Target Material Tests at Facilities in Hamburg

- **So far:** Tests at Mami / Mainz
- **Coming:** Analysis of structural changes using synchrotron radiation @ PETRA III
- **Planned:** Compact irradiation source for in-situ investigations of structural changes

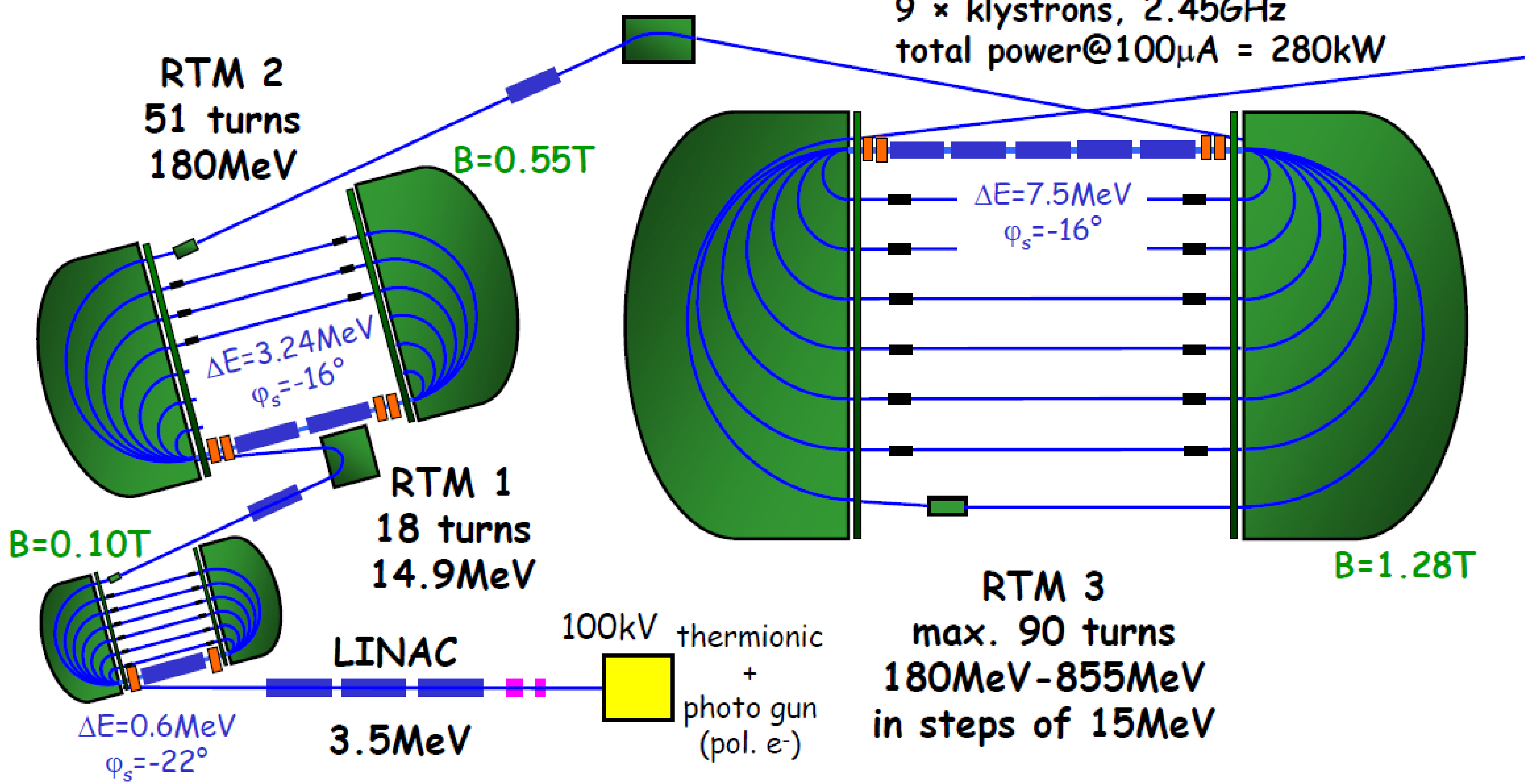
G. Moortgat-Pick, A. Ushakov, A. Prudnikava, Y. Tamashevich, W. Hillert (UHH)
S. Riemann, A. Ignatenko (DESY)
D. Lott (Geesthacht)
K. Aulenbacher, T. Beiser, P. Heil, V. Tioukine (U Mainz)

Target Experiments @ MAMI

Successful Runs @ MAMI / Mainz:

