Deflector Development

at the Cooler Synchrotron COSY/Jülich

October 2, 2012 | Ralf Gebel

Institute for Nuclear Physics (IKP-4/COSY)

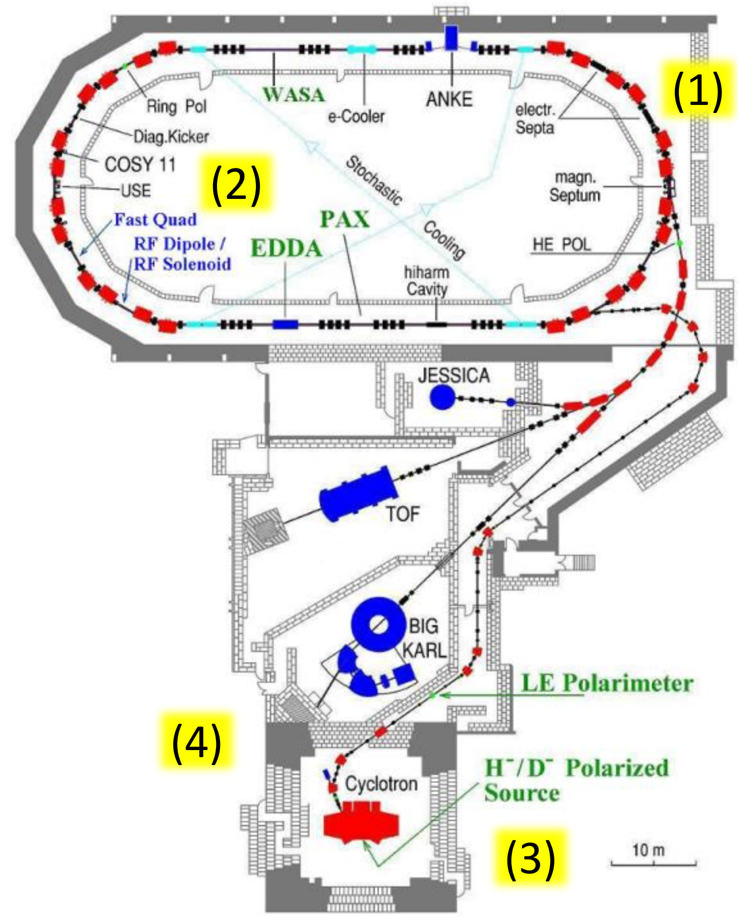
ECT* 2012, Trento, October 1-5, 2012

Outline

- Overview
- COSY extraction
- RF spin manipulation
- Ion sources and beam transport
- Cyclotron extraction
- Options for improving performance
- srEDM deflector Prototype
- Outlook

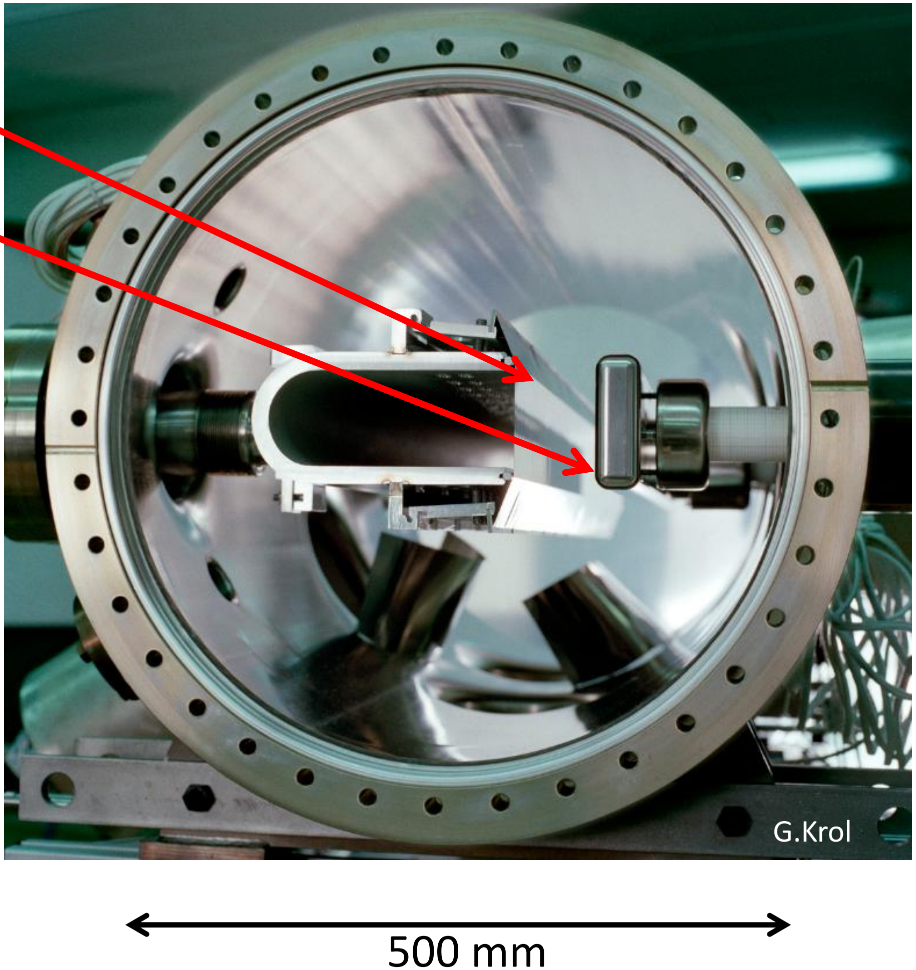
Deflectors at COSY

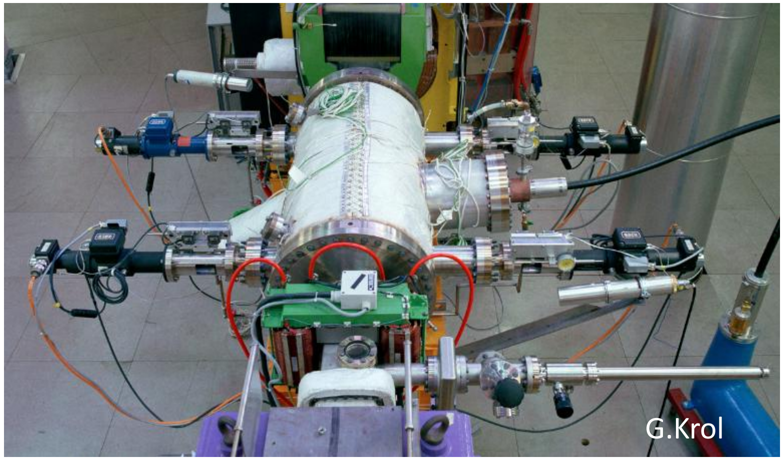
(1) Extraction of COSY beams
(2) rf devices
  - Solenoid
  - Dipole(s)
(3) Ion sources
  - pol. Source: 90° extraction
  - Beam line: 135° to polarimeter
  - (Extraction at high voltage)
(4) Cyclotron
  - Extraction of pos. and neg. ions
  - Injection



