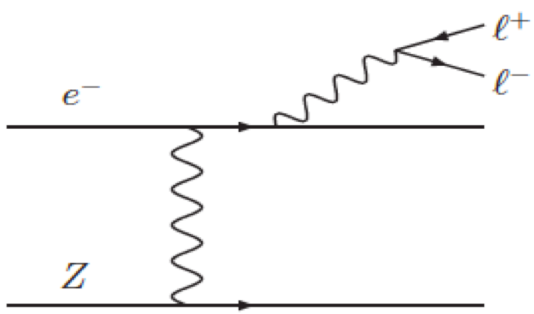
2.4 Dark matter searches –the $(g\text{-}2)_\mu$ temptation

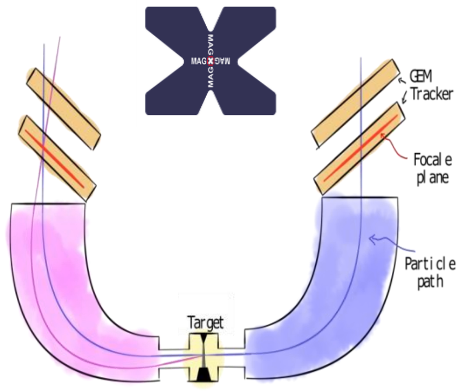
The gyromagnetic anomaly a=(g-2)/2 of the muon has been measured at BNL with extremely high accuracy- and disagrees with the standard model prediction by about 3-4 standard deviations.

In 2012 it was claimed that the existance of a dark photon would explain the result. And that the properties of the dark photon would corrrespond (approximately) to the red line in the figure

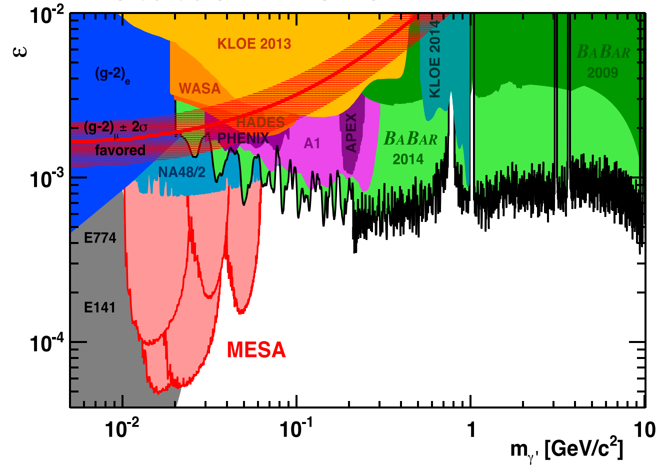


2.4 Dark matter searches with MAGIX

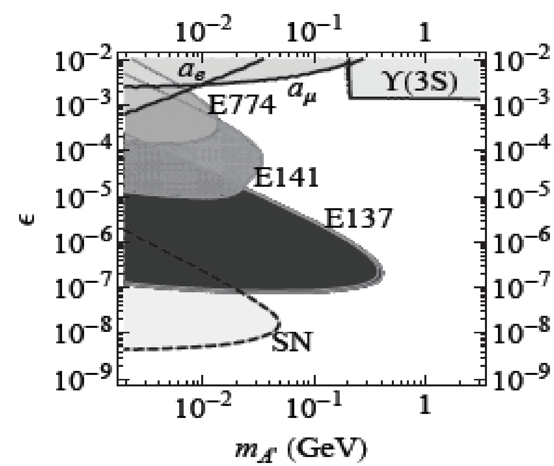




Status in 2016

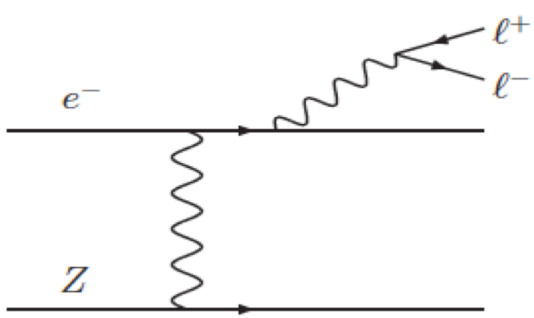


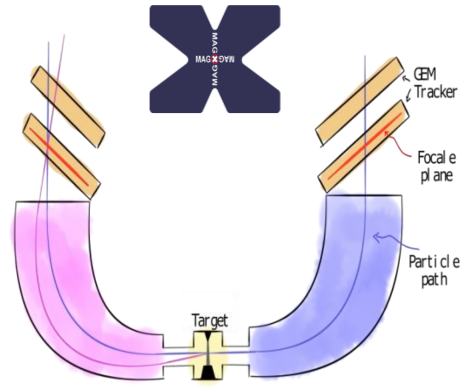
Status in 2013

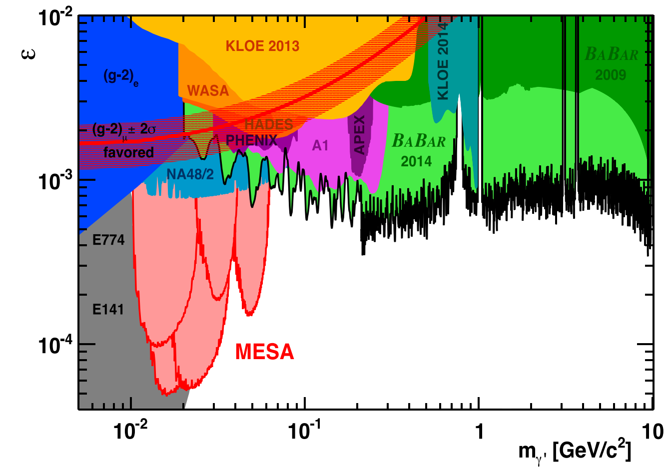


The strong suggestion that it would be possible
to discover the partice has meanwhile covered the „red line“
(without finding the dark photon…)

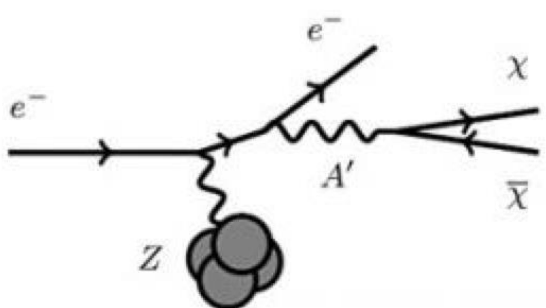
2.4 Dark matter searches with MAGIX







- g-2 band could as well be motivated by „invisible“ decay into dark matter…

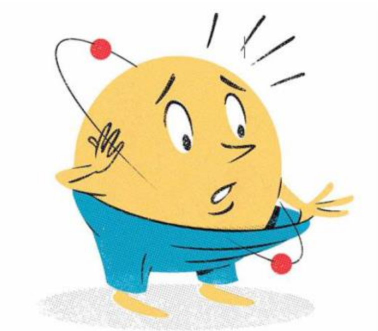


Nucleus

$$m_{A'}^2 = (p_e + P_{nucleus} - p_{e'} - P_{nucleus}^{'})^2$$

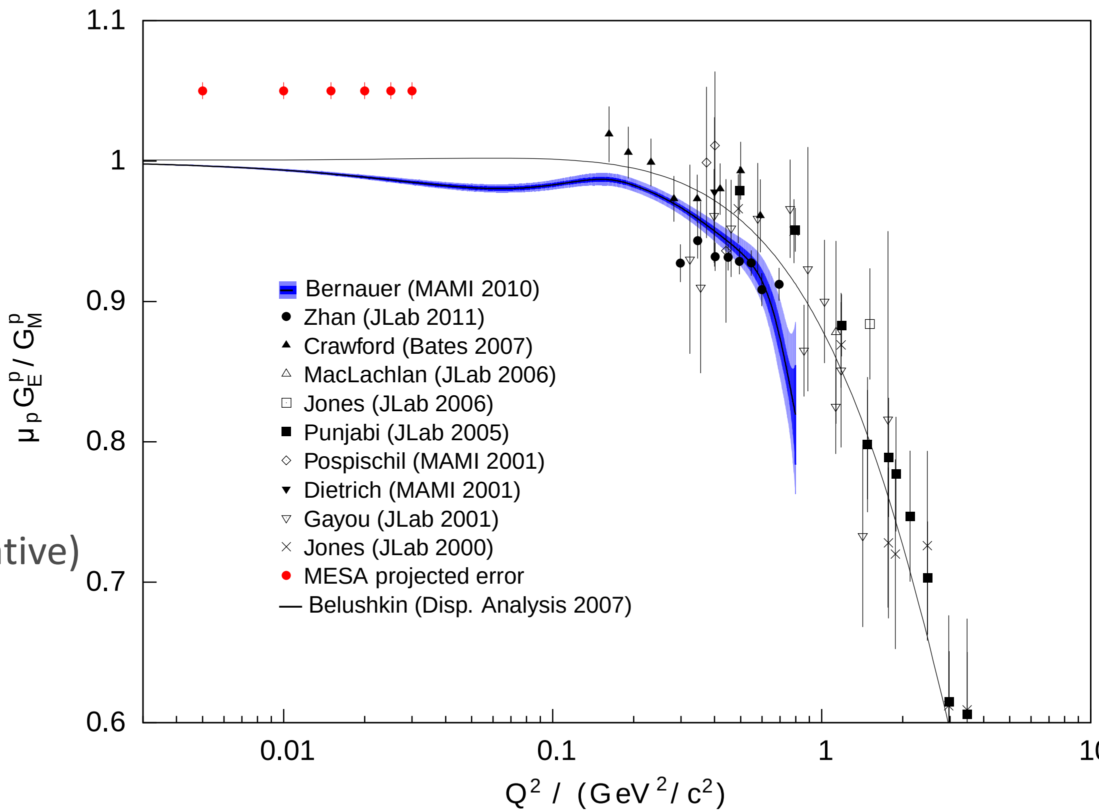
By measuring the (very small) recoil of the Nucleus (proton)
One reconstract if particles of the A‘ type have been
Produced – very good conditions for this in the PIT regime

2.5 MAGIX portfolio-II / Form factors & the Proton radius puzzle



H^- ion by
The New York Times

MAGIX allows to address much smaller momentum transfer due to very low energy, momentum transfer and minimzed material budget…



Simulation:

- Polarized target, 3 x 10^{15} / cm^2 (very conservative)
- 80% **polarisation**
- 1mA beam current, 105 MeV

3 Introduction: ERL‘s in the LINAC/RING configuration

Physics motivation is mainly **deep inelastic** lepton/hadron scattering with the intetion to increase knowledge **beyond** the results obtained at the **ring/ring** collider HERA.

$$s \approx 4E_{lepton}E_{ion} \approx 10^{5}\,GeV^{2}$$

$$L \approx 10^{32}\,cm^{-2}s^{-1}$$

The objectives are:

- Increase the center of mass energy $s^{1/2}$ considerably with respect to HERA
- Increase the luminosity in the same way
- Add double polarisation (HERA double polarized only in fixed polarized target mode, with $s^{1/2}$ very low.

Two approaches:

1.)eRHIC double polarized adding ERL to existing RHIC ring (double polarized, > 10*Hera Luminosity, smaller s.)

2.) LHeC 60 GeV e- beams collides with LHC at 7 TeV → much larger s, >10*L, single polarized,

3 Introduction ERL‘s in the LINAC ring configuration

Physics motivation is mainly **deep inelastic** lepton/hadron scattering

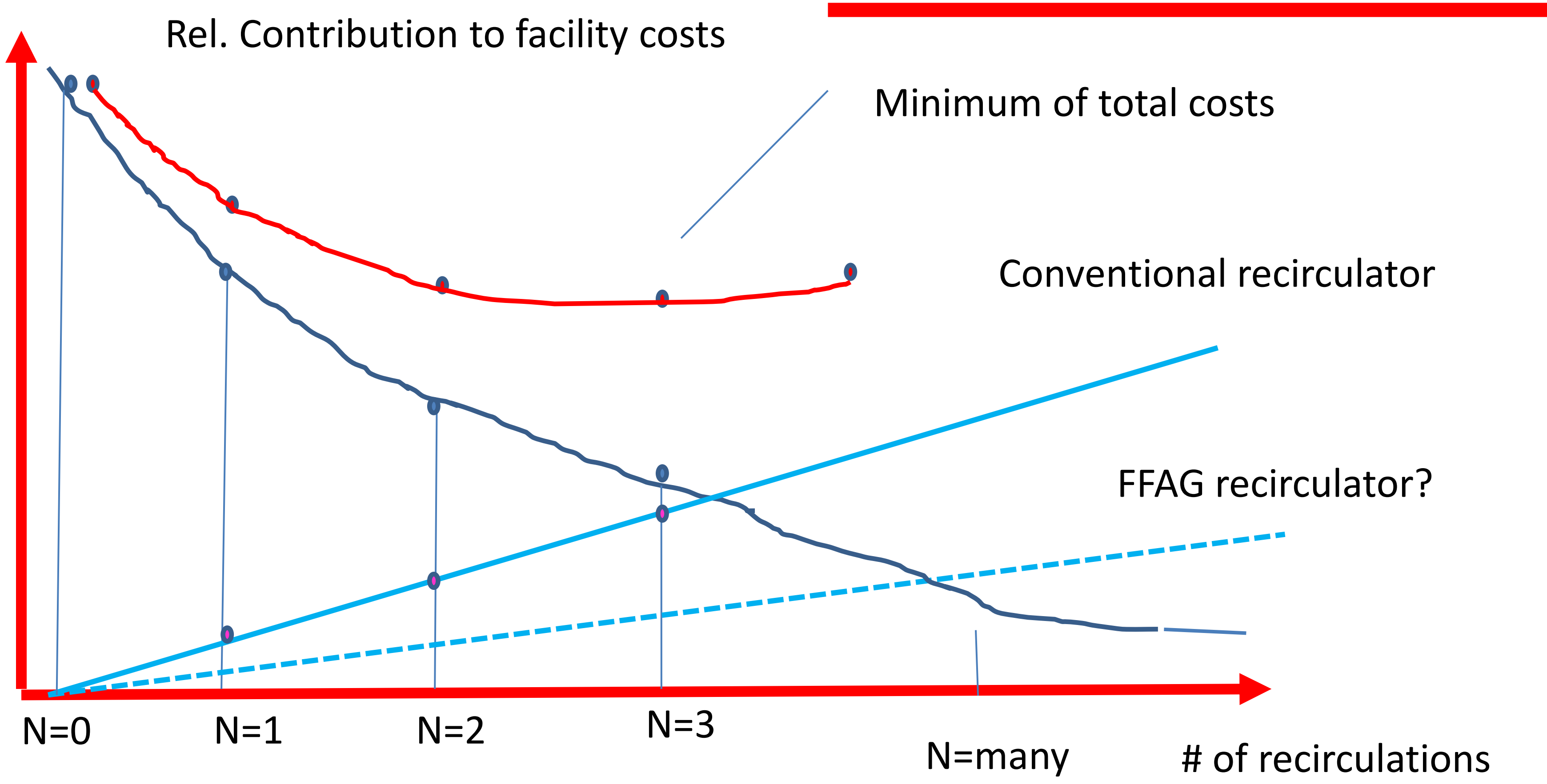
- Collider mode: Luminosity given by

$$L = f_{Coll} \frac{N_{el} N_{ion}}{\varepsilon \beta^*} * O(1)$$

- The large tune shift for the electrons can be tolerated because of ERL operation!