- Injector (3.5 MeV) and MAMI A1 (14 MeV):
  - 3/16, 11/16, 1/17, 3/17,…. next run probably begin 2018
  - generating similar load as for ILC target within short time
  - several targets, different thickness

The Mainz Microtron MAMI, scheme



beam parameters: 100μA max cw current (86kW beam power)

injector linac:	RTM 1:	RTM 2:	*) RTM 3:
σE=1.2keV ($3\cdot10^{-4}$)	σE=1.2keV ($8\cdot10^{-5}$)	σE=2.8keV ($1.5\cdot10^{-5}$)	σE=13keV ($1.5\cdot10^{-5}$)
$\varepsilon_{x,n}=0.05\cdot10^{-6}$ m rad	$\varepsilon_{x,n}=0.07\cdot10^{-6}$ m rad	$\varepsilon_{x,n}=0.25\cdot10^{-6}$ m rad	$\varepsilon_{x,n}=13\cdot10^{-6}$ m rad
			$\varepsilon_{x,abs}=8\cdot10^{-9}$ m rad

*) Increase in energy spread and emittance due to sr-effects

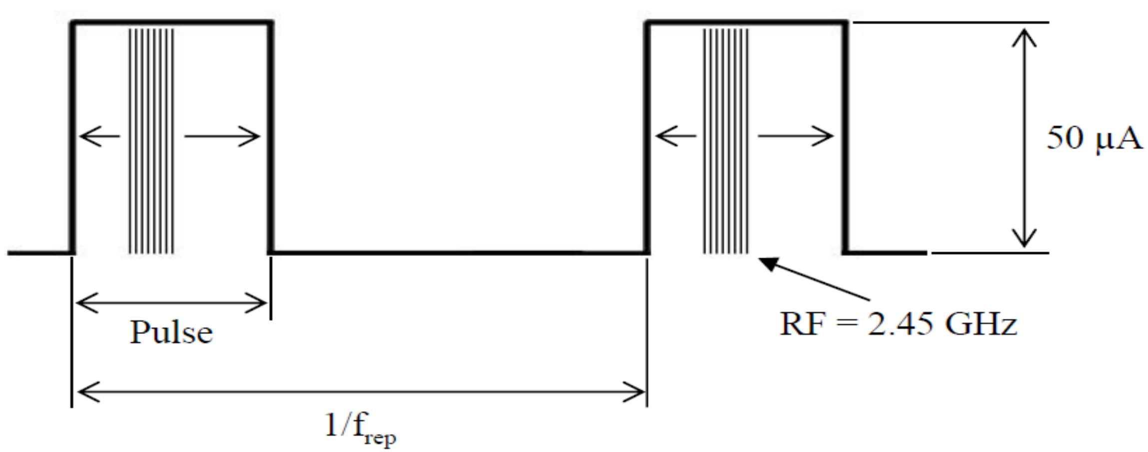
MAMI A @ Mainz

Target Experiments @ MAMI

Simulate ILC load on e+ target (or windows) using e- beam @ MAMI / Mainz

Testing conditions @ LINAC and MAMI A1:

- **10 μA average beam current, f_{rep} = 100 Hz**
- Pulse length: mainly 2 ms (rotating ILC target: ~50 μs)
- 1.28×10^{5} e-/bunch, 4.08×10^{-10}s bunch spacing
  → 4.9×10^{6} bunches in 2 ms, 6.25×10^{11} e- per 2 ms pulse
- Beam sizes focused below 200 μm



Target test run 1 (March 2016)

All targets:
50 μA during pulse

#1: 1 mm thickness
wo thermal contact to holder
2 ms, 100 Hz
~18.5h of irradiation

#2: 1 mm thickness
with thermal contact to holder
3 ms, 67 Hz
~4h of irradiation

#3: 2 mm thickness
wo thermal contact to holder
2 ms, 100 Hz
~14.5h of irradiation