COSY Extraction Septum

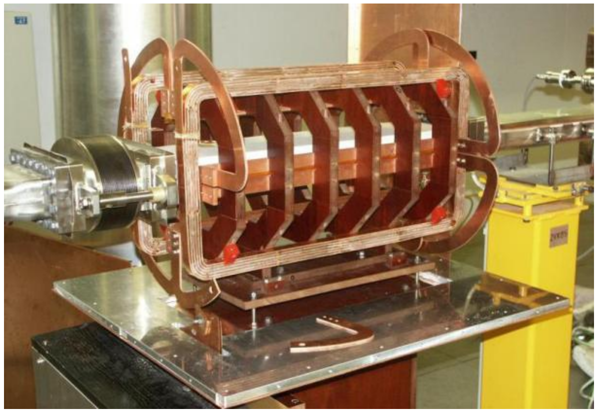
- Grounded septum foil (0.1 mm Mo)
- Max. 200 kV on cathode (Ti)
- Max. 120 kV/cm (3.3 GeV/c)
- In situ bakeable to 300°C
- Moveable electrodes (r, r')



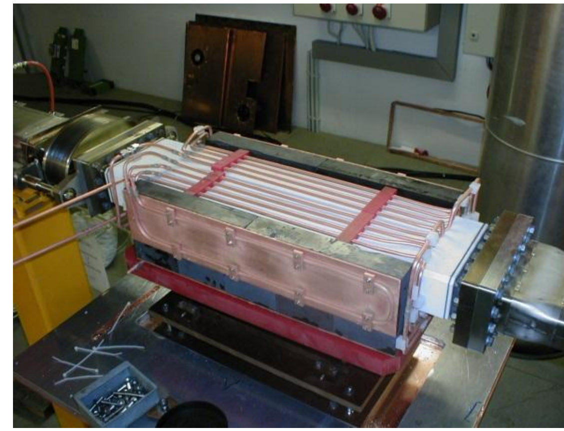


RF Deflectors for Spin Manipulations

Helmholtz dipole (2002)



Ferrite dipole (2003 – `07)



Parameter range:

- **250 to 1450 kHz**
- **0.2 - 1 T mm**

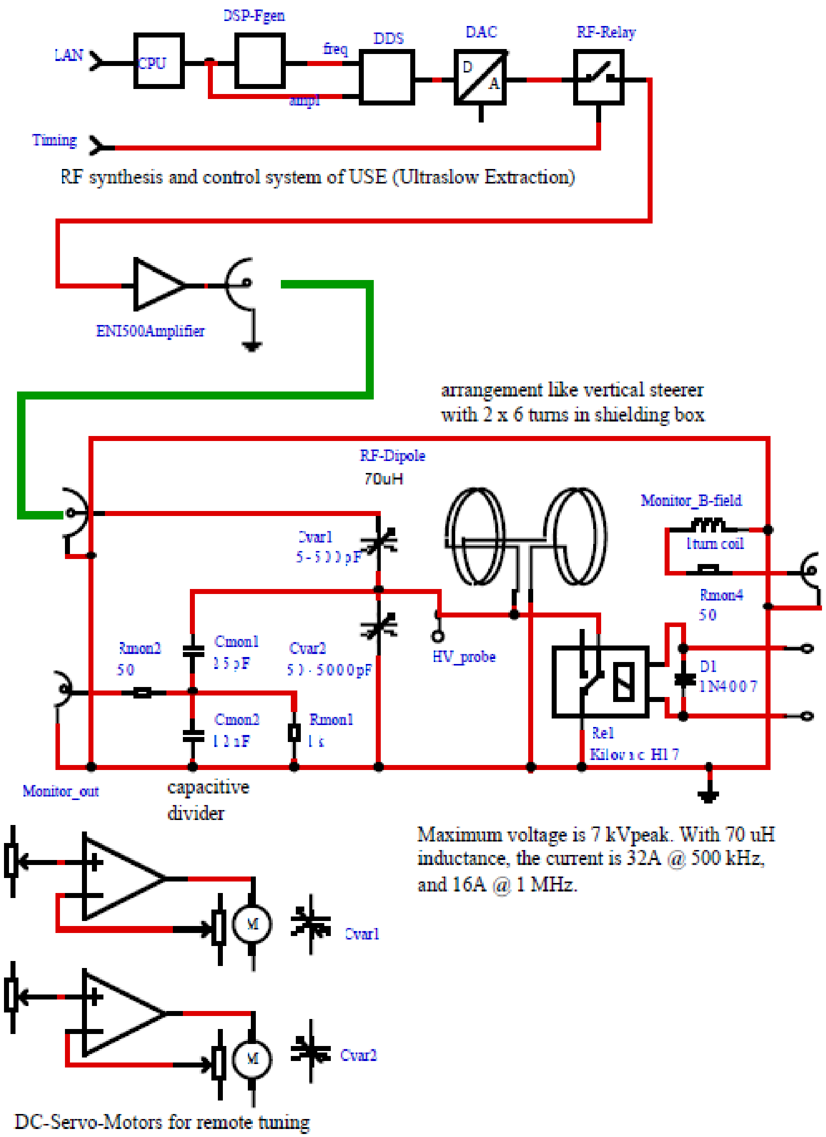
Solenoid (2007 -)

Plan for 2013+

Dipole + combined E/B

-> A.Lehrach's talk

RF Amplifier for the Spin Flipper



RF system (A. Schnase et.al.)

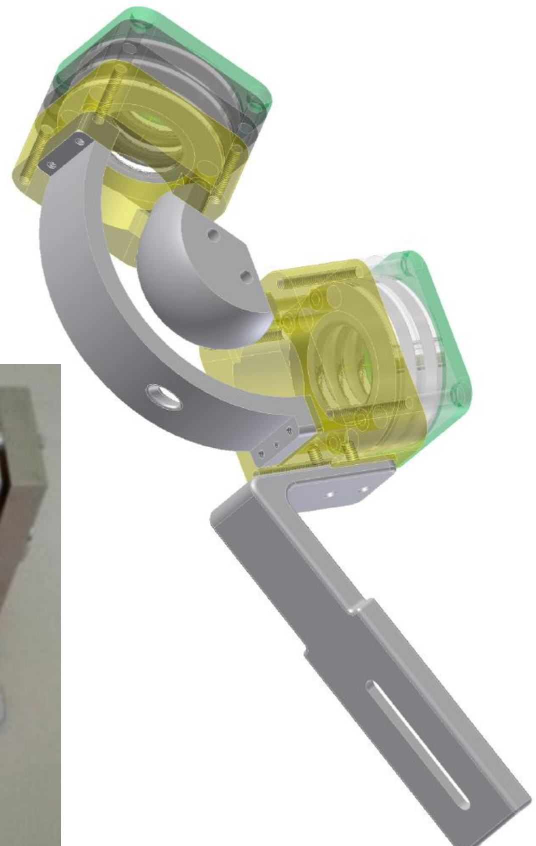
- Provides up to 1 kW RF power (resonant, up to 10 kV_p and 20 A_p)
- Locked to the COSY RF and timing
- System will be copied, enabled for E sin(ωt) +B sin(ωt + ϕ) operation