- Spin polarization is mandatory, at least for the ERL beam, better for both (Double polarized collider)

3 Introduction: Cost issues (Schematic)

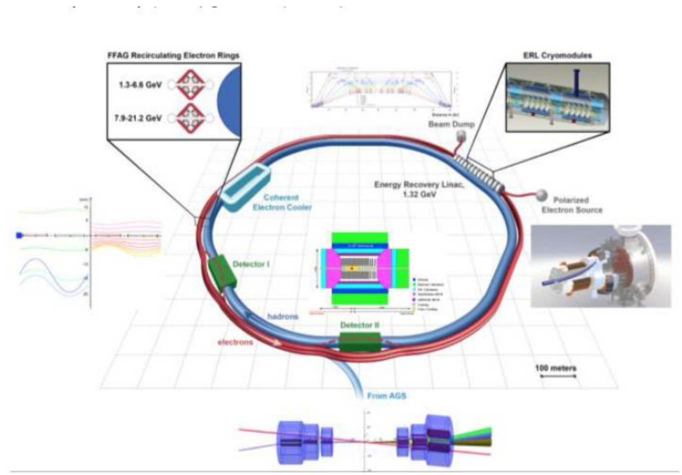


3 ERL's in the L/R configuration:eRHIC

- 16 recirculations in two beamlines!
- Only on 1,3 GeV Linac required
- FFAG test set up presently being designed at Cornell University

Table 1: BNL eRHIC Beam Parameters and Luminosities

	e	P	$^{3}He^{2+}$	$^{197}Au^{79+}$
Energy (GeV)	15.9	250	167	100
CM energy (GeV)		122.5	81.7	63.2
Bunch freq. (MHz)	9.4	9.4	9.4	9.4
Bunch Int. (nucl.), 10^{11}	0.33	0.3	0.6	0.6
Bunch charge (nC)	5.3	4.8	6.4	3.9
Beam current, mA	50	42	55	33
Hadron *rms* ε_N (μm)		0.27	0.20	0.20
Electron *rms* ε_N (μm)		31.6	34.7	57.9
β^* (cm) (both planes)	5	5	5	5
Hadron beam-beam ξ		0.015	0.014	0.008
Electr. Beam disruption		2.8	5.2	1.9
Space charge par. ξ		0.006	0.016	0.016
rms bunch length, cm	0.4	5	5	5
Polarization, %	80	70	70	none
Peak $\mathcal{L}$, 10^{33} cm^{-2}s^{-1}		1.5	2.8	1.7
Improve $\mathcal{L}$, 10^{34} cm^{-2}s^{-1}		1.5	2.8	1.7
Ultimate $\mathcal{L}$, 10^{35} cm^{-2}s^{-1}		1.5	2.8	1.7



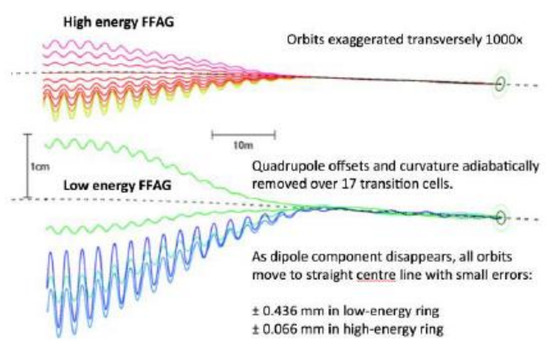
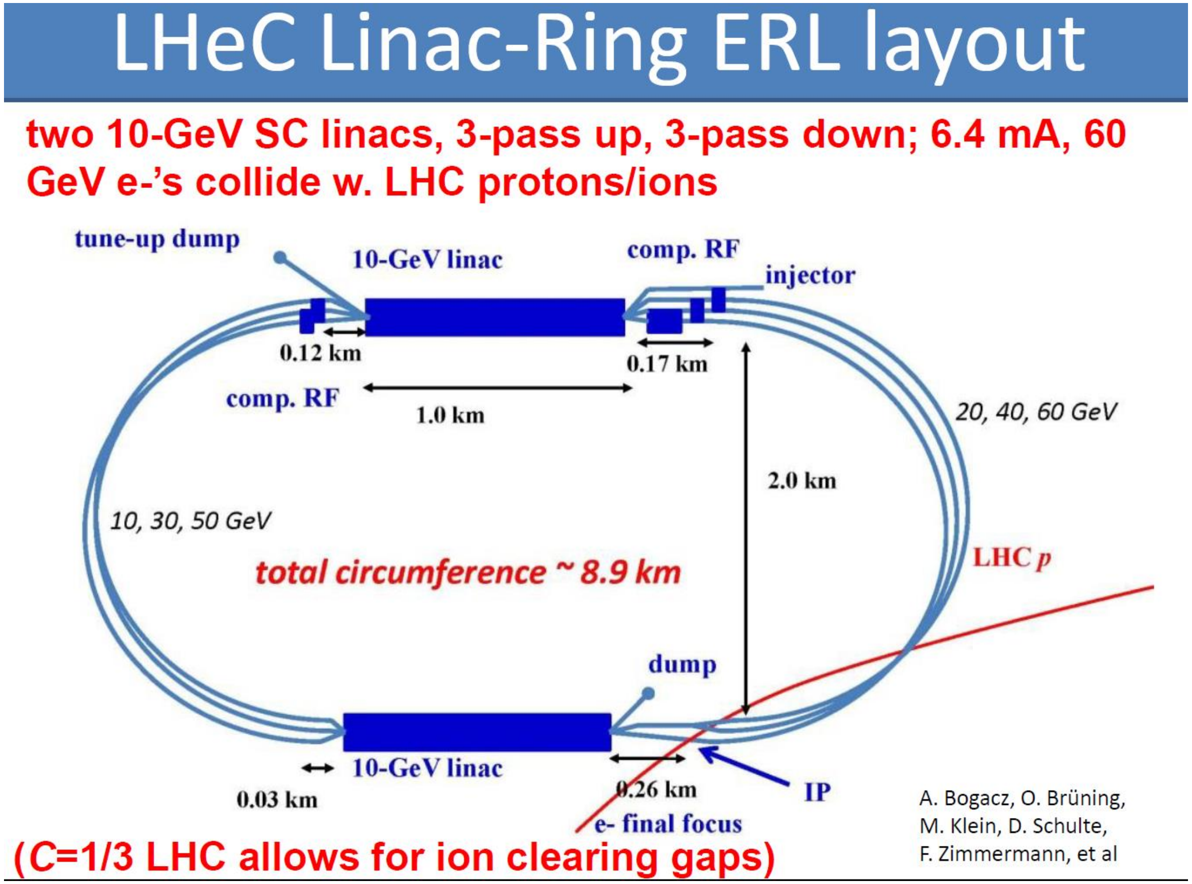


Figure 6: Straight section design for the eRHIC NS-FFAG beam lines.

V. Litvinenko et al.
TUPTY047 Proceedings of IPAC2015, Richmond, VA, USA

3 ERL's in the L/R configuration:eRHIC



- „Single“ polarised collider
- Higher CM energy than eRHIC
- Luminosity ~10^33
- Seperate recirculation orbits

Frank Zimmermann, LHeC workshop 2014
https://indico.cern.ch/event/278903/contributions/631178/attachments/510300/704305/LHeC_overview.pdf

4 Electron Spin-Polarisation for L/R colliders

4 Electron Spin-Polarisation for L/R colliders

ERL based L/R colliders require to improve the „lifetime parameters“ of polarized sources since the average beam currents are about 1-2 orders of magnitude higher than presently practical.

→ Physics of polarized electron sources

4.1 Basics of photoemission

4.1.1 Basics of Photoemission

- **Remember**: A laser of 1 Watt power with 1 eV photon energy (1240nm wavelength) carries 6 *10^{18} photons per second.

$$1\,\mathrm{Watt} = P = n\underbrace{\hbar\omega}_{1eV} \Rightarrow n = \underbrace{1/e}_{numercal!}\left[s^{-1}\right]$$

- If each Photon is converted into one electron by the photoelectric effect the current is n *e=1Ampere!,
- The **quantum efficiency** is the fraction of Photons that are converted into electrons for a given photocathode
- More practical : Photosensitivity S

$$S[\mathrm{A/Watt}] = QE \cdot \frac{\lambda[\mu\mathrm{m}]}{1.24}$$

- 1% at 800 nm wavelength is therefore ~6mA/Watt
- Many Watts Laser power available even under ERL conditions (ps pulses, high rep rate…)

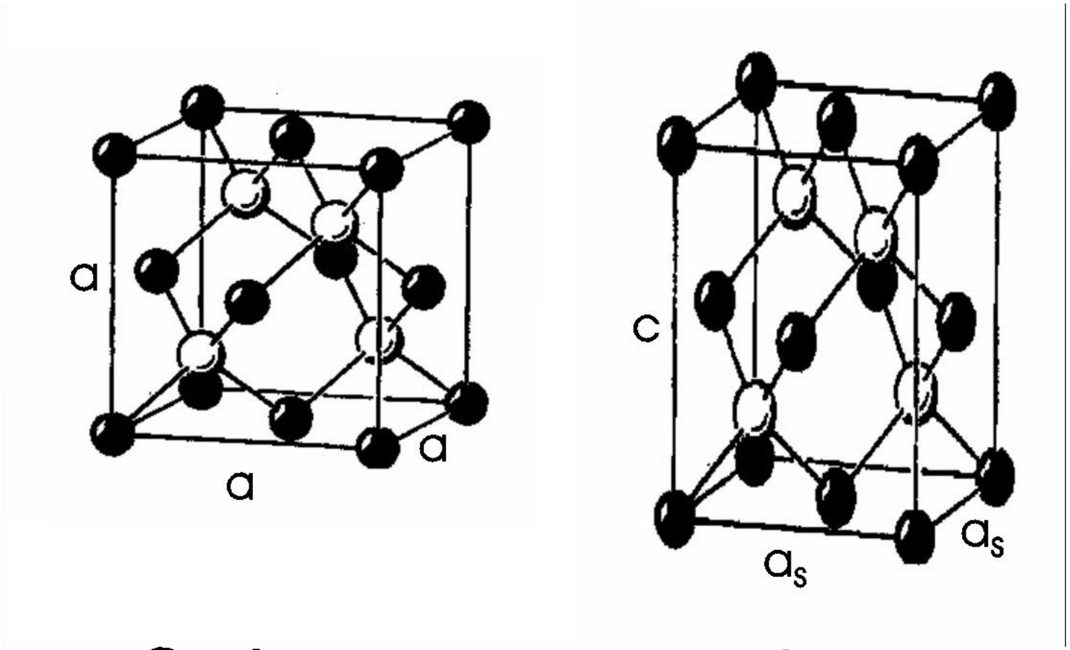
4.1.1 Basics of Photoemission

- „Direct“ Semiconductors offer the following effects/options:

- Strong photoabsorption
- Long lifetime of electrons in conduction band
- Nanostructuring developed for semiconductor lasers allows „band structure design“

→ Create an artificial crystal optimized for spin transfer from photons to electrons

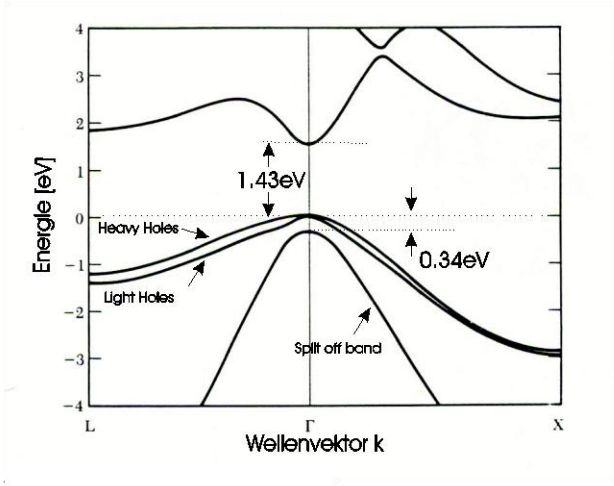
4.1.2 Band structure design
Importance of symmetry breaking