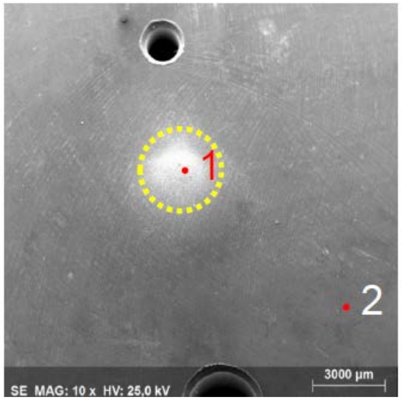
#4: not used

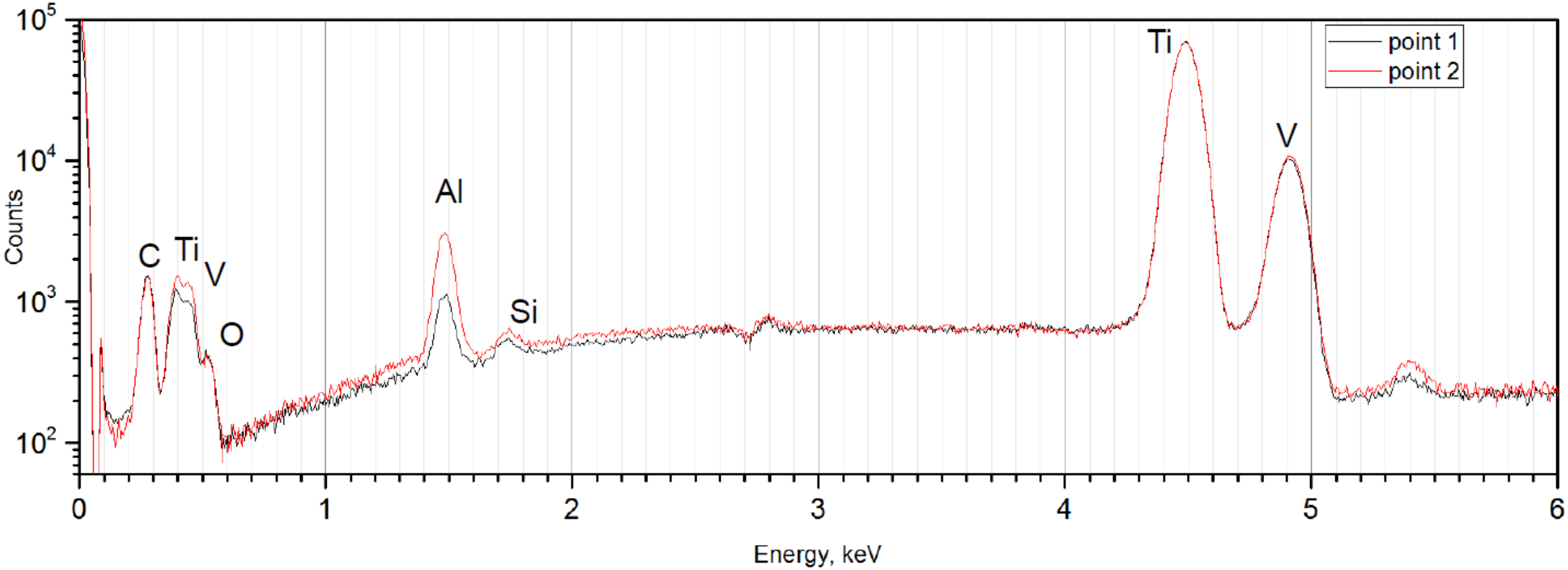
SEM result for target #3 (2mm thick)

Point 1: beam spot area

Point 2: non irradiated area

After irradiation, Al concentration was reduced in beam spot ares

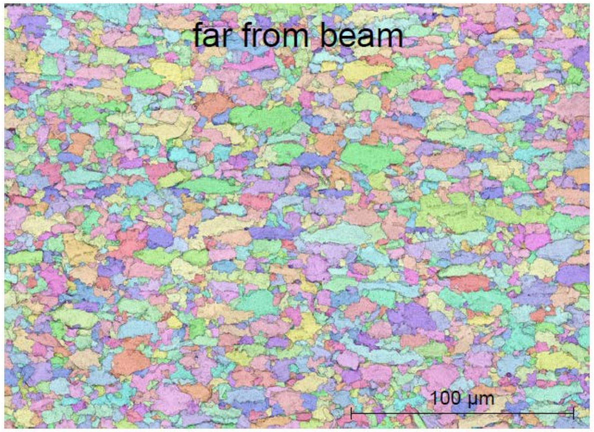




*Results are normalized to Ti (4,5 keV)