Ion Sources and Beam Transport

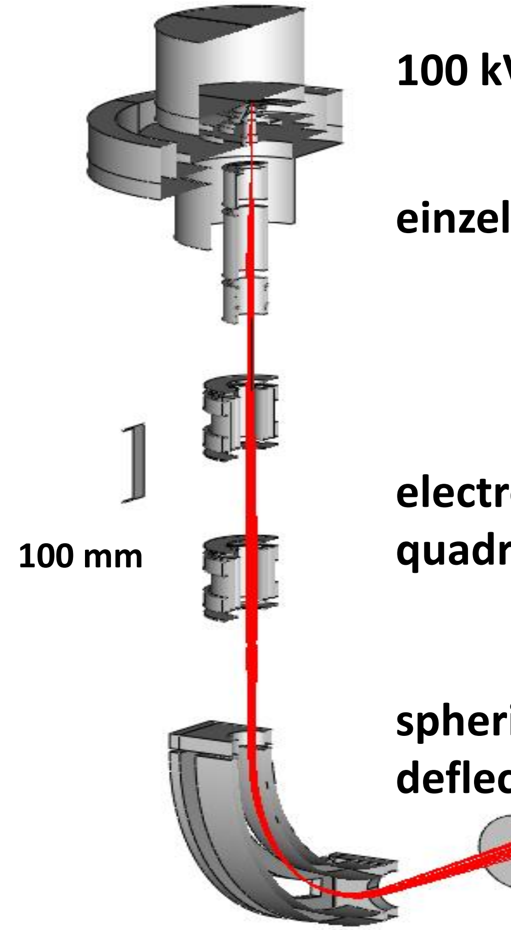
Spherical beam deflectors for ion beams

- 90° / 135°
- Low fields
- Low aberrations

90° deflector for pol. ions

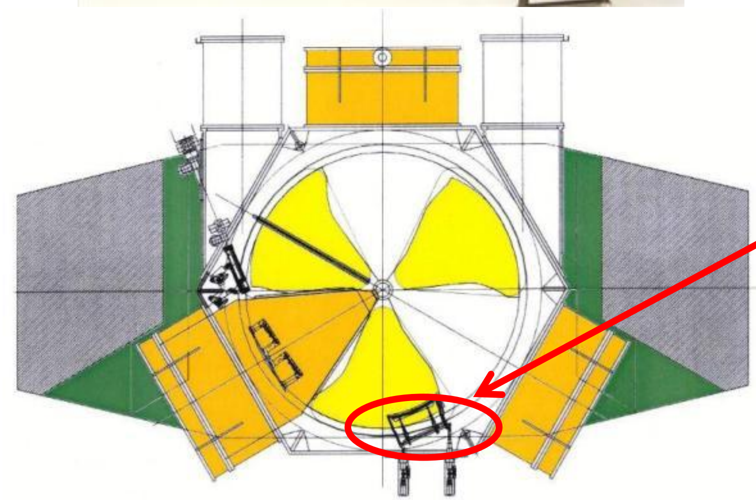


135° deflector



Study for ELENA/CERN

Cyclotron Extraction



AEG cyclotron

AEG design (RFQ: 1961)

1st internal beam: 1968

Pole diameter 3.3 m -> 700 t iron

$\langle B \rangle_{max}$ =1.35 T, B_{hill} = 1.97 T

RF 20 – 30 MHz (h=3, 100 kW_{peak})

22.5-45 MeV/A light ions

2-4.5 keV/A injection

3 ion sources (2 multicusp + pol. CBS)