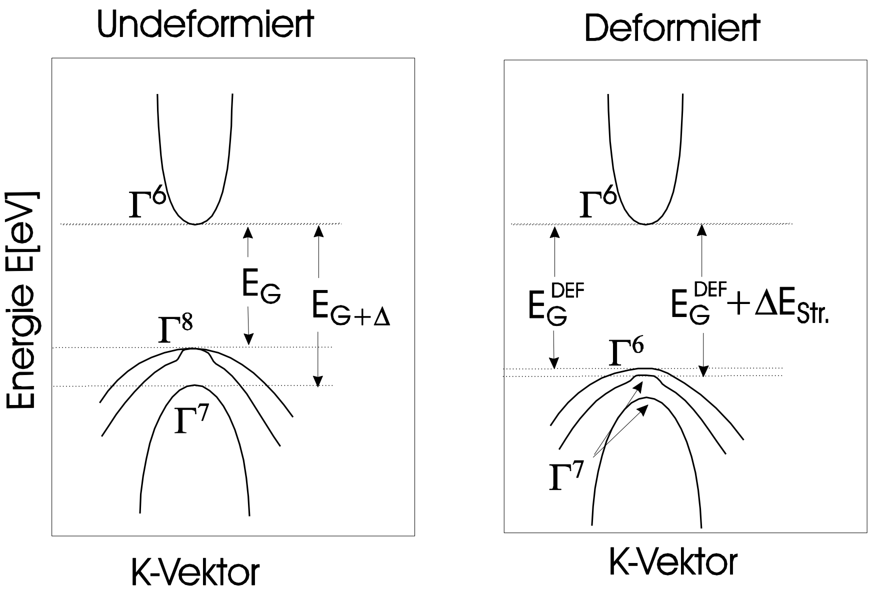


GaAs s-GaAs

$a_s < a < c$

4.1.2 Band structure design

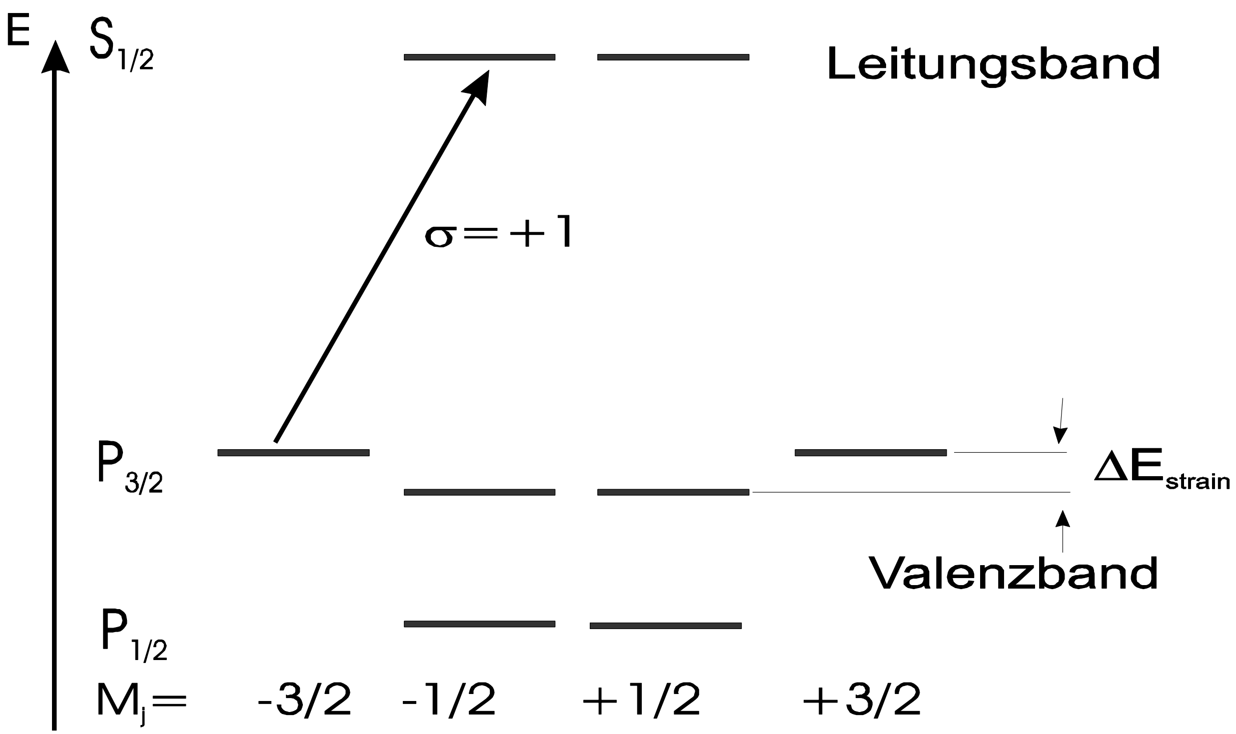




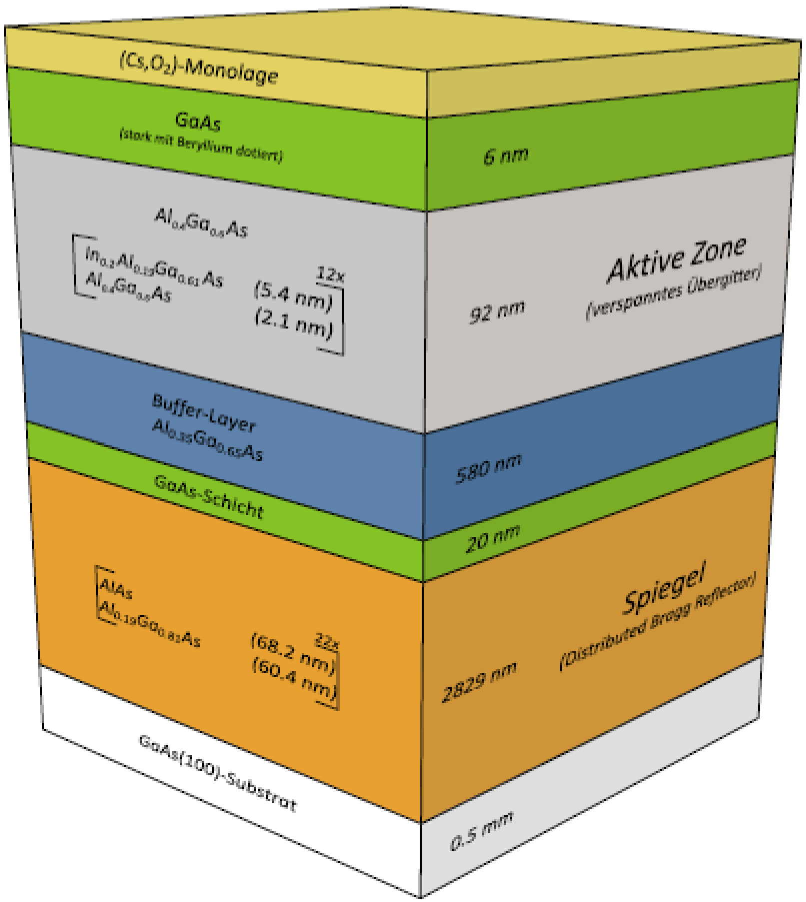
4.1.2 Band structure design

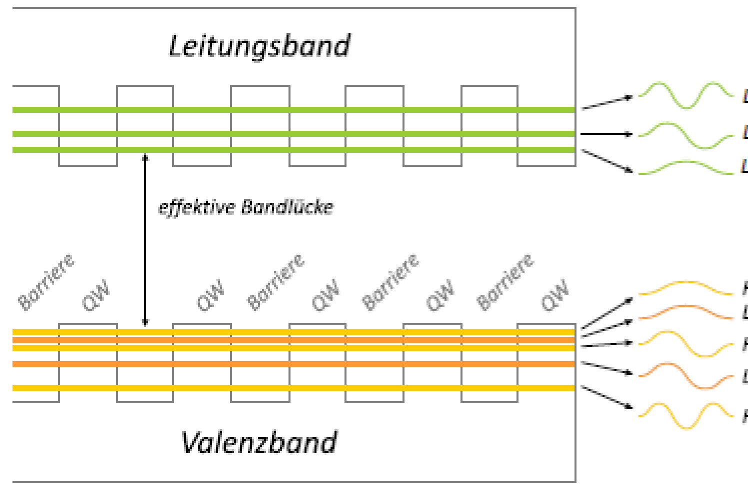
Priicnciple of GaAs-source (Meier und Lampell (1975))
Maruyama und Nakanishi (1991) (s-GaAs)

- Idea: Use spin orbit coupling togehther with symmetry breaking



4.1.3 Advanced Band structure design: Superlattices



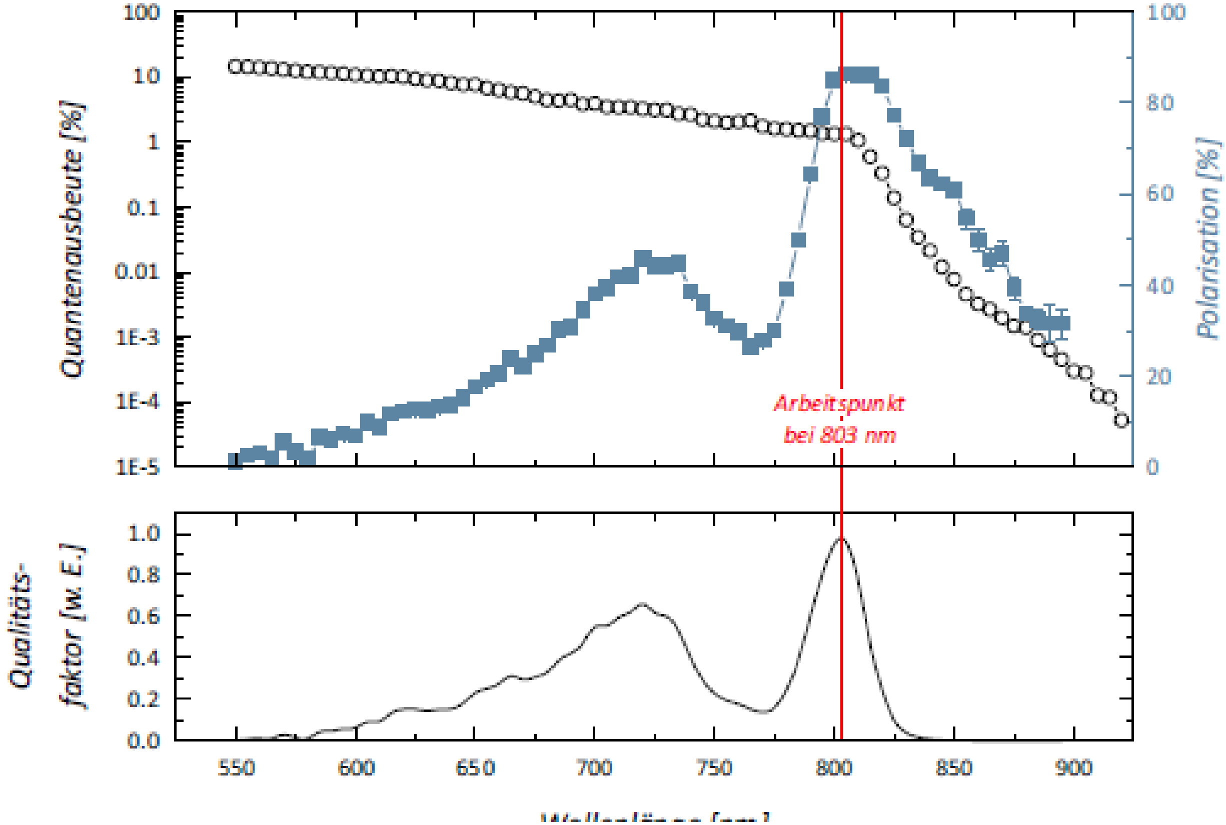


E Riehn, Dissertation 2011

Maruyama et al, Nakanishi et al. , Mamaev et al (SLAC/Nagoya/St. Petersburg)

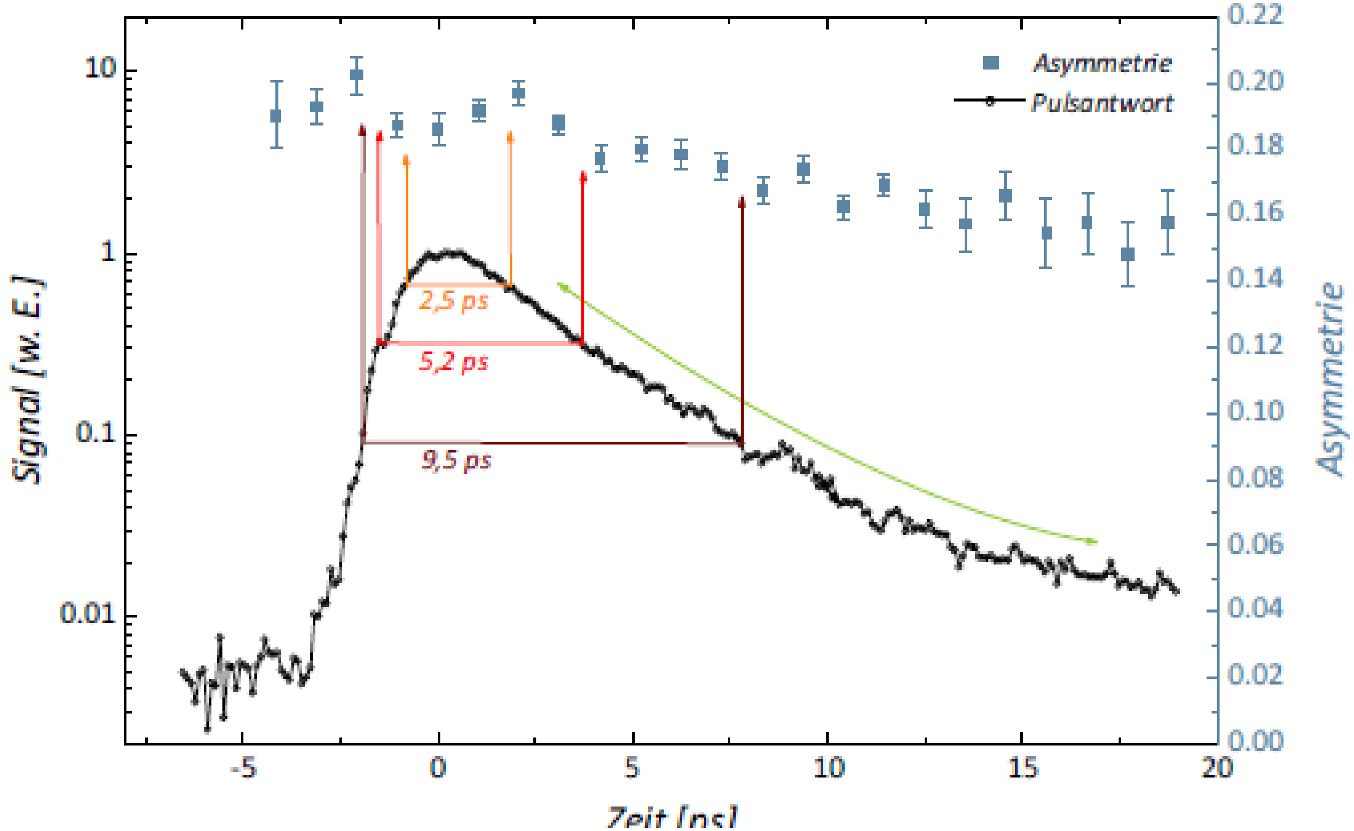
„Hot rod“ photocathode: with built in Bragg reflector for optimized thermal conditions and high QE! (Mamaev et al. 2007)

4.1.3 Band structure design: Achievable performance



Y. Mamaev et al.

4.1.3 Band structure design: Achievable performance



E. Riehn et al

Photocathode active layer thickness D=100nm
D^2 scaling of response time reduces pulse response with respect to normal „bulk" GaAs. Note tail at ~1% intensity

4.2 Beam brightness

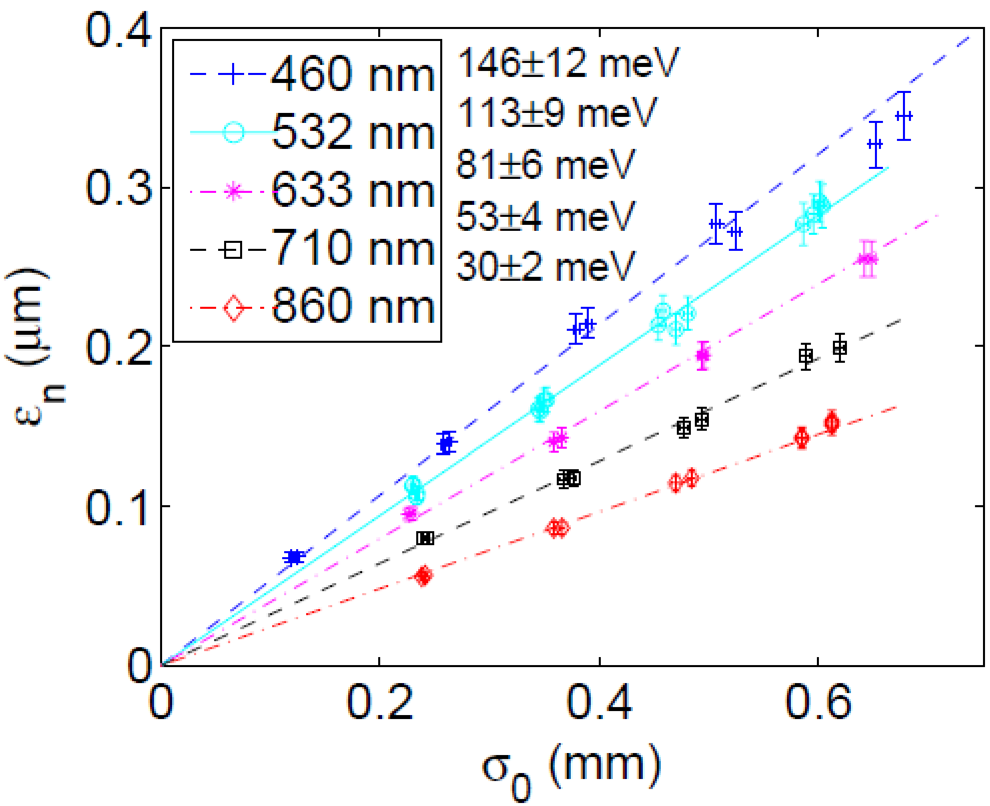


Figure 5: Measured thermal emittance for GaAs.

I Bazarov et al.
Proceedings of PAC07, Albuquerque, New Mexico, USA TUPMS020

$$B = \frac{I}{\varepsilon_{r,n}^2}$$

$$\varepsilon_n = \sigma_o \sqrt{kT_\perp / mc^2}$$

$$\sigma_0 = \text{beam radius at cath.}$$

For given source field parameters, the maximum brightness is given by the transverse temperature of the emitted Ensemble.

This is **optimal** in spin polarized Photemission!