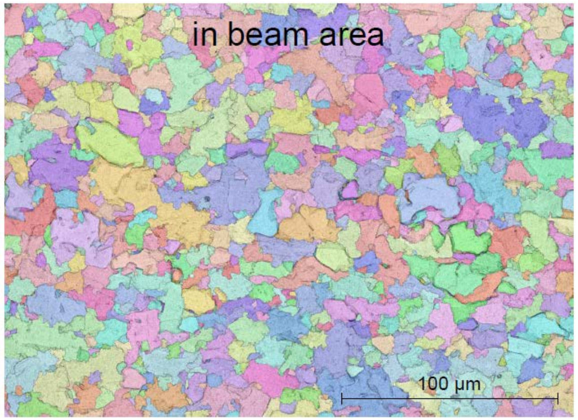
Target	Thickness	Cooling	Irradiation regime	T_{ave} [C] (sim.)	T_{peak}[C] (sim.)	#of load cycles	Deformation front/exit
1	1mm	thermal radiation	2ms 100Hz	629	690	6.8×10^6	0 / ≤15μm
2	1mm	Thermal contact +radiation	3ms 67Hz	max		1.2×10^6	0 / 0
3	2mm	thermal radiation	2ms 100Hz	713	713	5.2×10^6	≤28μm / ≤15μm

- All targets stand the long term irradiation without cracks or holes
- At temperatures above 700˚C we obtained dimensional changes and substantial grain growth in the region around beam path



main grain area [μm^2]:
19 μm^2 (far beam area)
50 μm^2 (far beam area)

main grain area [μm^2]:
291 μm^2 (far beam area)
982 μm^2 (far beam area)



Irradiation of thin targets (Nov 2016)

Irradiation regime:

- 2ms/100Hz, 10uA average current
- Cooling: thermal radiation + heat conduction to holder

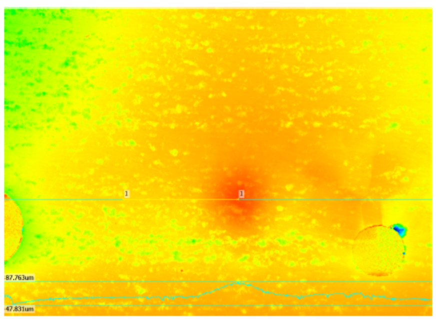
Irradiation of thin layers (2017)

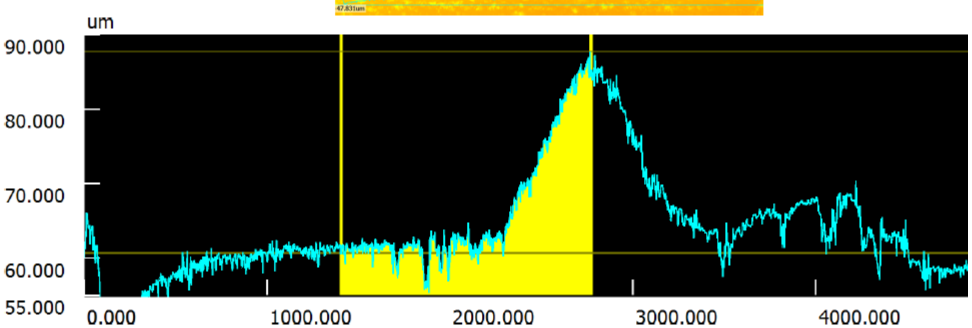
- Irradiation regime:
  - 50uA peak current, but
  - longer pulse length,
  - low rep rate
- Goal: vary the pulse length up to 5ms to achieve high peak load
- Cooling: thermal radiation + heat conduction to holder

Irradiation of thin layers – preliminary result

- No changes obtained for irradiation with 2ms pulses (100Hz, 1Hz)
- Plastic deformation (27-39um) for 0.2mm Ti6Al4V, 5ms, 1Hz
  - Possible reasons:
    - beam size smaller as expected
    - Lower surface emissivity
  - analyses will be continued