Extraction channel starts with E-Septum

40 kV for 75 MeV d / gap: 0.35 cm

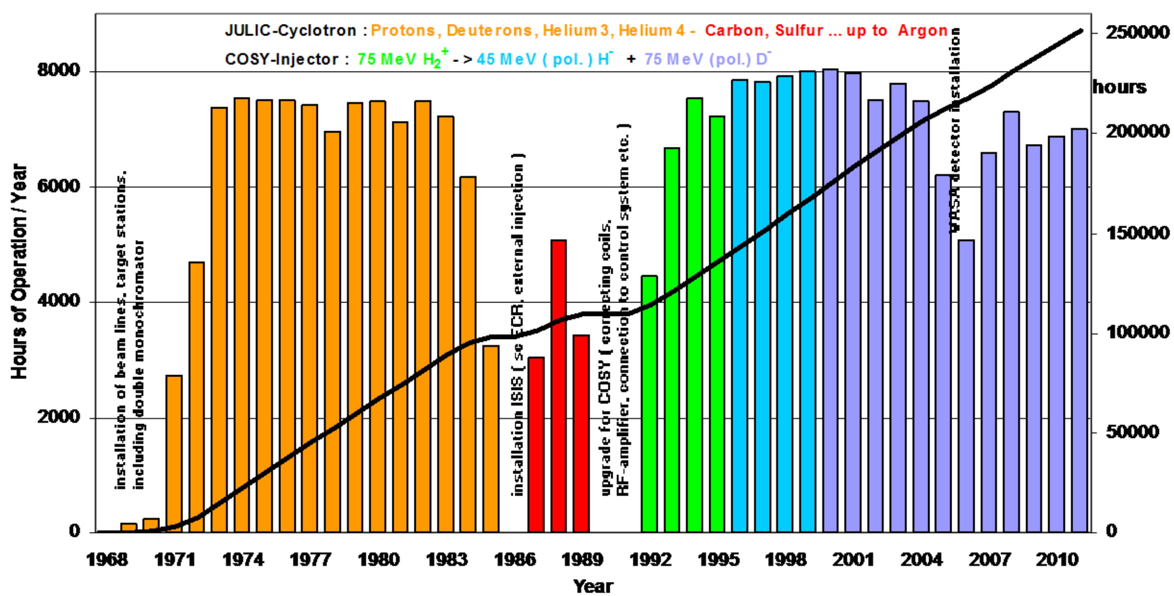
E-Field: > 115 kV/cm

B-Field: ~ 1 T

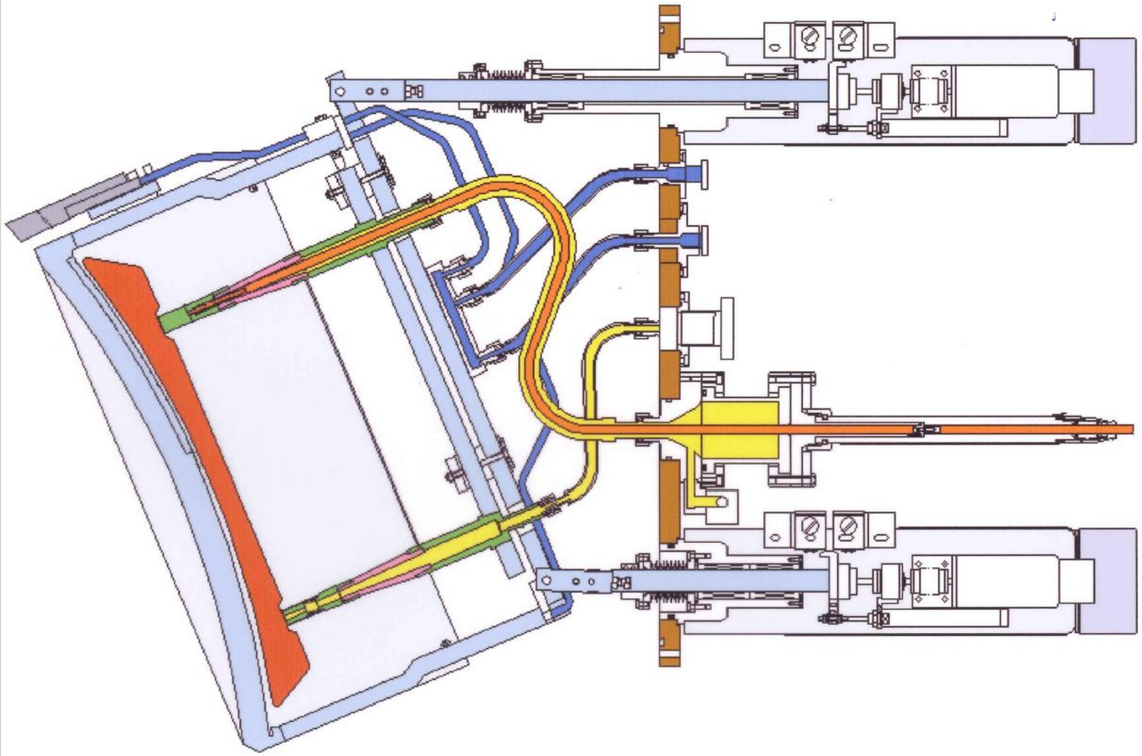
Cyclotron Extraction

Summary of septum operation

- Positive ions with negative voltages: okay
- H^- with positive voltages: developing since 1995
- D^- operation: pulsed operation since 2000



Septum Features



- FC77 cooling for HV parts (mineral oil before 2000)
- Ti septum
- Water cooling for anti septum
- Position control

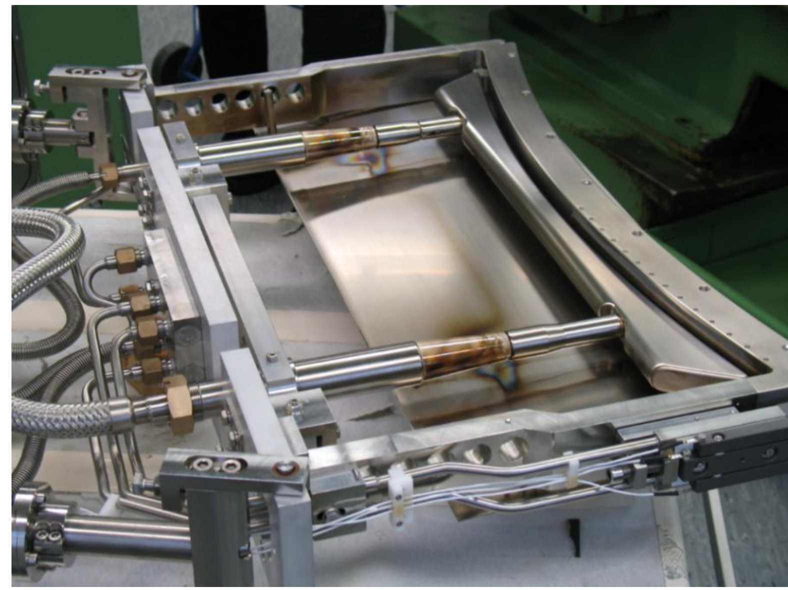
Treatment

- Material selection (Ti)
- Diamond paste polishing (DPP)
- Electro chemical polishing
- Oxygen processing

Operational issues:

- Conditioning (rev. Voltage)
- Accept mA dark current
- Pulsed operation

Cyclotron Septum



Before 2000:
No spares
no long term D^- operation possible

Since 2000: continuous improvement
2 spare septa
exchange rate: about 1 / year

Deflector Preparation

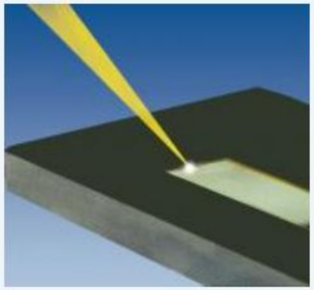
- Mechanical production and polishing with different grits
- DPP: Diamond paste or spray polishing
- BCP/ECP: Buffered/electro chemical polishing
- HPR: High Pressure Rinsing (not at FZJ)
- Ultra sonic cleaning
- Acid-, Alkali- cocktails, …
- Vacuum / plasma annealing

Up to now: Long term D^- only in pulsed operation possible.

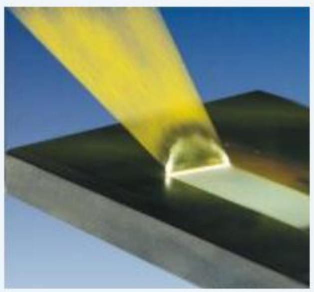
Candidates for improvement:

- **Laser cleaning**
- **Gas conditioning** (PT cyclotrons; Oxygen, Jefferson Lab: Krypton)