4.3 Lifetime issues

Exploiting the properties of near band gap photoemission for spin polarized, highly effcient, high brightness beams

Requires maintainig the state of „Negative Electron Affinity“ (NEA)

Definition of Electron Affinity

$$EA = E_{VAK} - E_{CB}$$

$$E_{VAK}, E_{CB} \ \text{Energy of Electron in Vacuum}$$

$$\text{and in Conduction band minimum respctively}$$

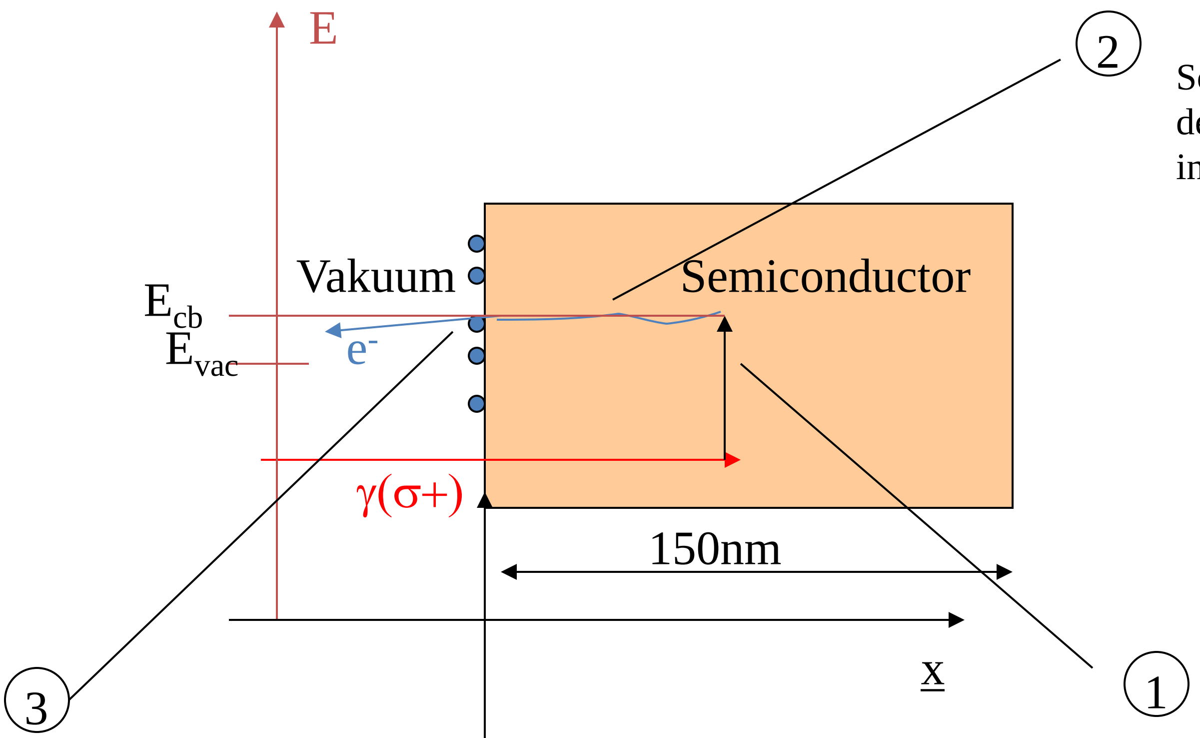
Negative Electron affinity means that electrons can escape from The crystal once they reach the surface

Natural NEA is possible in wide band gap crystals such as diamond

- Its employment for low band gap material requires „work function lowering“ by monoatomic layers of Cesium

7.1.3. Modell der Photoemission aus Halbleitern

Dreistufenmodell: Emission und Zweifel an der Polarisationserhaltung



(2) Schneller Zerfall der Polarisation in weniger als 100ps!

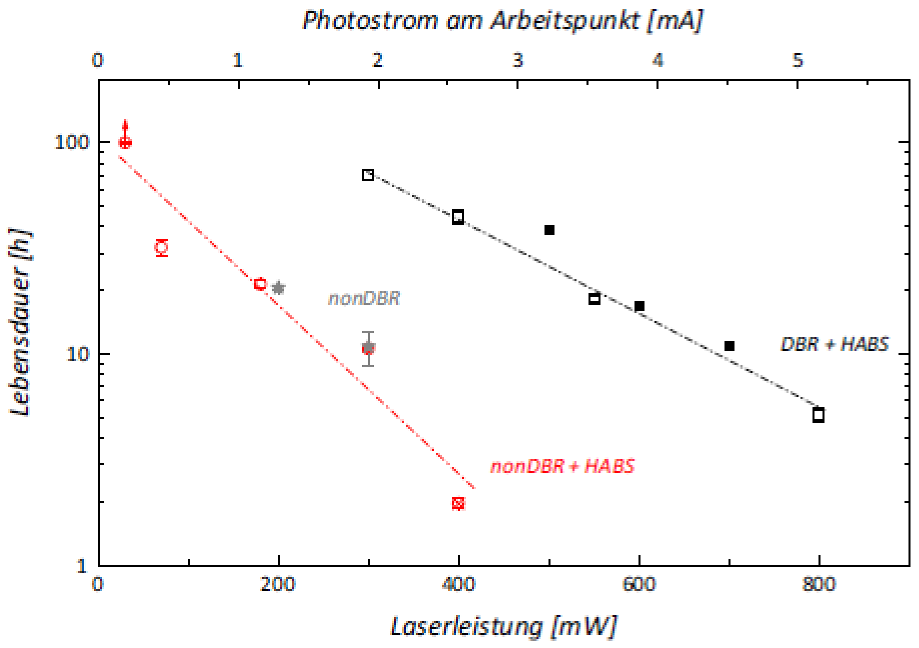
$$P(t) = \frac{P(0)}{1 + t/\tau_{spin}}$$

(1) eventuell nicht vollständige Polarisation nach der Absorbtion

(3) Extraktion inelastische und elastische Streuprozesse mit depolariserender Wirkung vorstellbar

Halbleiter/Vacuum Granzschicht (10nm) Raumladungszone,komplizierte Streuprozesse

4.3 Lifetime issues- temperature



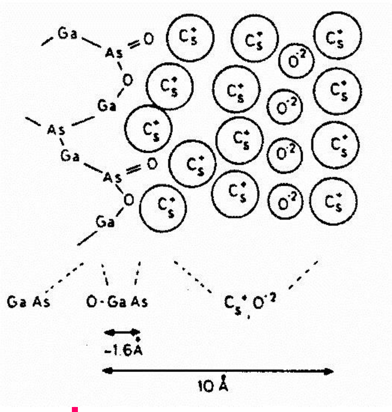
Lifetime is temperature dependent!
Relatively low qunatum efficiency req

4.3. 1 Lifetime - more effects

$$Qe(t) = Qe_0 \exp(-t/\tau)$$

Parallel actng processes:

$$\frac{1}{\tau} = \sum_i \frac{1}{\tau_i}$$



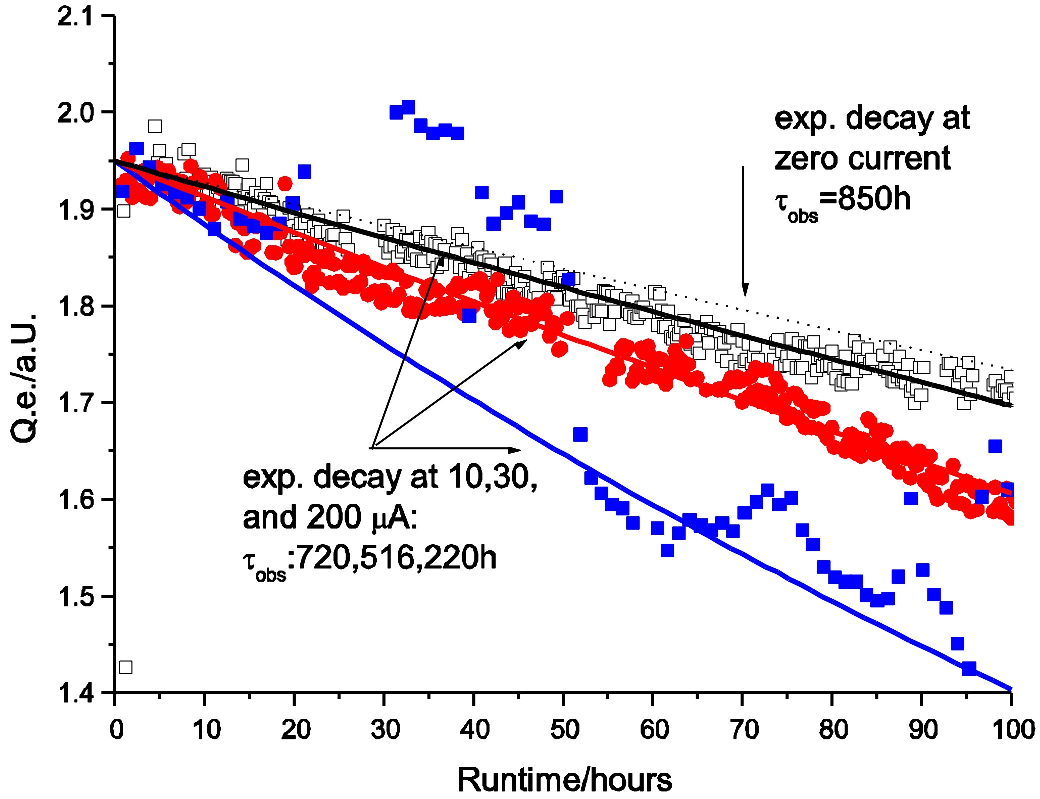
z.B. Restgasspezies H_20:

$$\tau_{H_2O} = \frac{k}{p}$$

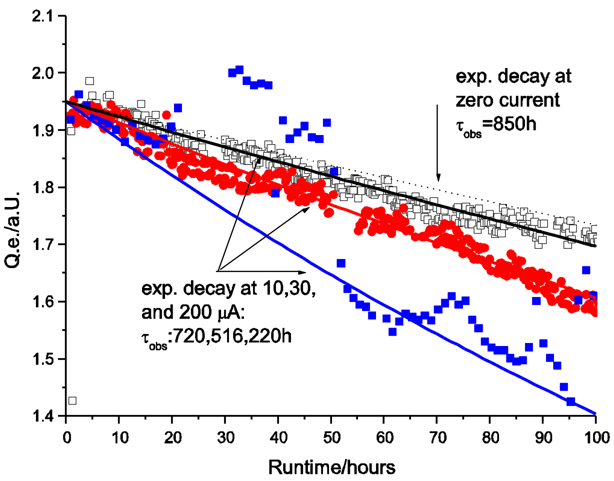
τ_{H2O}=20days→ p=4.2*10^{-13}mbar
)

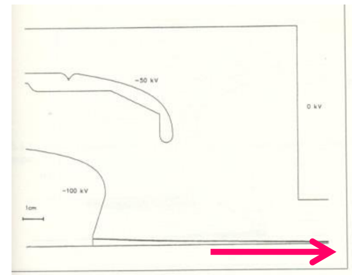
Many other processes: transmission loss, heat, ion backbomardment

4.3. 3 Fluence Lifetime

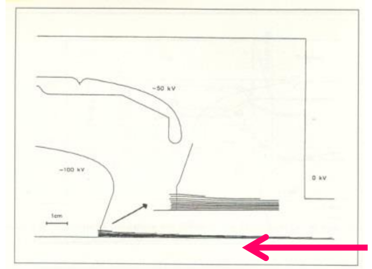


4.3. 3 Fluence Lifetime





Excentriccaly
started electron beam



Backward travelling,
positive Ions

QE- distribution
Before/after

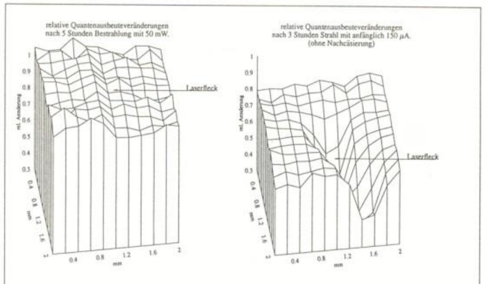


Abbildung 5.27: Lokale Quantenausbeuteveränderungen nach reiner Bestrahlung und nach Stromproduktion.

→ FLUENCE lifetime ~10^3 C/cm^2
→ 50mA is 180 C/hour ???

K. Aulenbacher SLAC report, 1993

4.4 Possible Lifetime Improvements

- Multiple cathodes in time sharing system: BNL „gatling gun“
- Improve vacuum conditions, reduce backbombabardment: SRF gun (ELBE, BNL,)

The End & thank you for your attention

Spares

Electron beam polarimetry at ERL's

ERL workshop , Novosibirsk
15. 03. 2013
Kurt Aulenbacher for the
P2 collaboration
at IKP Mainz

Introductionary remarks-1

Spin polarized beams give acces to mainly two fundamental questions
- Spin structure of strongly interacting particles
- Parity violating processes

Observables : Scattering **A**symmetries $$A_{\exp} = P_{beam} S$$

1.) The interesting quantity is **S**
(the „analyzing power" of the scattering process)
2.) Beams are always partially polarized an error of the polarization measurement may limit the accuracy for **S**!
3.) A „polarimeter" uses a process for which S is well known and measures $A_{exp}/S=P_{beam}$

Introductionary remarks-2

- Spin-Polarized beams at ERL: LHeC. eRHIC, MESA….
- 'Polarimetry' must be minimal invasive if installed upstream of the experiment
- Consequence: Online Operation!
- Polarimetry may also be done in invasive fashion in the beam dump
- Contrary to synchrotrons, depolarization (and self-polarization) should be strongly suppressed

Example: Polarimeter-chain for MESA

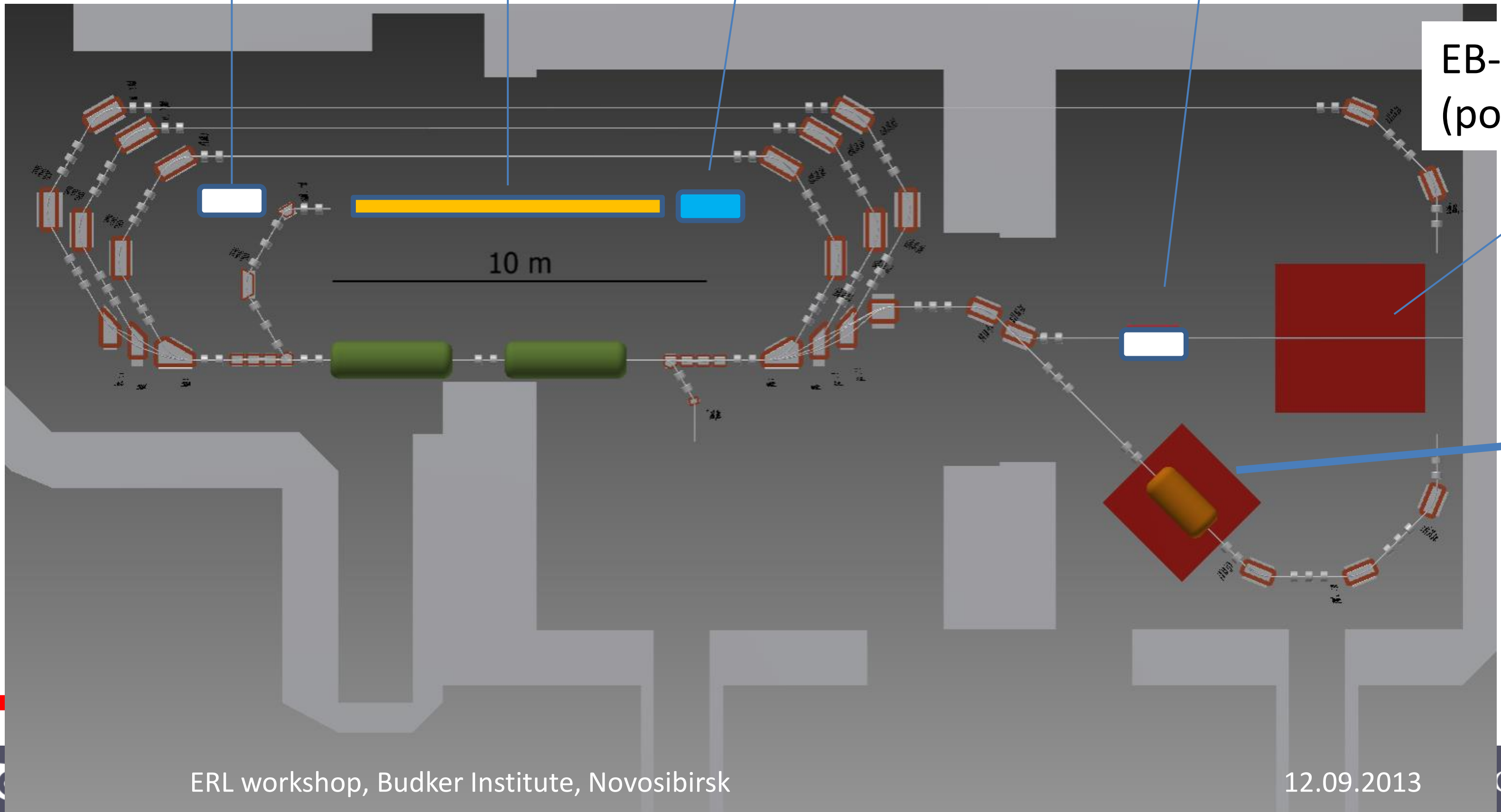
MESA: so far, Polarimetry is foreseen only in EB mode!