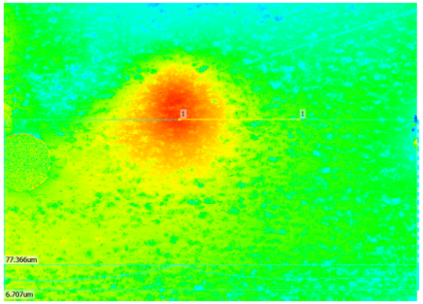
front side

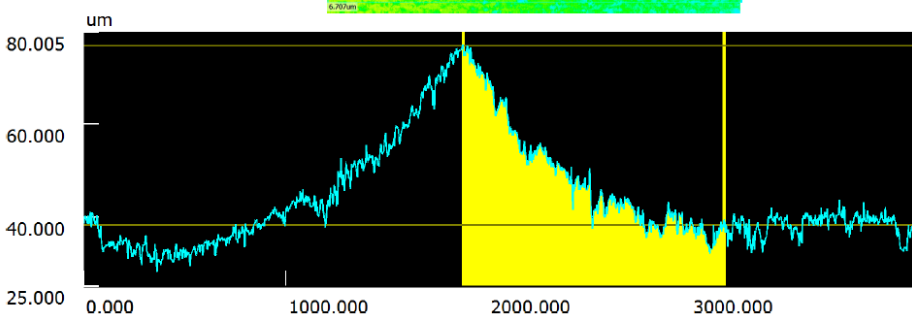




Hight difference = 27 μm

back side





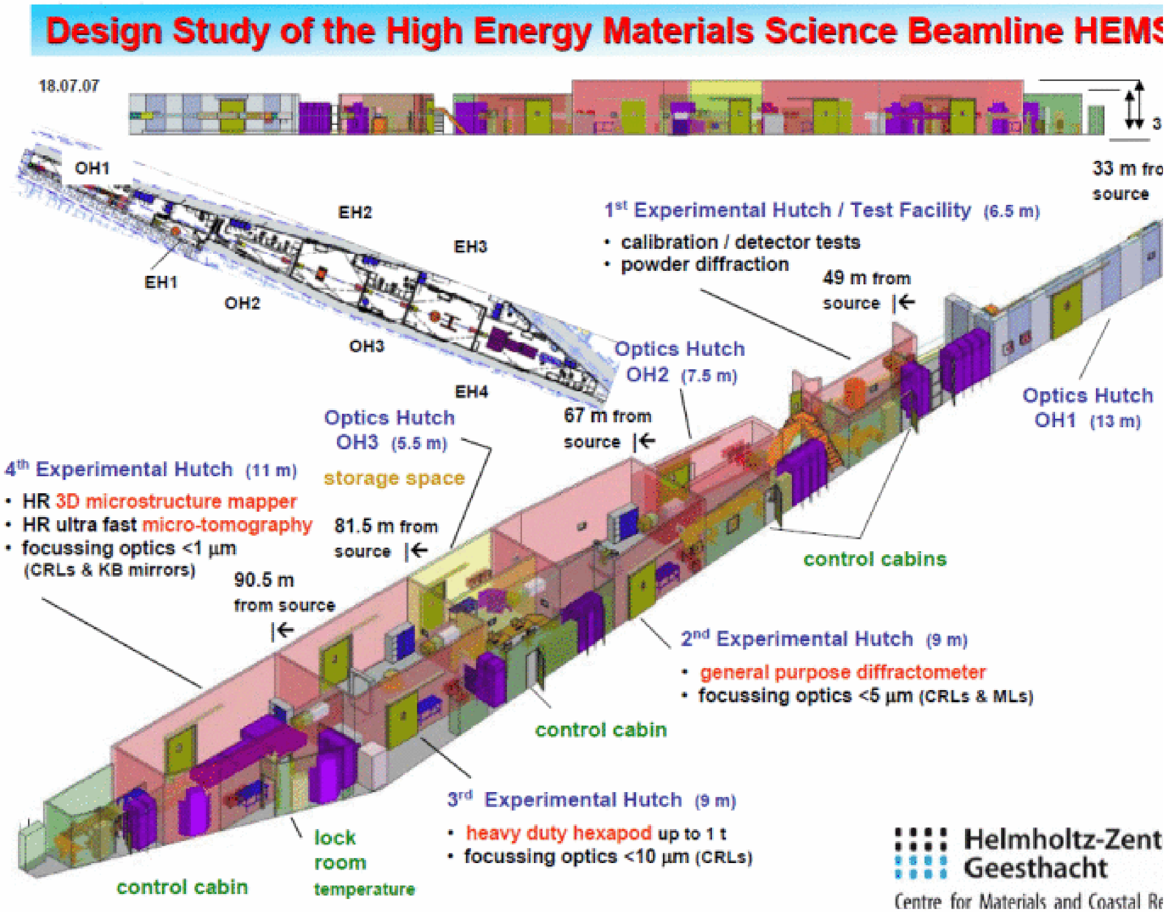
Hight difference = 39 μm

New Plans for DESY

'ex-situ'

- Using PETRA III beam for analyzing material
  - high-energetic synchrotron radiation of high brilliance: roentgen diffraction
  - **γ**-beam practically no divergence
  - point-like analysis of material **(beam <200μm)**
  - understanding of micro structure
  - high-energetic radiation (50keV-200keV) allows to analyse material of several mm thickness!
    - exactly what we need,……
- Planned: e.g. study different Ti-alloys, which phase, etc.