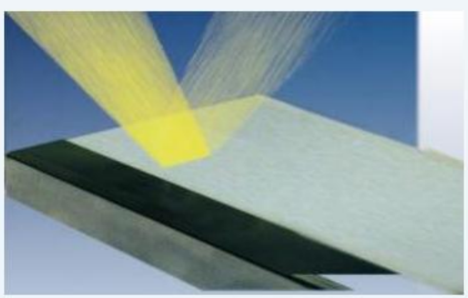
Cleaning with pulsed IR Laser Light



Rapid pulsed laser beam scans across treated surface

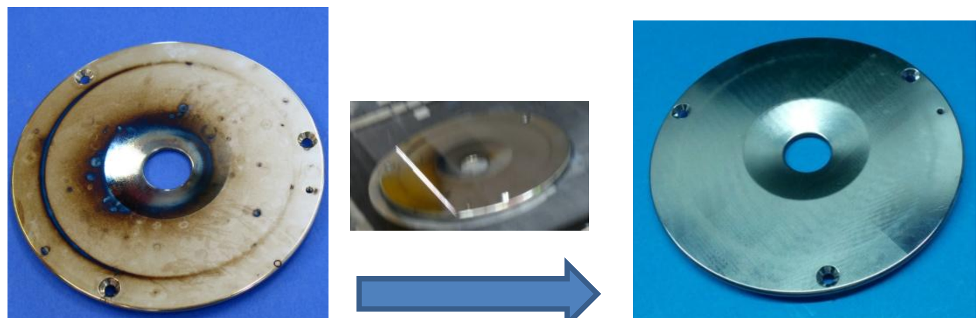


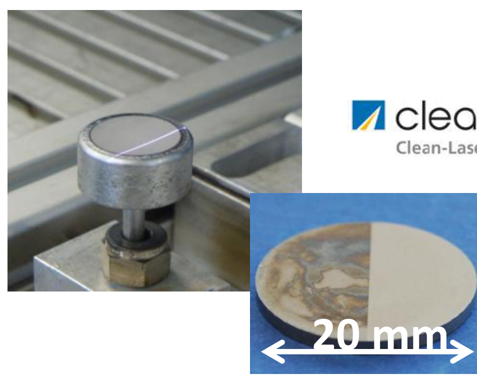
Target coating/contaminant is vaporized & residue is captured



Cleaning process stops when target material is removed

- **Application samples:**
  - **Extraction electrode**
  - **Tungsten ionizer, disk**
- **Speed: several cm²/s**
- **No chemistry, less waste (vapour only)**





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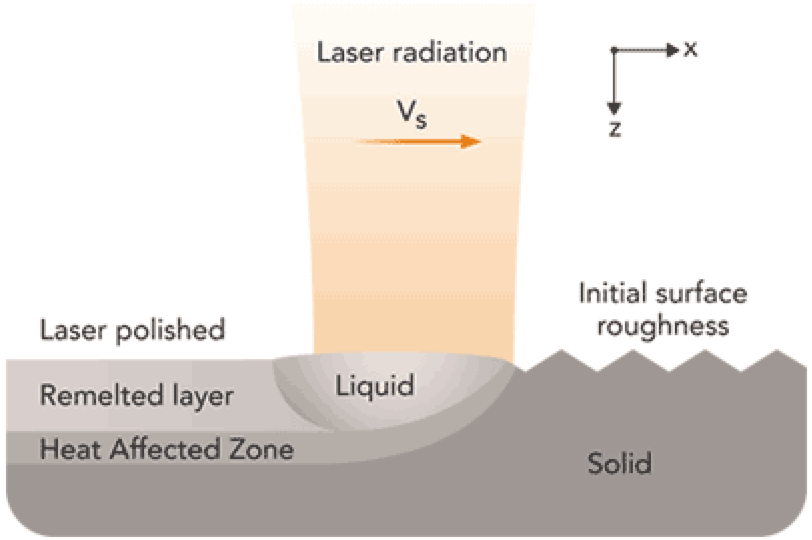
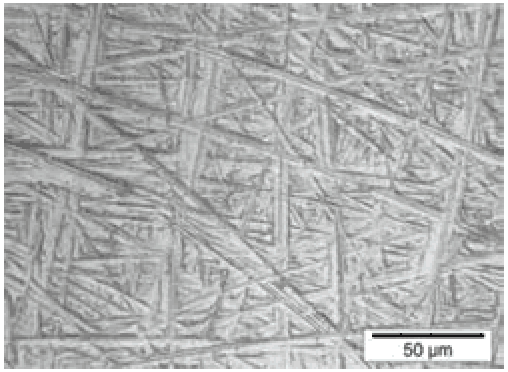
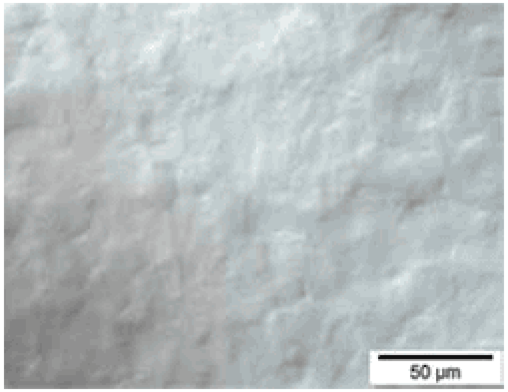
More power, continous operation

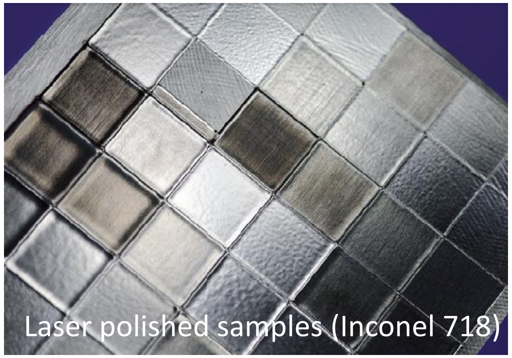






Polishing results for selected metals[3,4]

METAL	PROCESS VARIANT	INITIAL ROUGHNESS RA	ROUGHNESS AFTER LASER POLISHING RA	PROCESSING TIME
tool steels e.g. 1.2343, 1.2344, 1.2316, 1.2365	macro	1 - 5 µm	0.05 - 0.15 µm	» 60 s/cm²
1.3344	micro	0.5 - 1 µm	0.3 µm	3 s/cm²
Titanium, TiAl6V4	macro micro	3 µm 0.3 - 0.5 µm	0.5 µm 0.1 µm	10 s/cm² 3 s/cm²
Bronze	macro	10 µm	1 µm	10 s/cm²
Stainless steel 1.4435, 1.4571	macro	1 - 3 µm	0.2 - 1 µm	60 - 120 s/cm²


Laser polished samples (Inconel 718)

Fraunhofer ILT

Collected from web pages of: Fraunhofer-Institut für Lasertechnik ILT, www.ilt.fraunhofer.de

Polarized Electron Source "Musts"

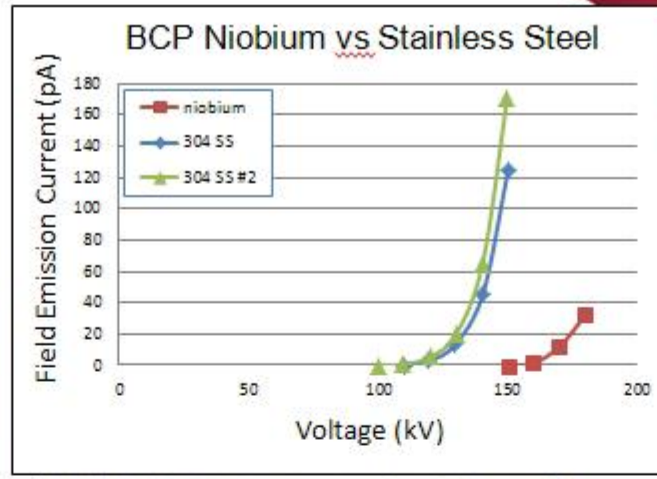
Good Electron Gun

Good Laser

Good Photocathode

- Ultrahigh vacuum
- No field emission
- Maintenance-free

Niobium
- Capable of operation at higher voltage and gradient?
- Buffer chemical polish (BCP) much easier than diamond-paste-polish