„Mott-polarimeter“ (5 MeV)

ILAC

Polarized source

Hydro-Möller Polarimeter (150-200 MeV)



EB-experiment (polarized)

ERL-experime (polarized)

Scenario: Polarimetry in ERL-mode

„Mott-polarimeter“ (5 MeV)

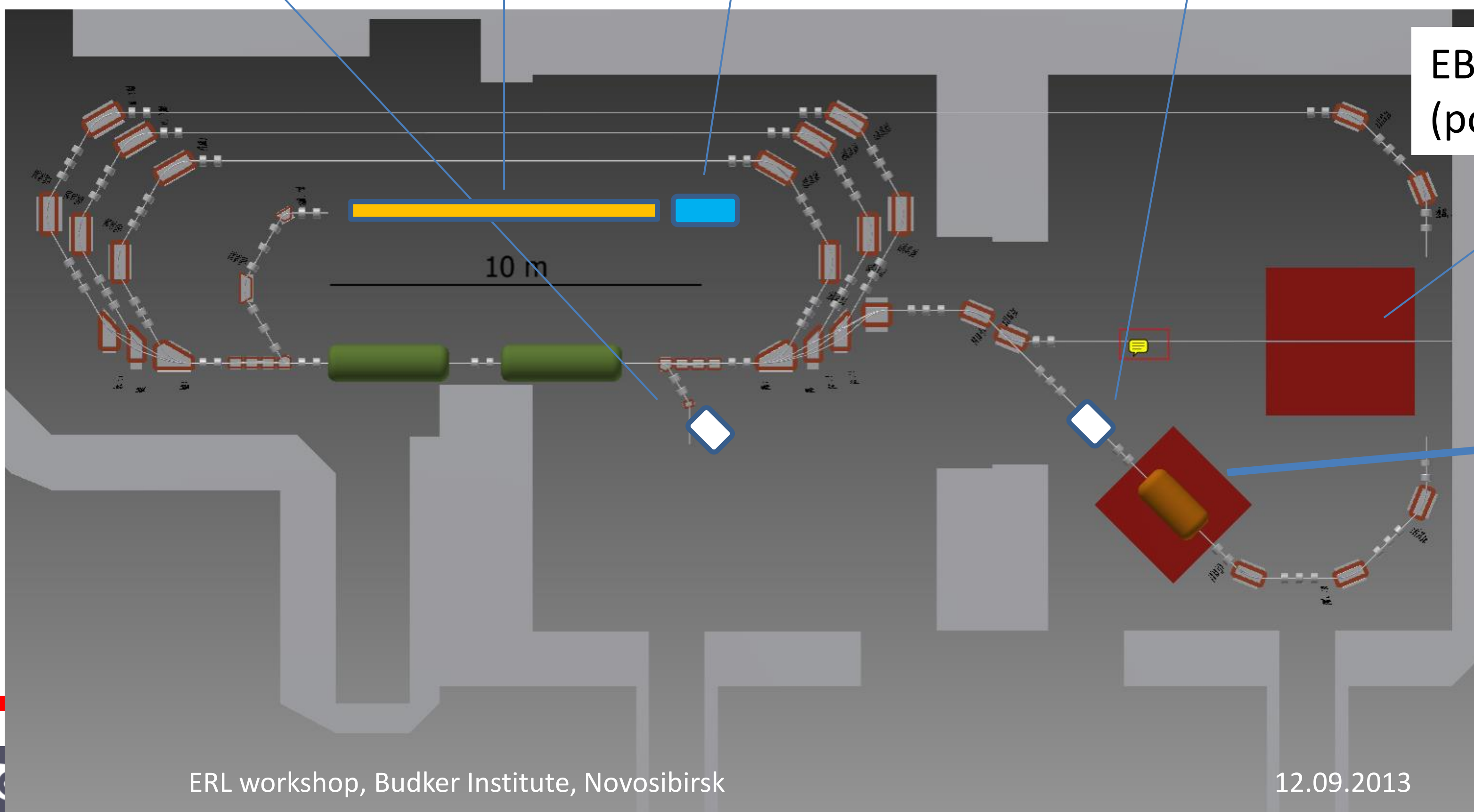
ILAC

Polarized source

Hydro-Möller Polarimeter (150-200 MeV)

EB-experiment (polarized)

ERL-experime (polarized)



Existing Electron-Polarimeter chain at MAMI

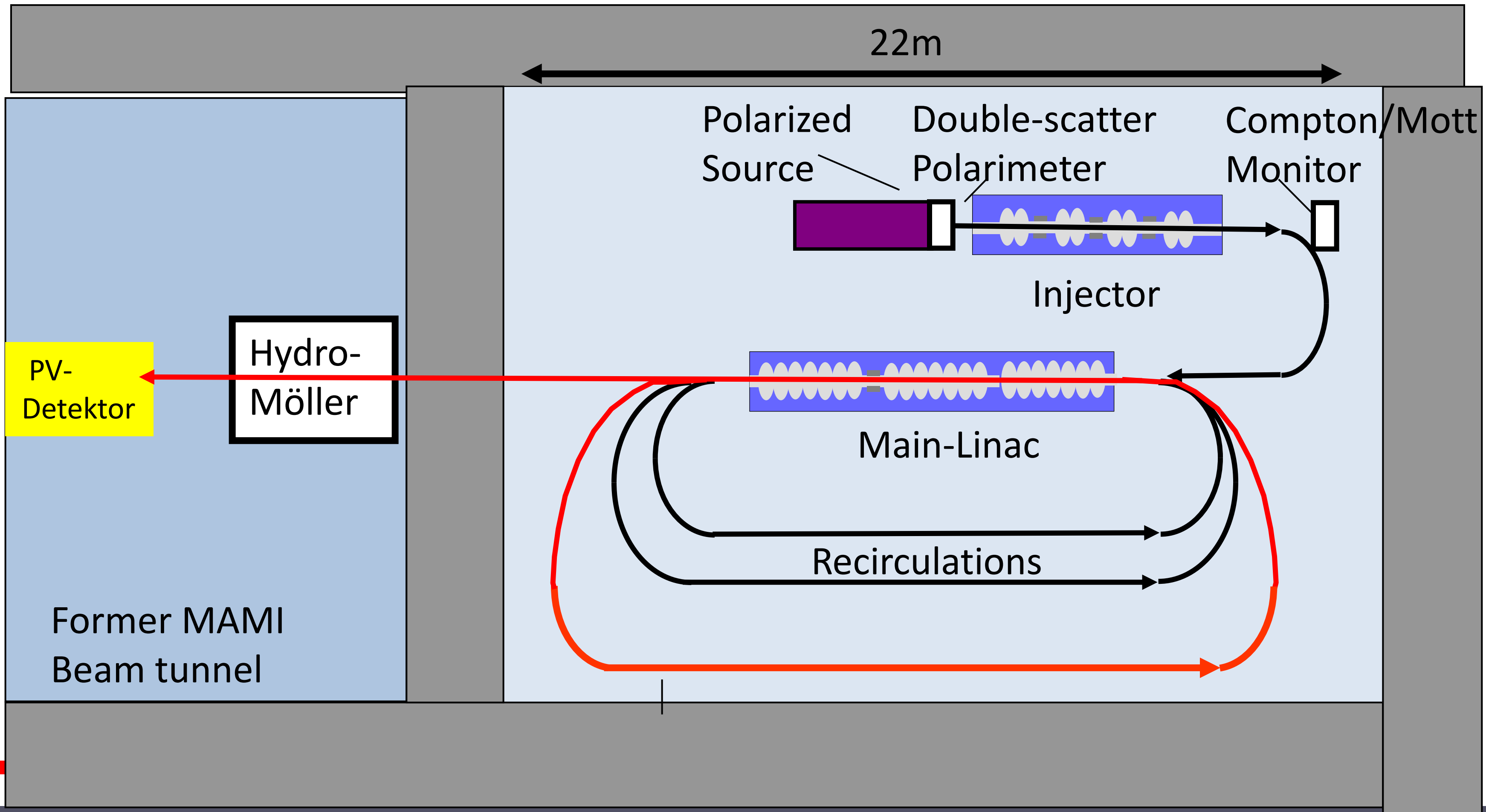
Polarimeter	ΔP/P present (Potential)	Main uncertainty	Measurement Time @1% stat	Operating current	Energy range [MeV]
Mott	0.05 (0.01)	Background	3s-1h	**5nA - 100μA**	1-4
Möller	0.02 (0.01)	Target pol.	30min	**50nA**	300-1500
Laser-Compton	0.02 (0.01)	Calibration, Target pol.	12 h	**20μA**	850-1500

Details : see talk by Valeri Tioukine!

A new concept is needed for demanding Experiments planned at MESA!

A new Polarimeter-chain for MESA

"Unimpeachable" polarization measurement: two independent polarimeters with $\Delta P/P$ <0.5% each. : "Double-Scatter-Polarimeter" +"Hydro Möller,"
Cross checks and intensity-linking by multi MeV Mott



Some remarks

low energy operation of Mott scattering

probably no cause for additional systematics at MESA

(→ exact spin tracking possible, no resonances)

LCP not possible at MESA due to small energy, Hydro-Möller could work

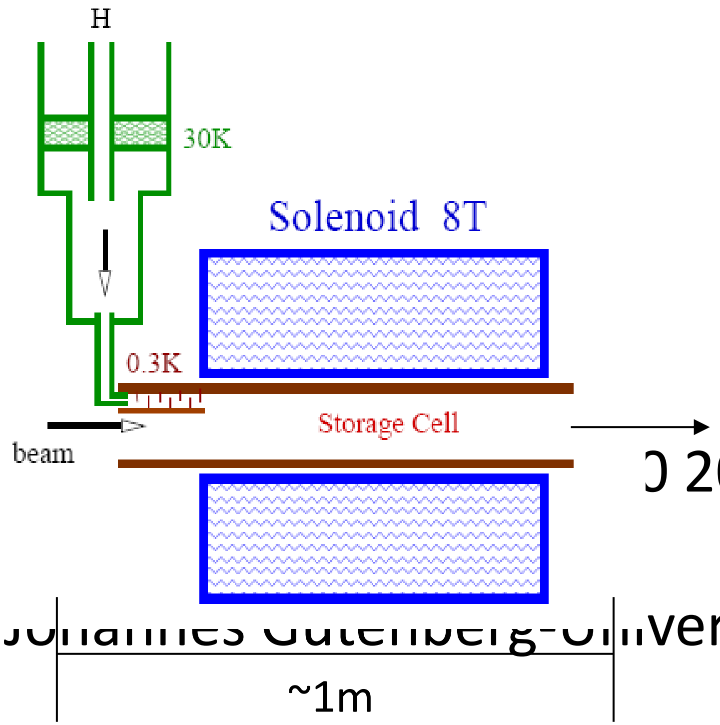
Different concepts (‚paradigms‘) of measurements:

- Hydro Möller ‚double-polarization‘
- Double-scattering Polarimeter ‚double scattering‘

Hydro-Möller

Differen… ERL Applications

Chudakov&Luppov, Proceedings IEEE Trans. Nucl. Sc. **51**, 1533 (2004)



…versität Mainz

2016

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

„Prototype" of atomic trap was donated by UVA/Don Crabb

→ Template for cryostate development

→ Solenoid may be usable

Details: see talk by Patricia Bartholomae

Foundations of Polarimetry

The Hydro-Möller follows a ‚paradigma‘:

„accurate determination of effective analyzing power is achieved by factorization of theoretical and several experimental effects and accurate determination of all of them“

$$A_{\exp} = P_{beam}\underbrace{Corr P_T S_0}_{S_{eff}} \quad \text{Corr} = \text{i.e dilution by background}$$

- Apparent attractiveness of standard (single-spin) Mott-scattering:

$$A_{\exp} = P_{beam}\underbrace{Corr S^{y}{}_0}_{S_{eff}} \quad \Rightarrow \text{No } \mathrm{P_T} \text{ !} \qquad \text{(but no change of Paradigma)}$$

Differen

A very old idea

In **double** elastic scattering S_{eff} can be **measured**! (...another paradigma...)

After scattering of unpolarized beam :

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

(Equality of polarizing and Analyzing Power :)

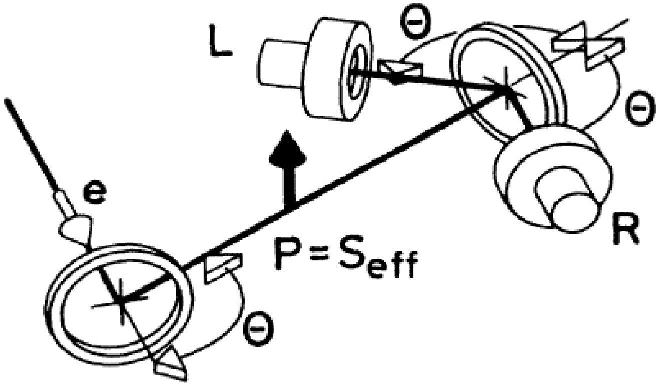
After second "identical" scattering process

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

with great effort to elliminate apparative asymmetries and to provide 'identical' scattering)

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

CAS
Hotel Scandic Emporio
Hamburg May 31-June 1
Kurt Aulenbacher
Johannes Gutenberg-Universität Mainz



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

- The apparatus of Gellrich & Kessler is in our possesion
- Goal:-1 Reproduction of Kesslers claims using test source
- Electronics has been upgraded , measurements will start in 2013 (PhD thesis M. Molitor)
- ~~Then installation at MESA~~

More remarks

DSP works at ~100keV; ideal for ‚1mA-MESA-stage-1

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

Claim: Inelastic contributions do not jeopardize the accuracy!

potential issues

→ how to use with polarized beam?

→ What if the two targets are NOT identical?

Hopster&Abraham (1989):

No problem, If a switchable polarized beam is available **(|P+|=|P-|),** the first target may then be treated as an **auxiliary target** which may be exploited for **systematic cross checks**

Differe

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

$$A_5 = P_0 S_T$$

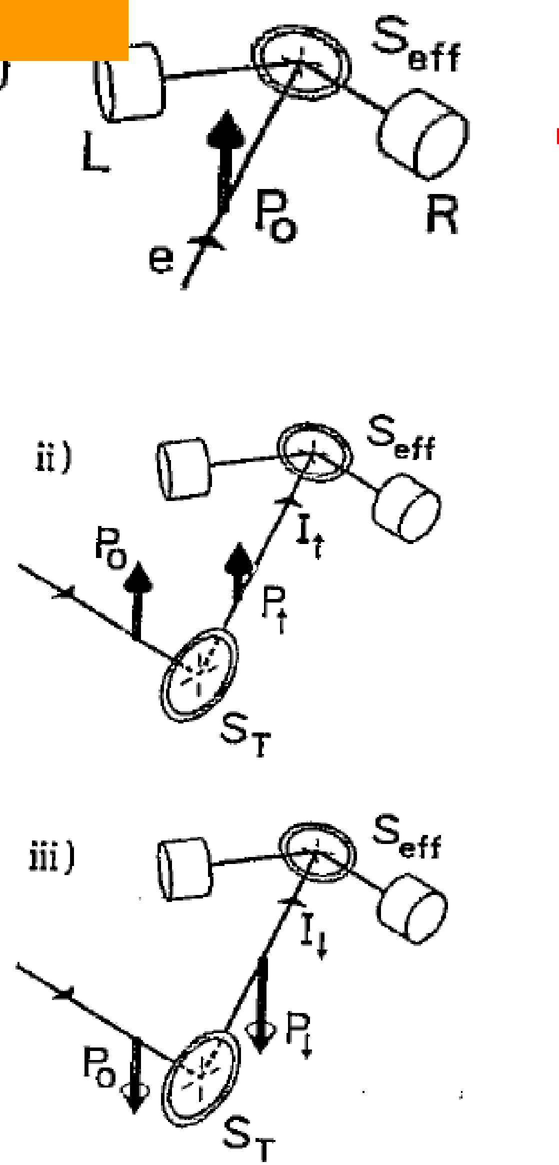
CAS

Hotel Scandic Emporio

Hamburg May 31-June 10 201

Kurt Aulenbacher

Johannes Gutenberg-Universita



5 equations with four unknowns→ consistency check for apparative asymmetries!