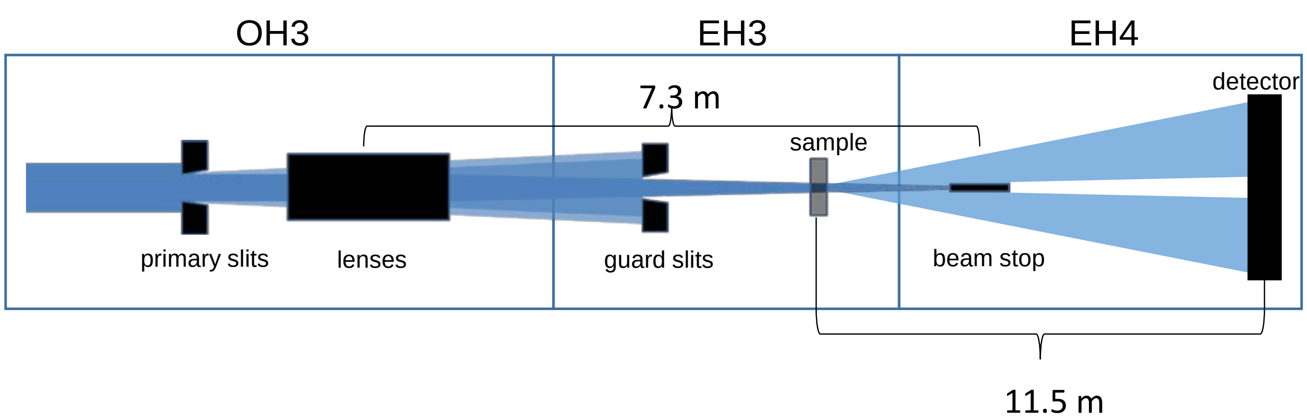
Small Angle X-Ray Diffraction with High Energy Synchrotron Radiation at HEMS (P07), HZG @ DESY



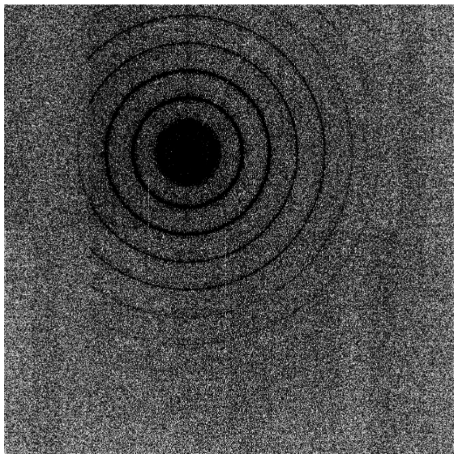
techniques available	XRD, PDF, SAXS, 3D-XRD, Tomography
photon source	undulator
period number of periods max power	29 mm (temporarily) 66 3 kW
source brilliance	10^{18} ph / s / 0.1% bw / mA
polarization available	linear horizontal
energy range	50 keV – 200 keV
beamline energy resolution	5 - 250 eV at 80 keV
max flux ON SAMPLE	7 x 10^{11} ph /s at 100 keV
spot size ON SAMPLE	1 mm x 1 mm down to 2 µm (v) x 30 µm (h) with Al CRLs 0.9 (v) x 6 (h) mm for 3D-XRD for low-beta mode
angle of incidence light – sample	0 to 90^o, 3.5 A^{-1}(solid, liquid in EH2) 0 to 15^0 (EH3), 0 for 3D-XRD and Tomography
sample type	solid or liquid, thin films

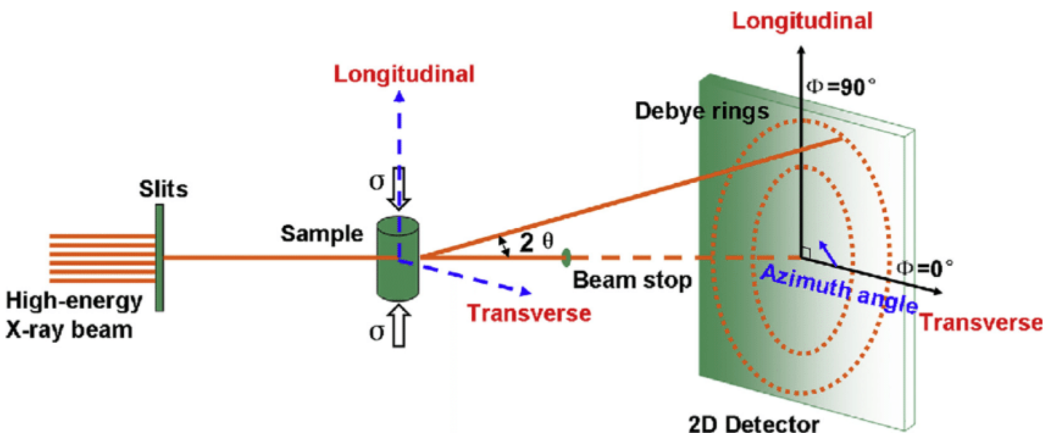
Small Angle X-Ray Diffraction with High Energy Synchrotron Radiation at HEMS (P07) at HZG @ DESY