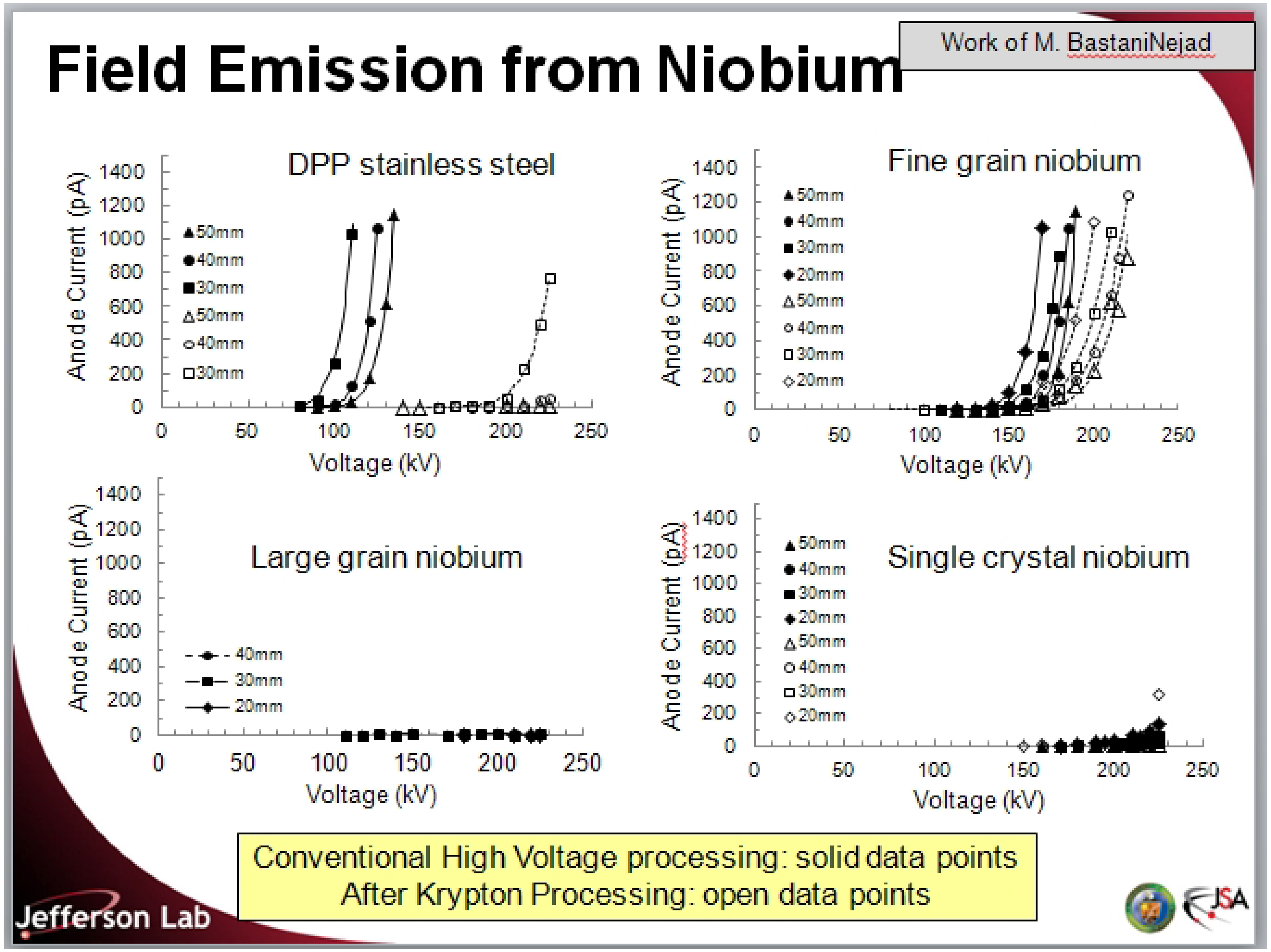


Conventional geometry: cathode electrode mounted on metal support structure

Replace conventional ceramic insulator with "Inverted" insulator: no SF6 and no HV breakdown outside chamber

Work of Ken Surles-Law

With permission of M.Poelker, from his talk at SPIN2012 (Dubna, 2012, September 16- 22)



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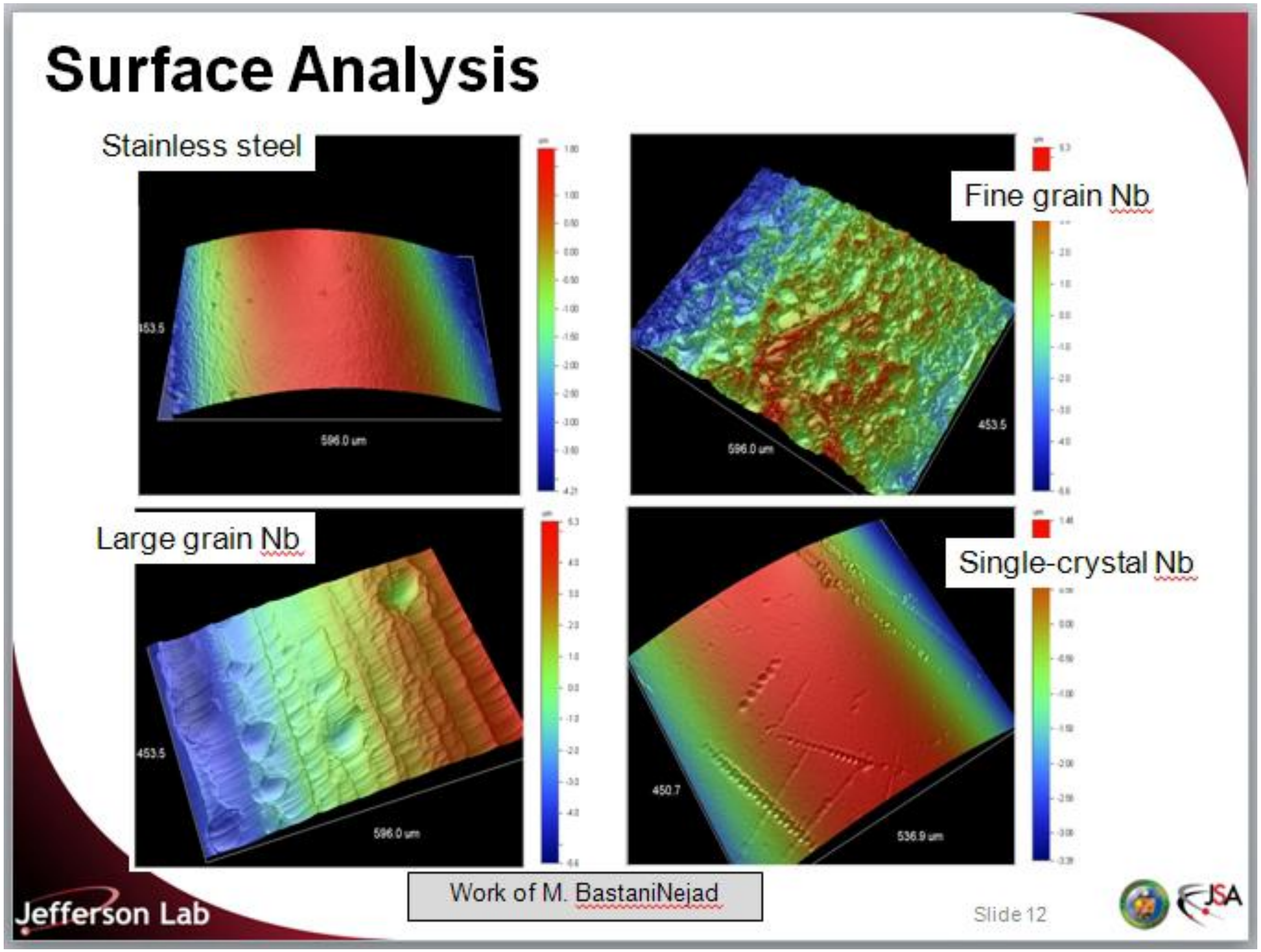
See also: PhysRevSTAB.15.083502