→ Results achieved by Kessler were consistent <0.3%

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

More remarks

Auxiliary target method was limited by statistical efficiency (today about 5 times better!)

DSP invasive, but fast.

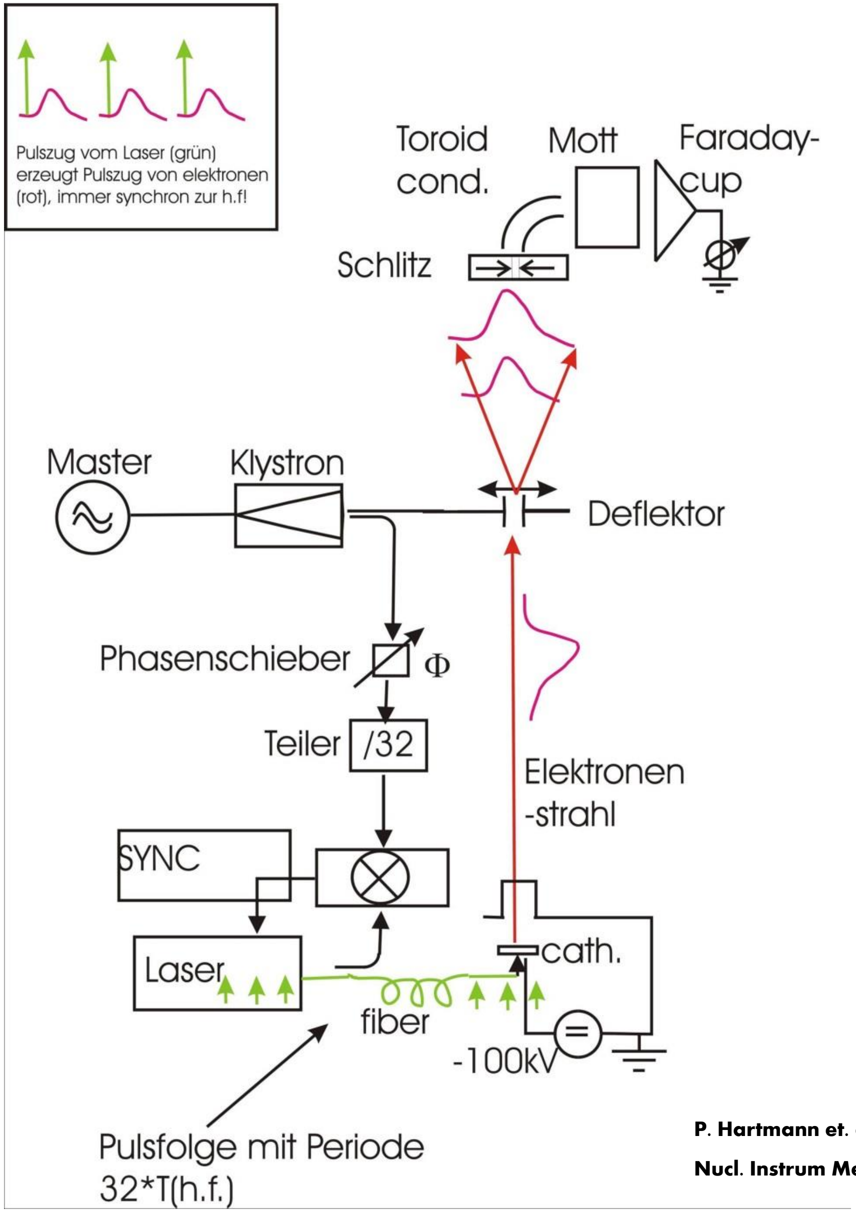
Probably not feasible to operate DSP at > 100μA current level, requires ‚linking Polarimeter‘

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

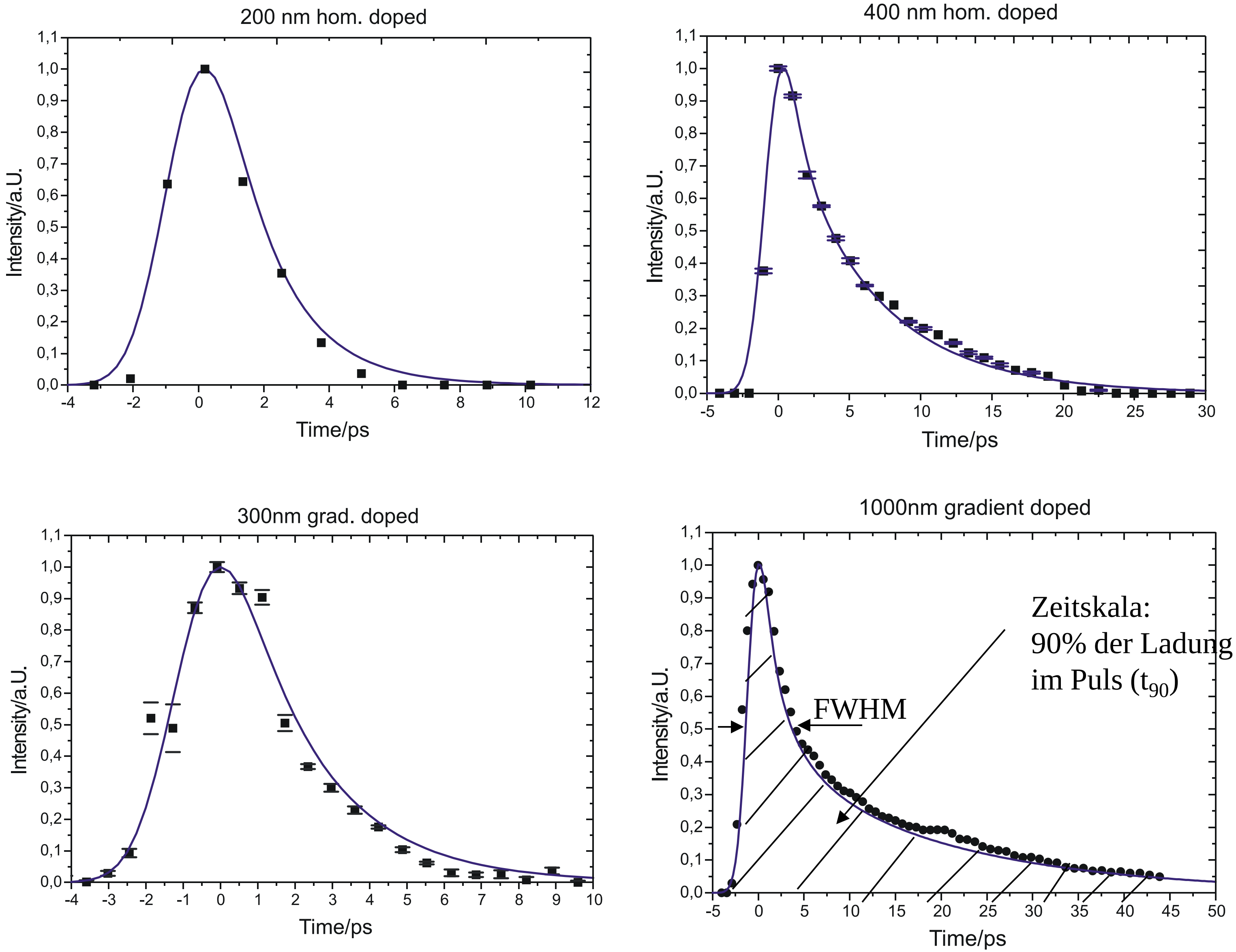
7.1.7. Impulsantwort von NEA Photokathoden

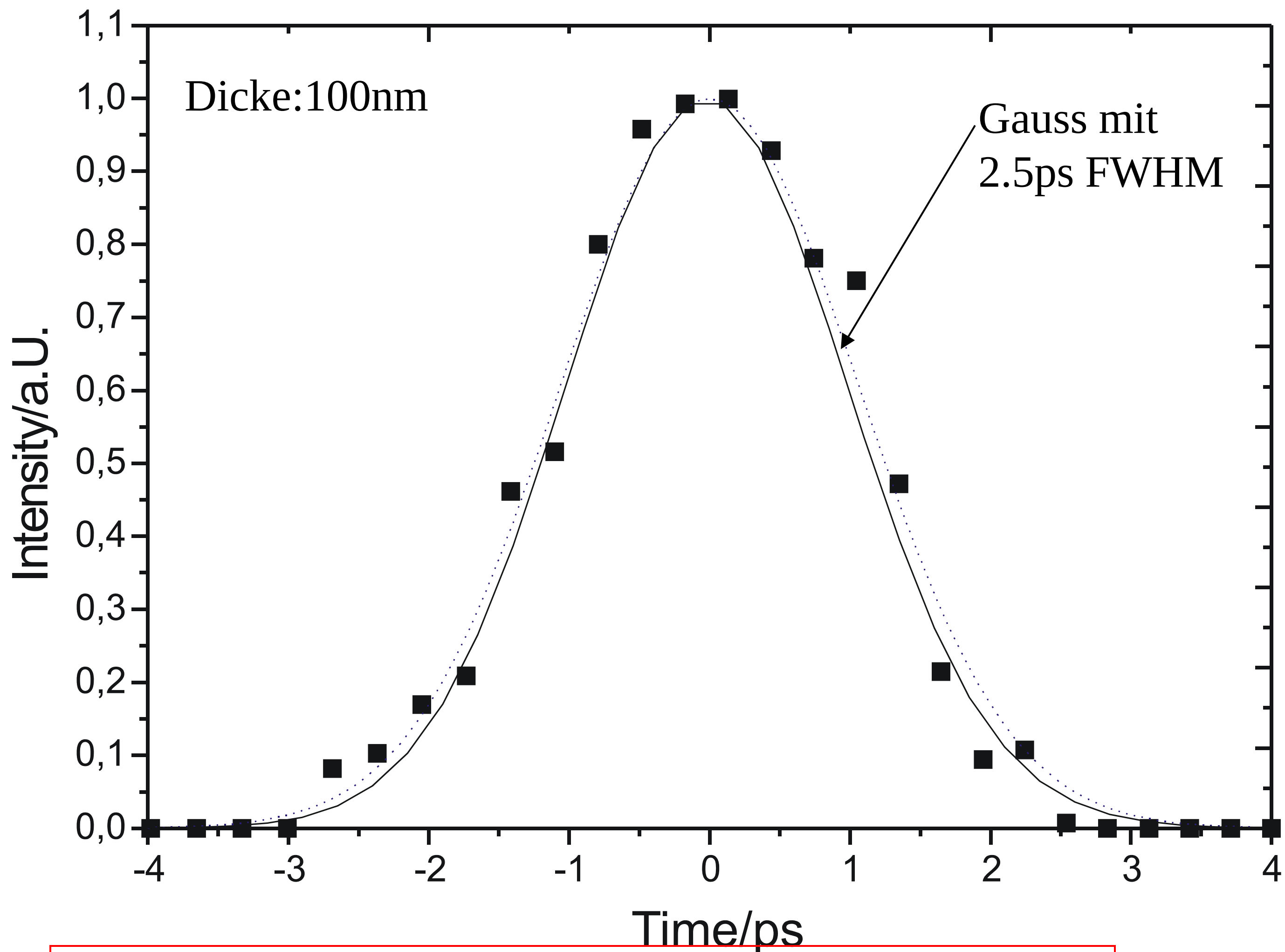
MAMI ca. 1995:
Aufgebaut wird der r.f.-synchrostreak Apparatur zur polarisationsaufgelösten Messung der Impulsantwort von Halbleiterphotokathoden



P. Hartmann et. al.
Nucl. Instrum Meth. A379 15-20 (1996)

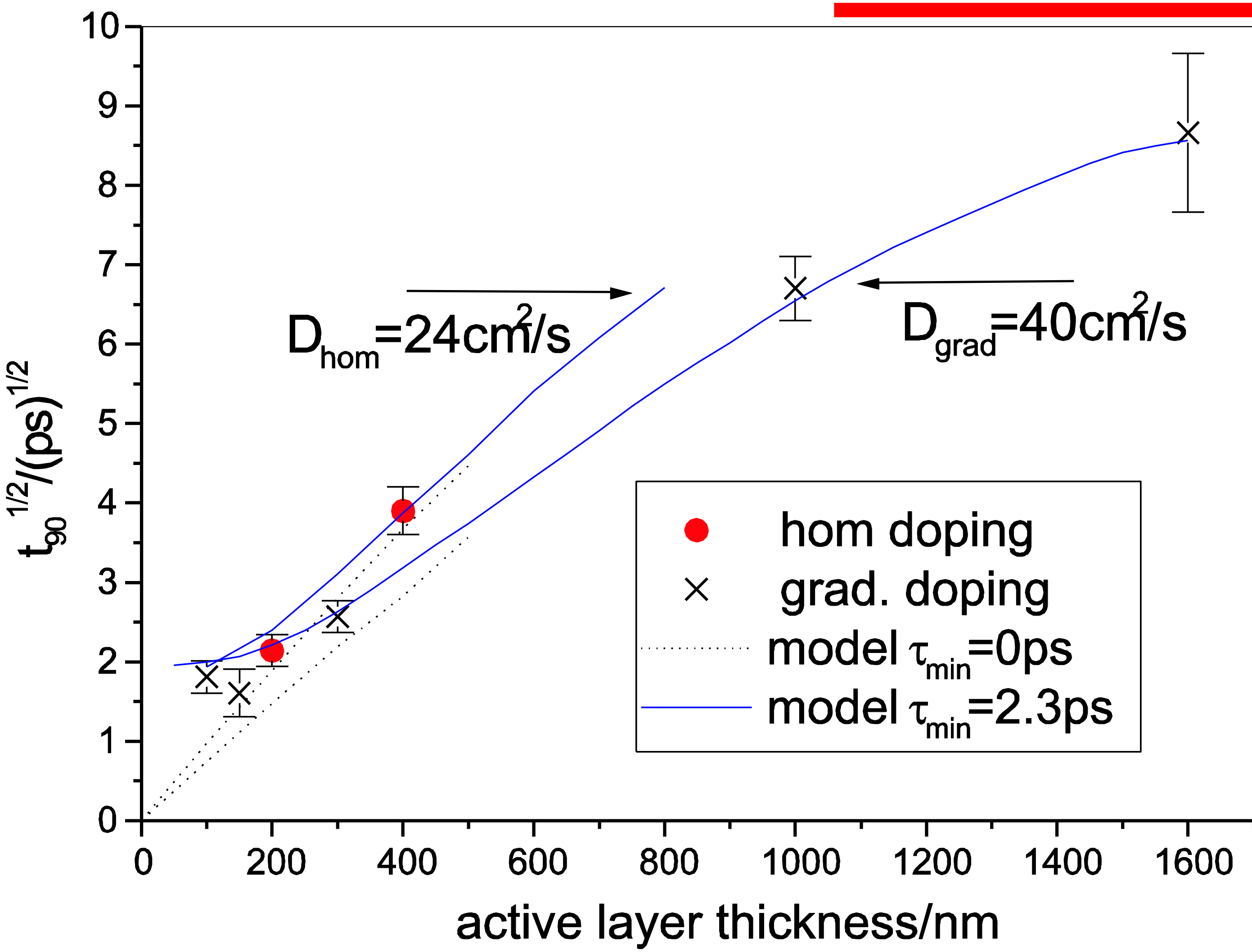
Schichtdickenabhängigkeit





limitiert durch experimentelle Auflösung von etwa 2.5ps.