Typical setup at HEMS:



Example: Debye-Scherrer-rings from TiAl alloy





- Determination of changes of crystal structure, texture, (internal) stress states, etc.
- Destructive free
- High penetration power due to high x-ray energies (50 -200 keV)
- High spatial resolution (slits, lenses) (≈200µm)
- Possibility of in-situ studies

Further new Plans for DESY

'in-situ'

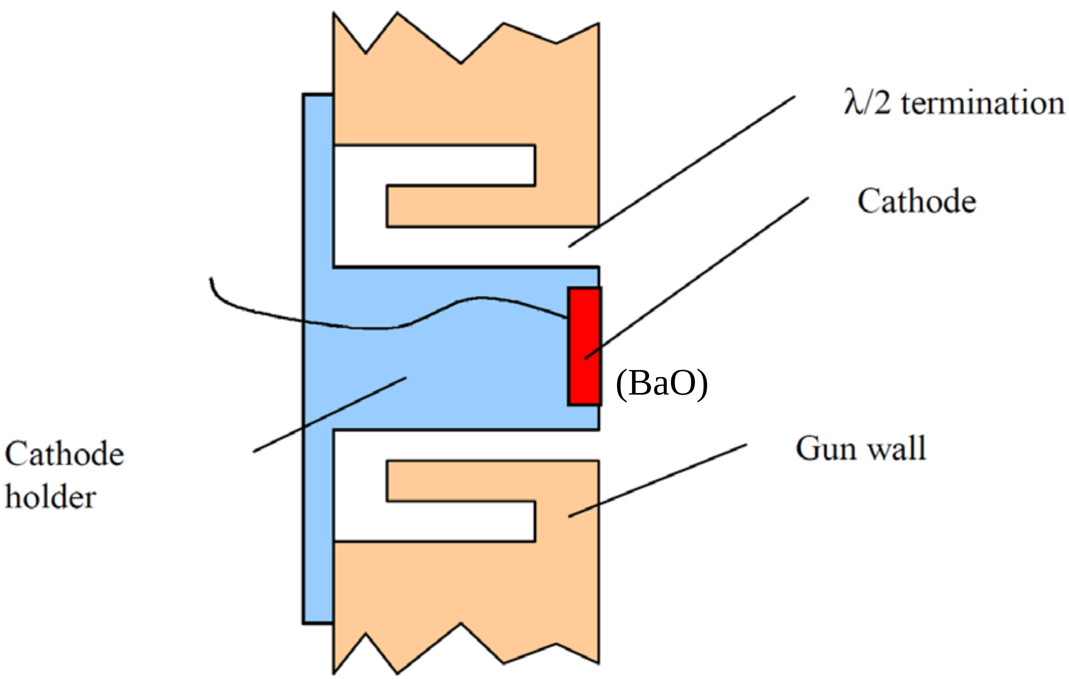
- New installation of e-beam at 1-10 MeV
  - **mean current strength of ~600μA (100 Hz)**
  - material tests not only with Ti-alloy, also WF
  - design study for shielding