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See also: PhysRevSTAB.15.083502 (optical profilometer images)

An iron free deflector

R.Talman's design proposal

- Landau-Lifschitz:
  - analytic model
  - Numerical model
  - Prototype
- Technical issues
  - Field quality
  - Thermal load, cooling
  - Precision

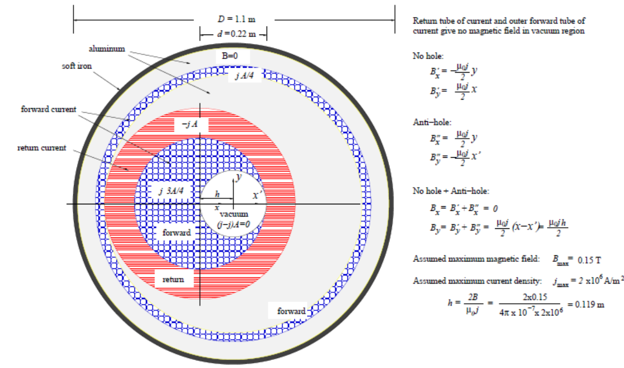
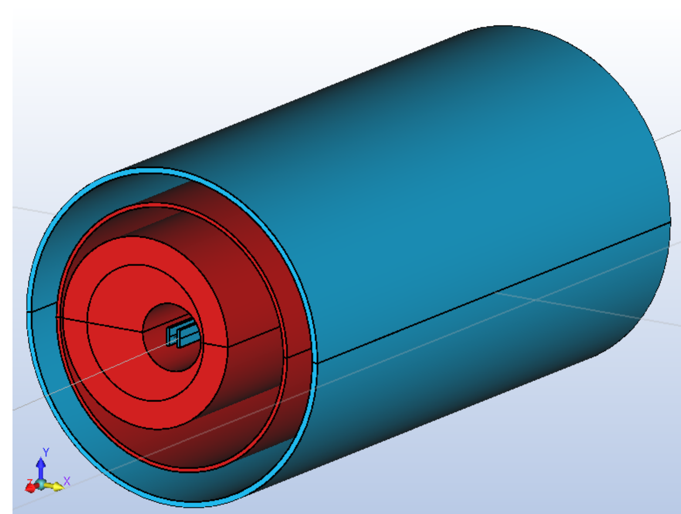
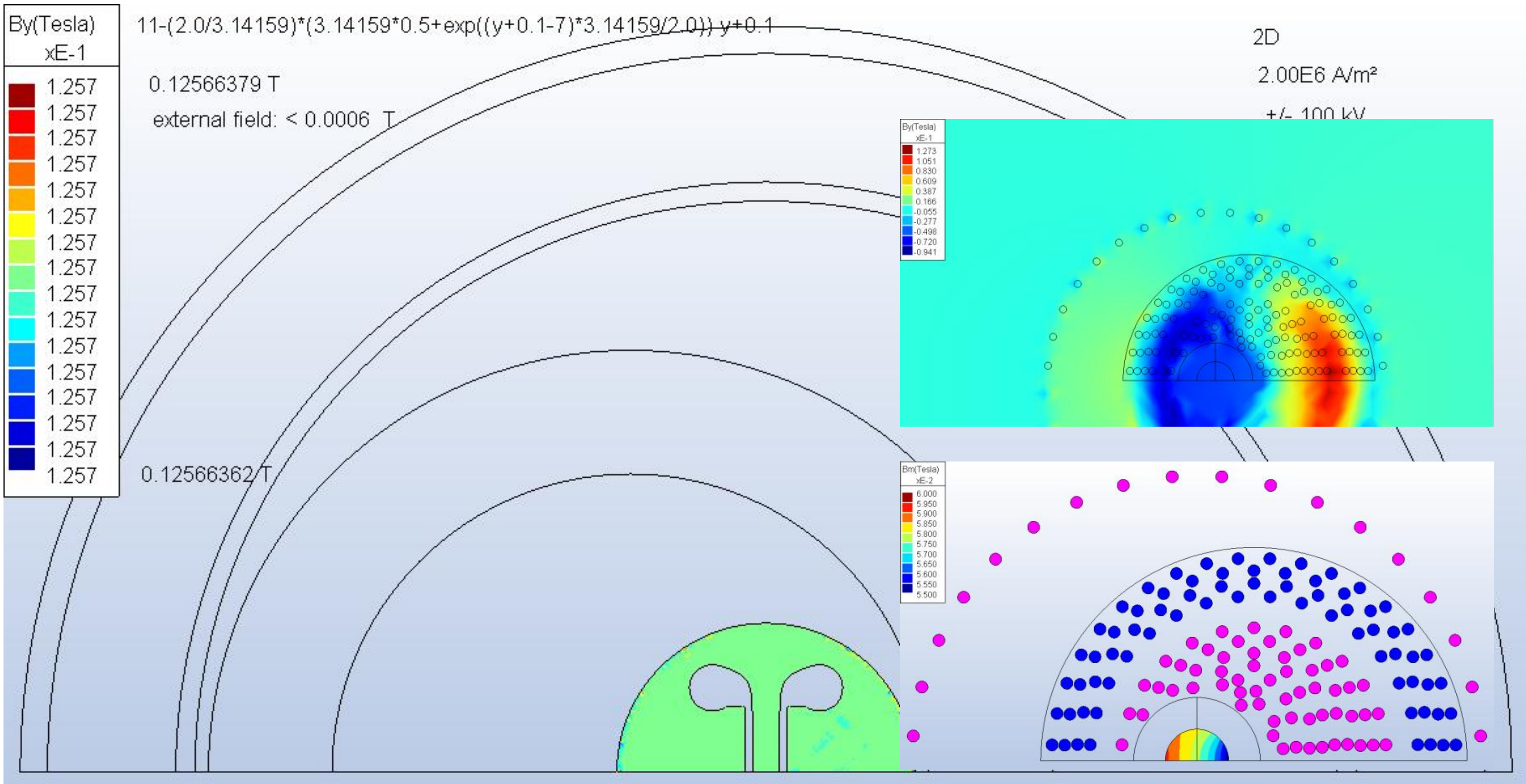