Experimentelles Resultat:



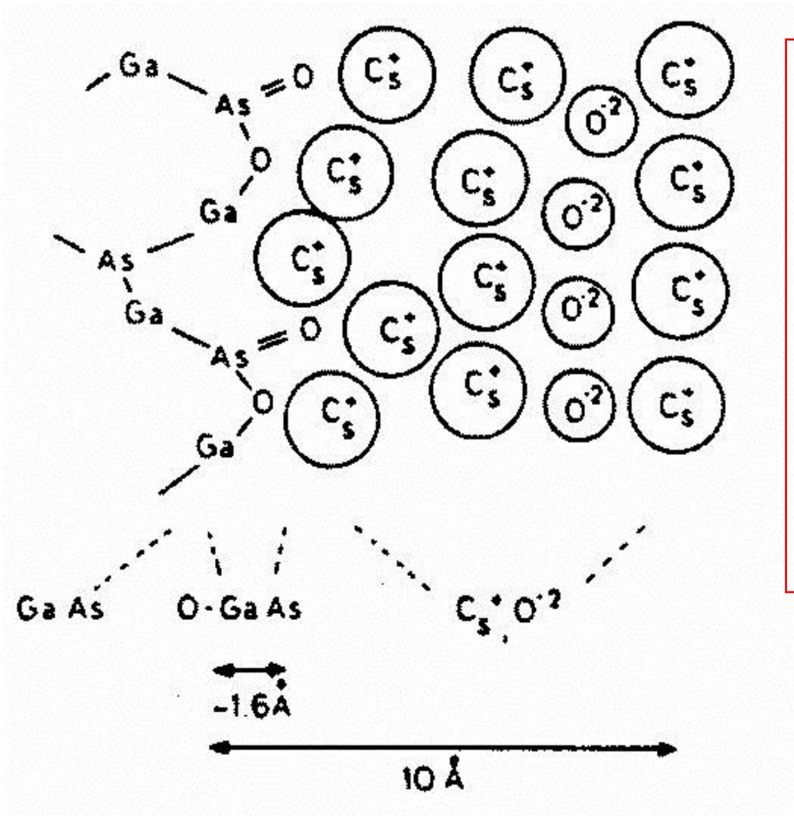
K. Aulenbacher et al. J. Appl. Phys. 92,12 7536, (2002)

Diffusionsmodell:
Modellvorhersage

$$<t> \approx \frac{1}{12}\frac{d^2}{D}$$

7.2. ‚Technische Effizienz‘ (Verfügbarkeit)

der pol. NEA-Photo-Elektronenquellen



1.) Problem ist Herstellung der richtigen Oberflächenrekonstruktion +Aufbringen der Dipolschicht.

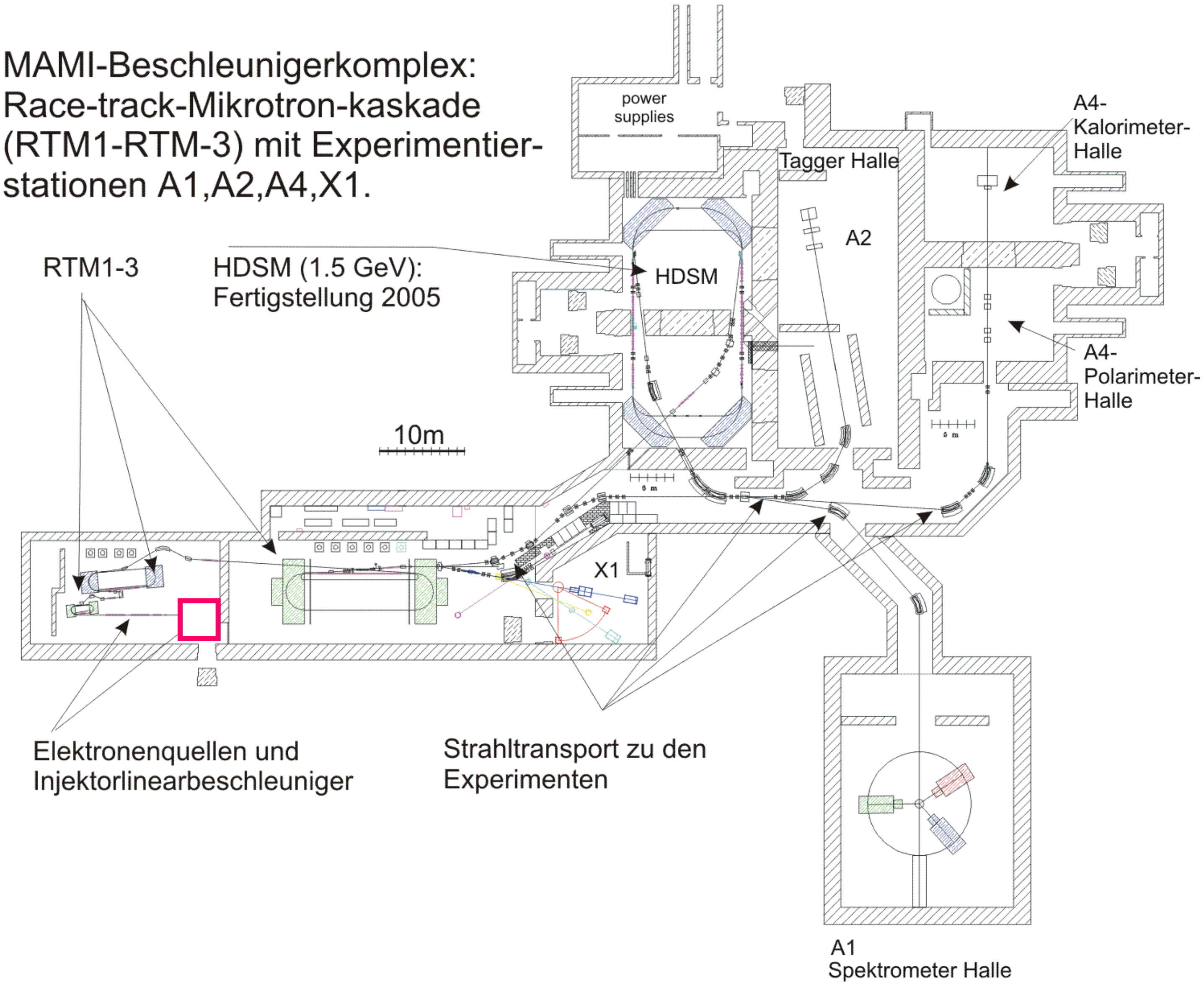
2.) Deutlich schwieriger ist die **Erhaltung** der NEA-Verhältnisse im Betrieb

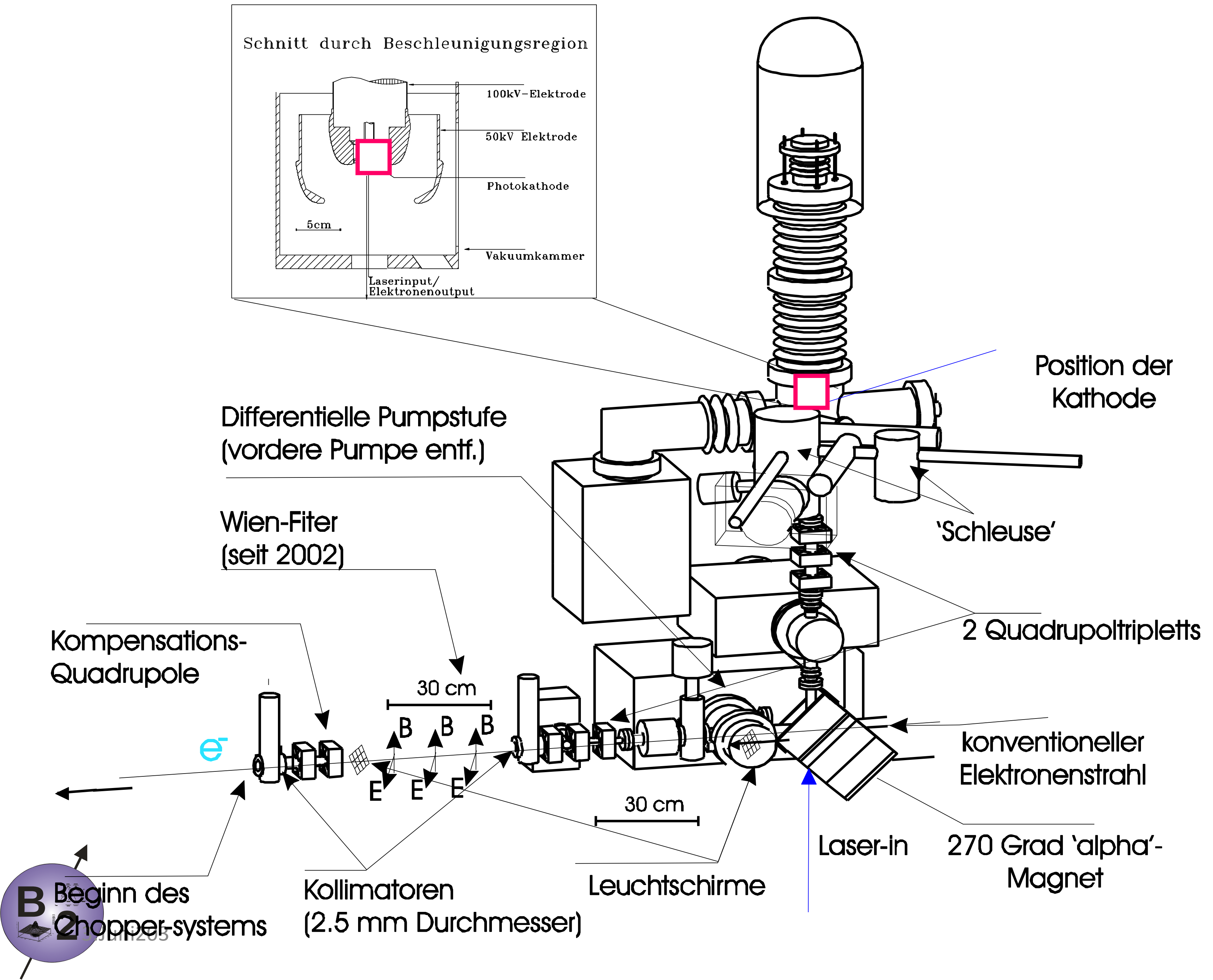
‚Doppel-Dipolmodell‘
(nach Spicer)

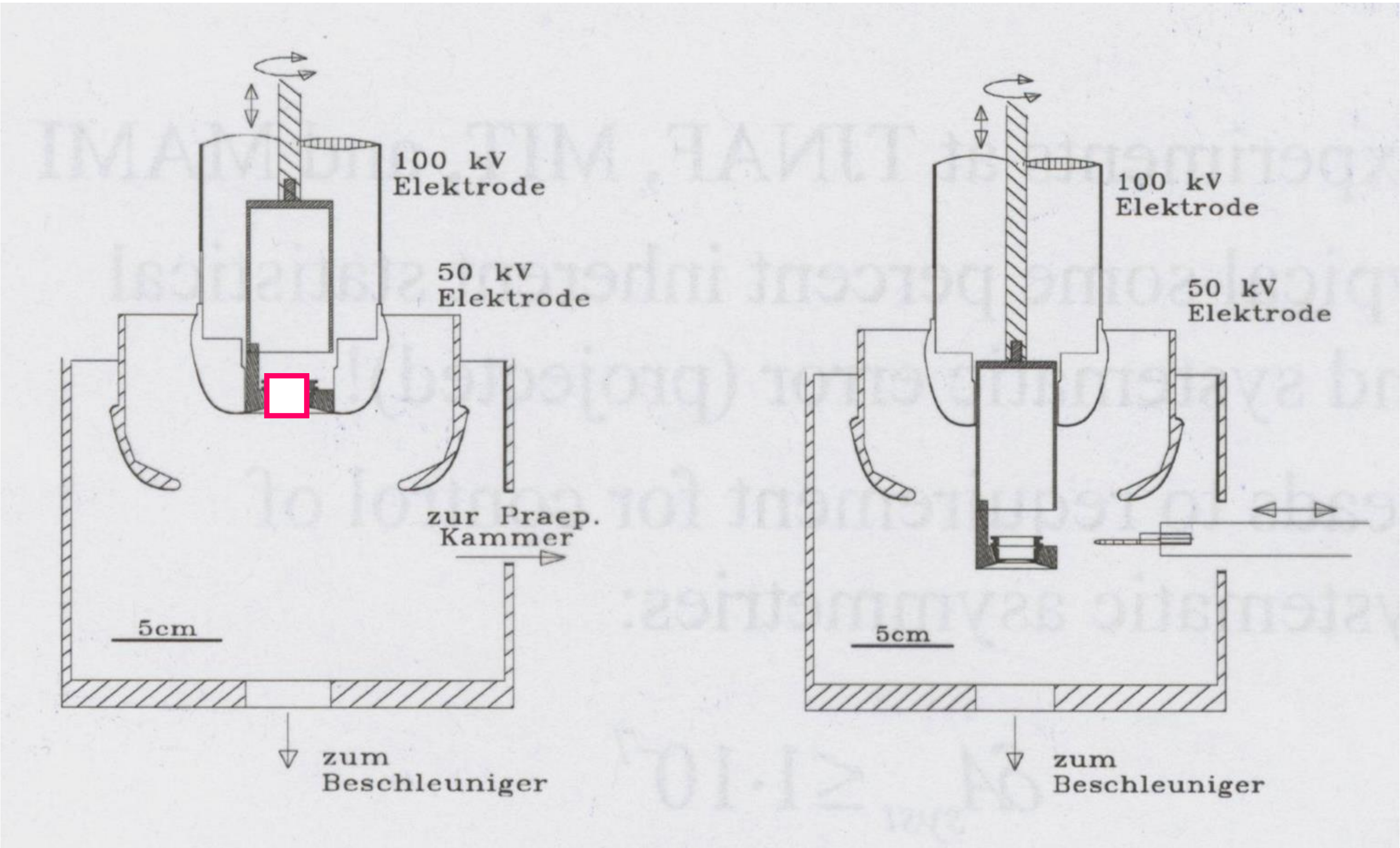
Polarisierte Elektronen an MAMI in schrittweiser Vergrösserung:

Gesamtanlage,Injektion,Photoquelle,Photokathode

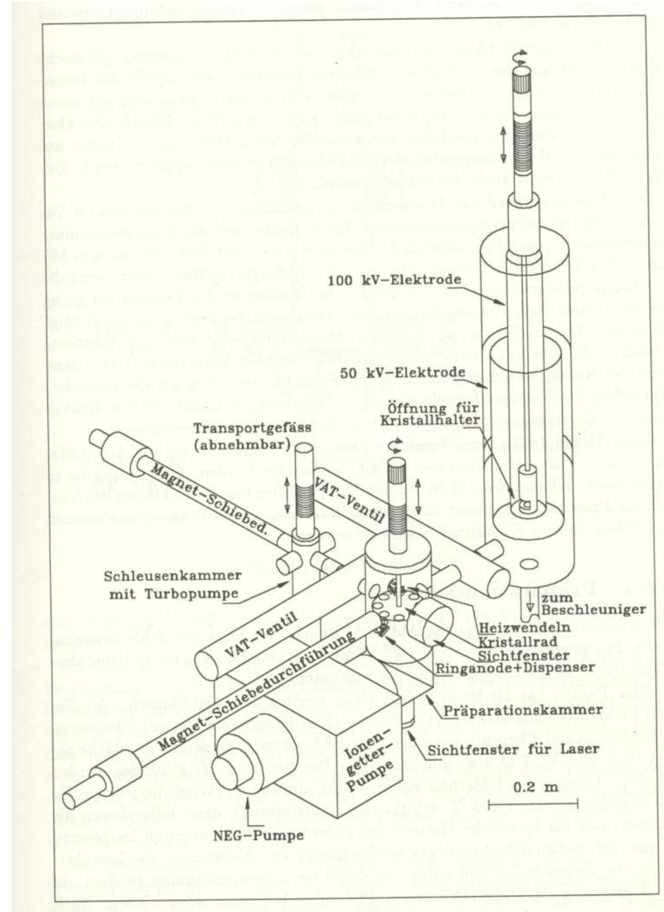
MAMI-Beschleunigerkomplex: Race-track-Mikrotron-kaskade (RTM1-RTM-3) mit Experimentier-stationen A1,A2,A4,X1.



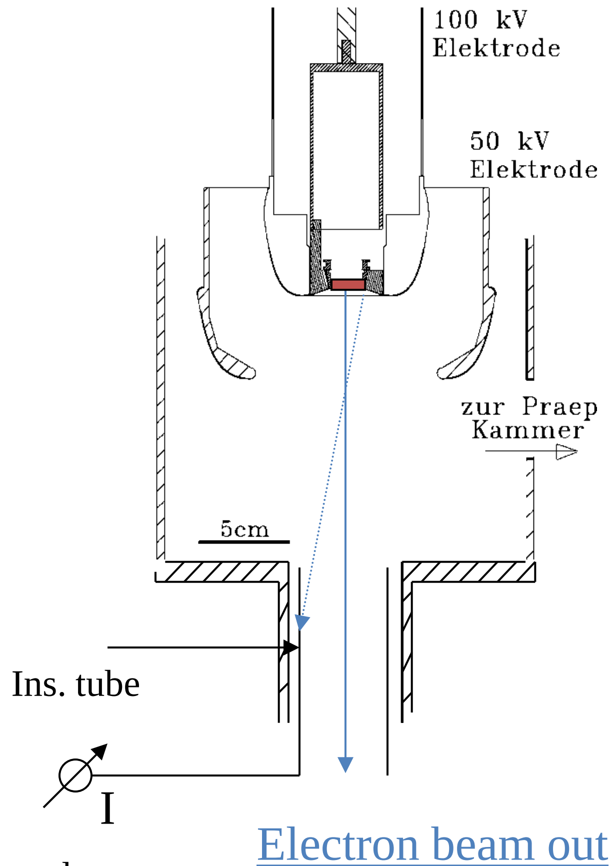

Schnitt durch Beschleunigungsregion
100kV−Elektrode
50kV Elektrode
Photokathode
5cm
Vakuumkammer
Laserinput/
Elektronenoutput
Position der
Kathode
Differentielle Pumpstufe
(vordere Pumpe entf.)
Wien-Fiter
(seit 2002)
'Schleuse'
2 Quadrupoltripletts
Kompensations-
Quadrupole
30 cm
B
B
B
E
E
E
e⁻
30 cm
konventioneller
Elektronenstrahl
Laser-in
270 Grad 'alpha'-
Magnet
Beginn des
Chopper-systems
Kollimatoren
(2.5 mm Durchmesser)
Leuchtschirme
B 2

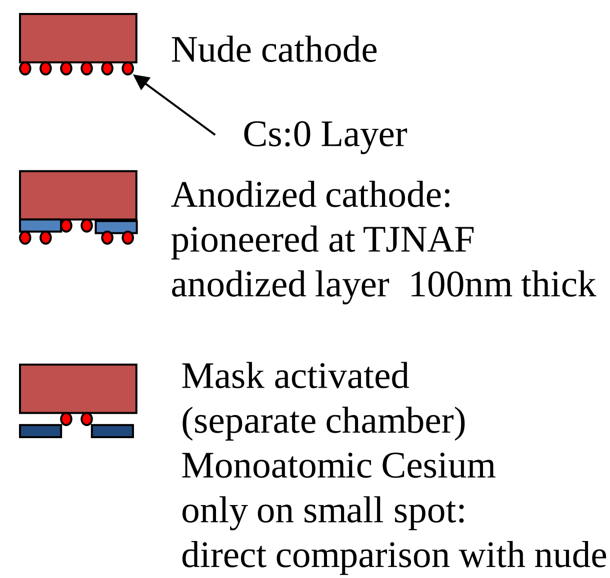


K. Aulenbacher et al. Nucl. Instrum meth A391 498-506 (1997)


100 kV–Elektrode
50 kV–Elektrode
Öffnung für Kristallhalter
Transportgefäss (abnehmbar)
Magnet–Schiebed.
VAT–Ventil
Schleusenkammer mit Turbopumpe
zum Beschleuniger
VAT–Ventil
Magnet–Schiebedurchführung
Heizwendeln
Kristallrad
Sichtfenster
Ringanode+Dispenser
Präparationskammer
Ionen-getter-Pumpe
Sichtfenster für Laser
0.2 m
NEG–Pumpe

Life time effects: transmission loss





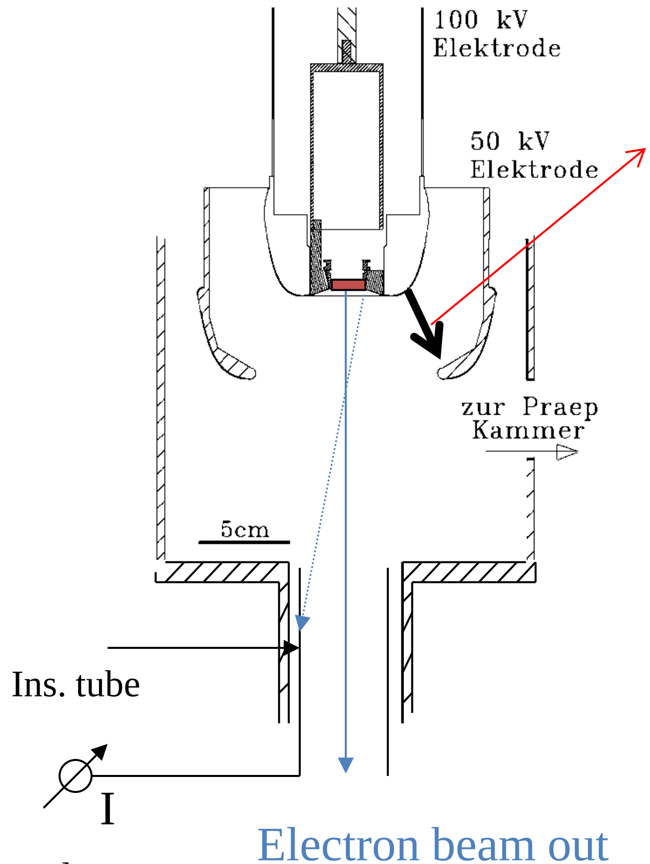
Measure loss:

$5*10^{-4}$ nude

$1*10^{-6}$ anodized

$<1*10^{-7}$ masked

Einschub: Feldemission



Measure loss:
$5*10^{-4}$ nude
$1*10^{-6}$ anodized
$<1*10^{-7}$ masked

Achtung: Feldemission ist de facto ein Transmissionsverlust!

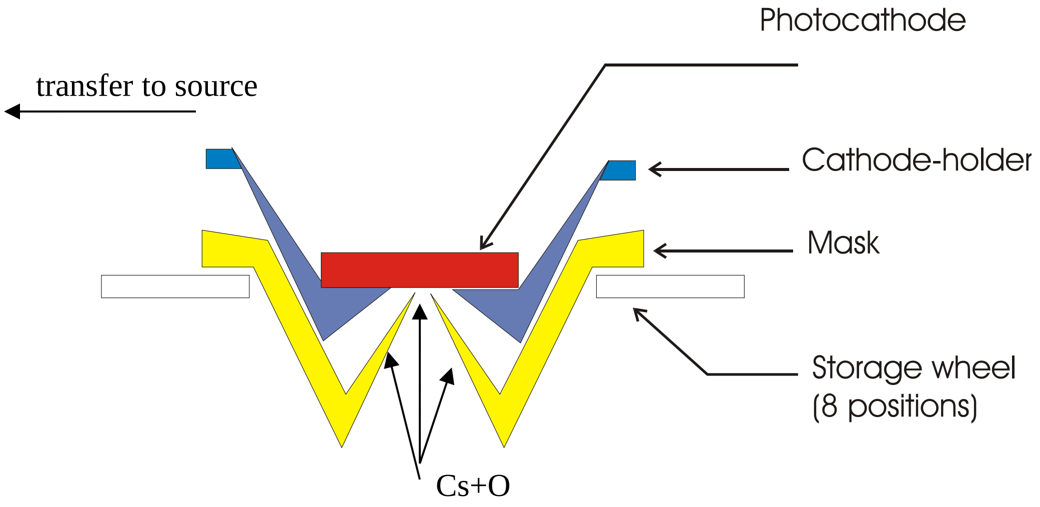
→ 100nA Feldemission limitieren die Lebensdauer

→ HV-Überschläge sind das Ende einer Kathode….

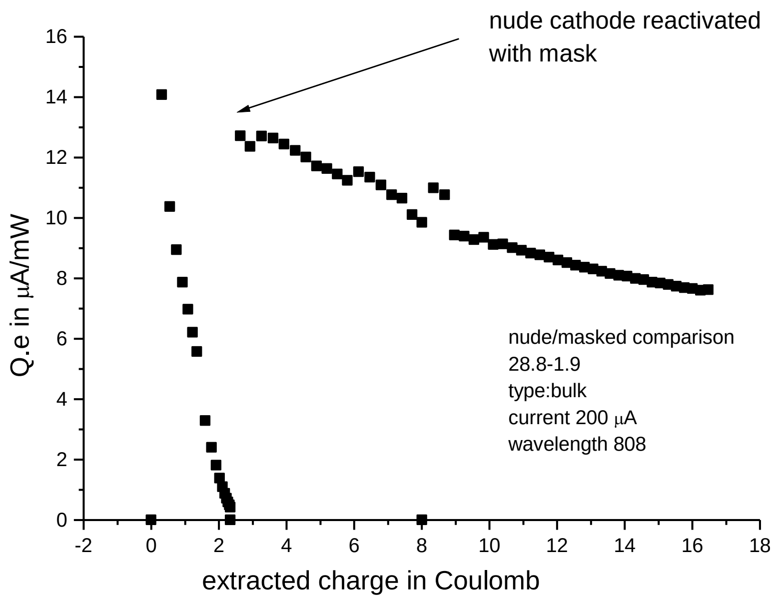
→ Bau von Quellen mit höheren Spannungen/Feldern erwünscht aber „Tanz auf dem Vulkan“

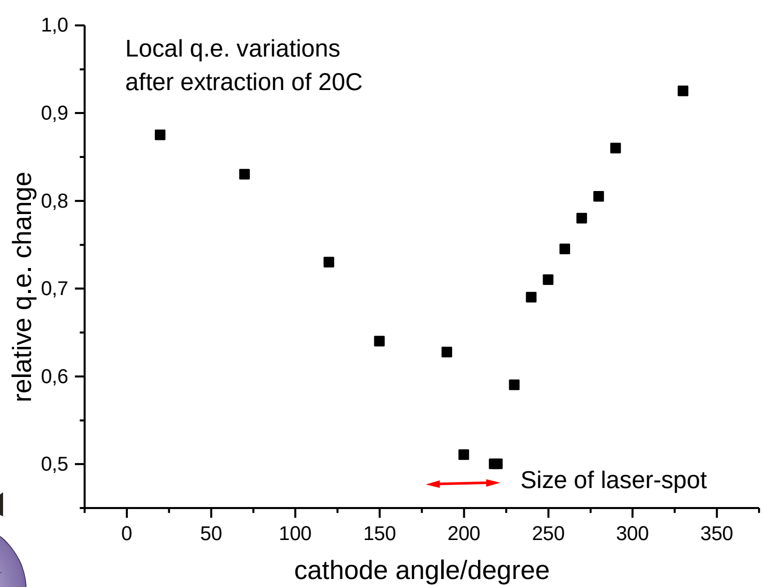
→ 200kV Quelle für MESA angedacht.

Nun weiter zu Transmissionsverlusten



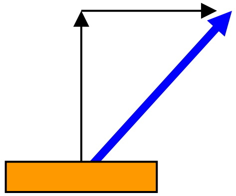
- Photocathode gets activated in conical mask (‘flower-pot’) with small hole in the bottom.
- 2.5 mm diameter covered with Cs only,
- no chemical treatment necessary
- direct comparison with ‘nude’ operation possible
- Cs does not ‘creep’ noticeably on surface.





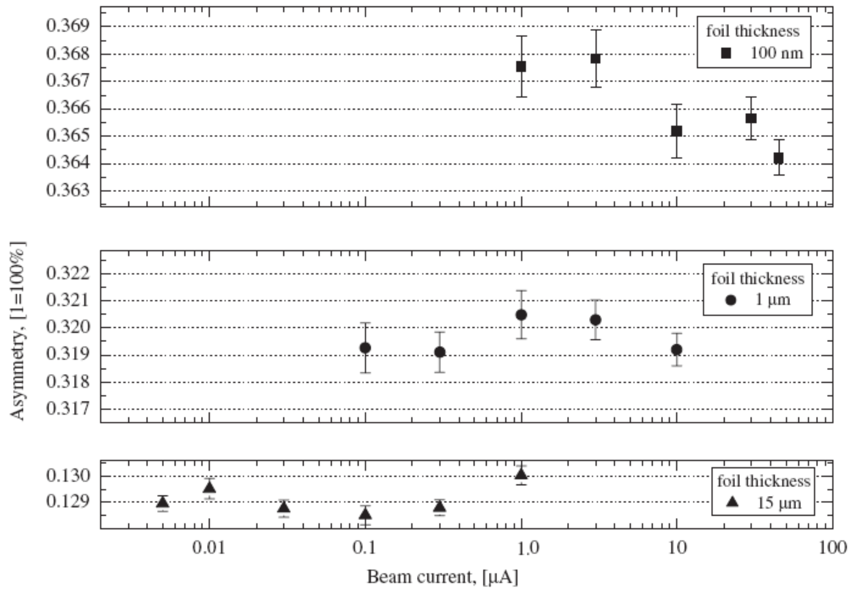
- direct comparison shows large improvement
- best nude operation lifetime: 22C
- with mask: lifetime 115C
- mask activated strained layer cathode used since spring 2002
- limited possibly by ‘hole burning’ (ion back-bombardment) to 30C/per laser spot (40000 C/cm^2)

Multi MeV Mott capabilities



Dynamic Range:

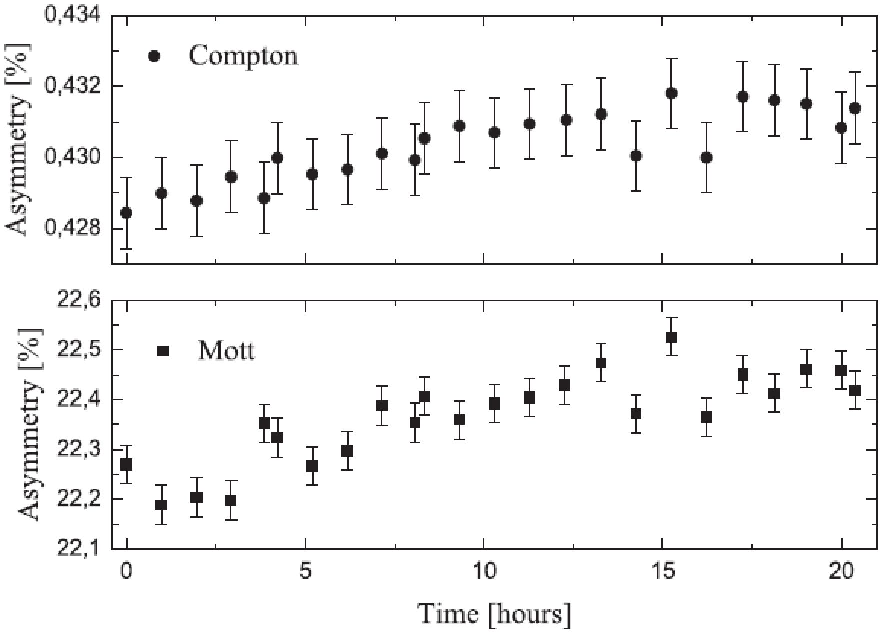
V. Tioukine et al. Rev. Sc. Instrum. **82** 033303 (2011)



Demonstration of constant polarization over large interval in intensities

Stability:

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



Polarization Drift consistently observed in transverse AND longitudinal observable at the <0.5% level

Different ERL Applications

Conclusion:

- 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,

CAS

Hotel Scandic Emporio

Hamburg May 31-June 10 2016

Kurt Aulenbacher

Johannes Gutenberg-Universität Mainz