Figure 10: Iron-free, all current, uniform field magnet. The current configuration starts from an example in Landau and Lifshitz, *Electrodynamics of Continuous Media.*

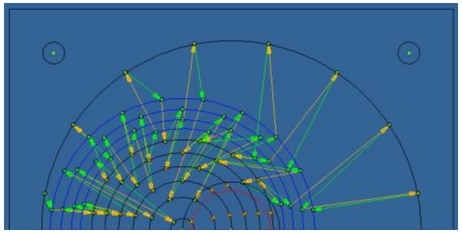


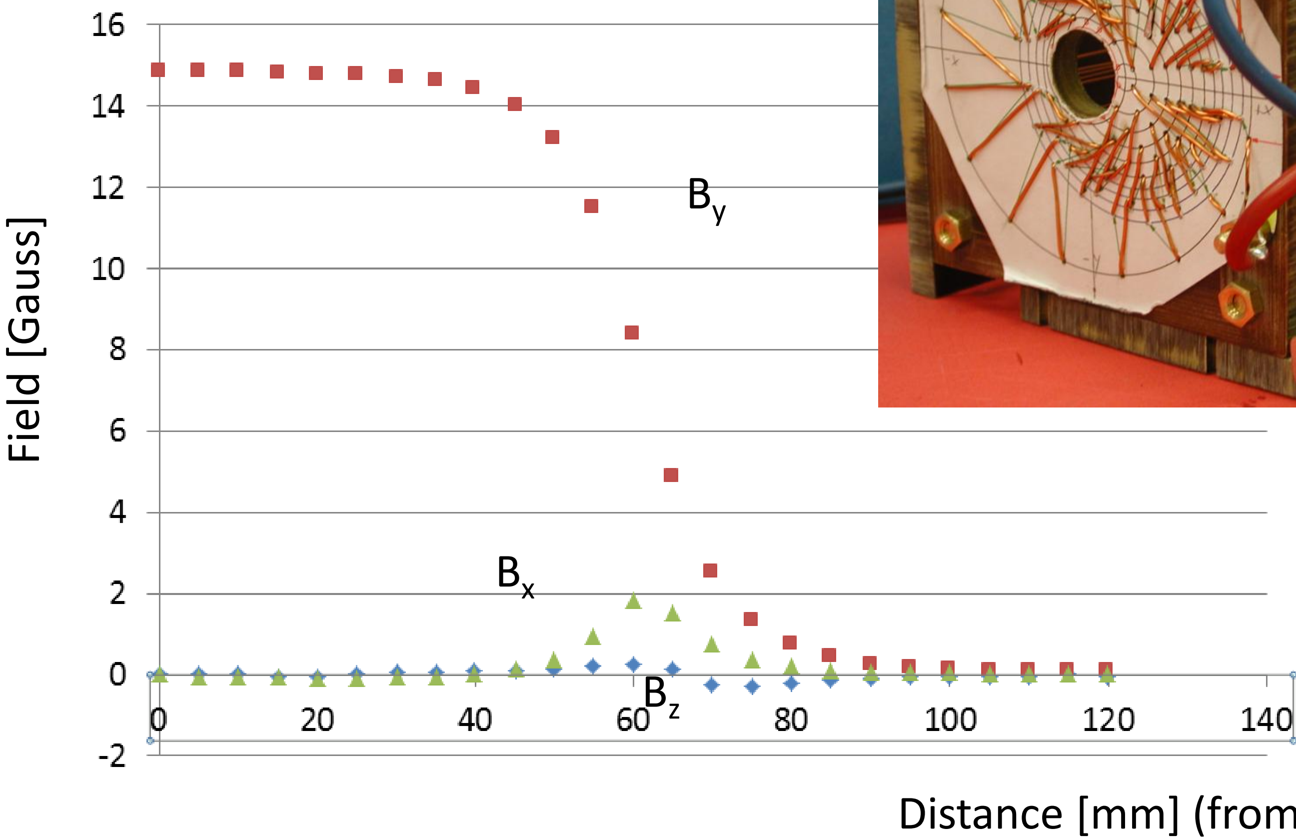
Development steps

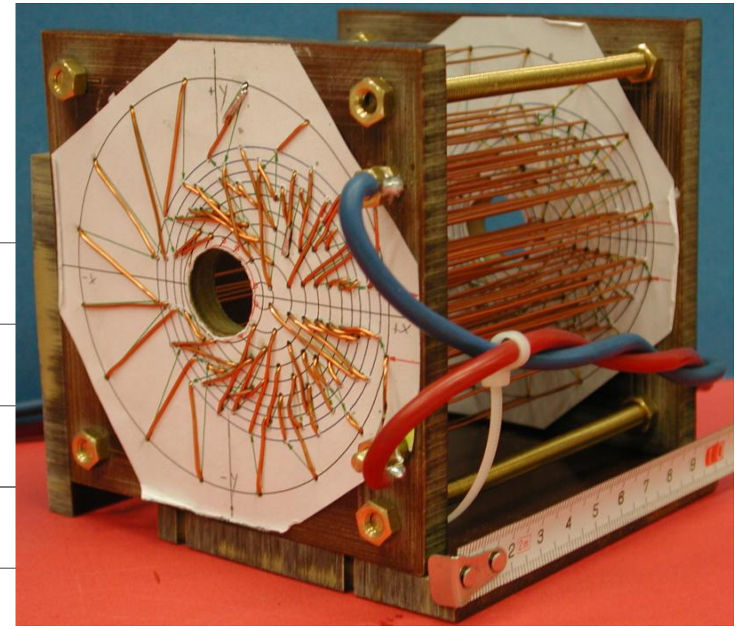
from Landau Lifschitz towards a real magnet



A first prototype







Magnet parameter
104 mm length
22 mm hole
Max. 5 A -> 1.5 mT
0.7 mm wire (22 W)

Outlook

- Deflector development
  - E/B spin manipulator test in 2013
- Application of new methods
  - laser clean cell available soon
  - check gas processing for both polarities
  - Tests with Nb (RRR300 samples available at FZJ)
- Magnet optimization
  - Improvement of srEDM deflector model

Thank you for your attention!