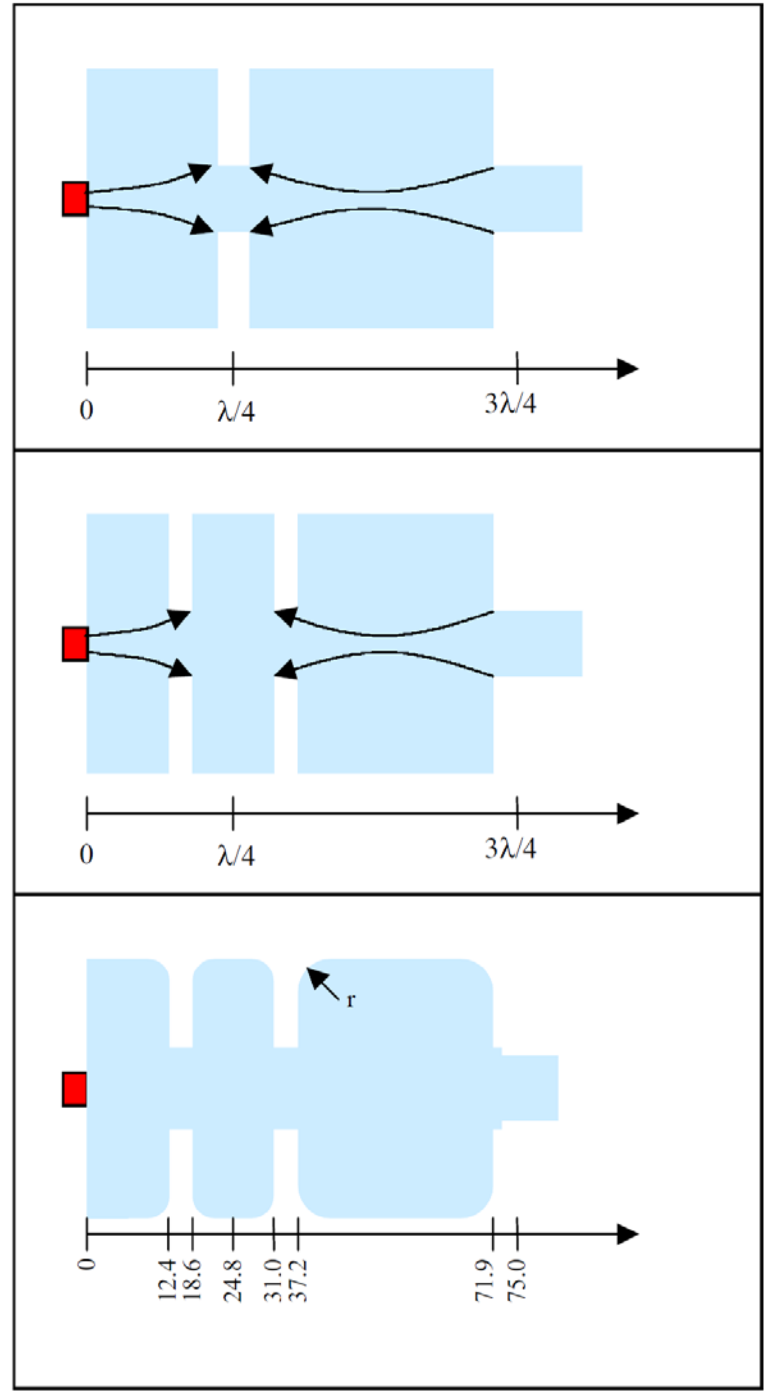
- Further idea: use e-beam directly at PETRA III
  - allows 'in-situ' target tests
  - *observe changes in target structures 'online'!*

RF Gun Design

High average current → therm. RF gun:

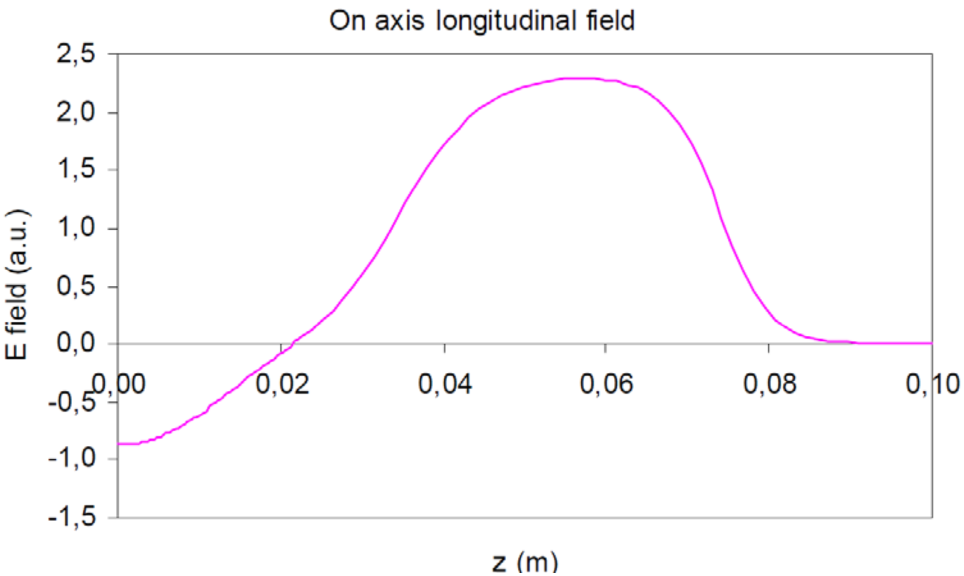
- high repetition rate (3 GHz)
- no laser system
- compact and robust
- „moderate“ energy spread & emittance

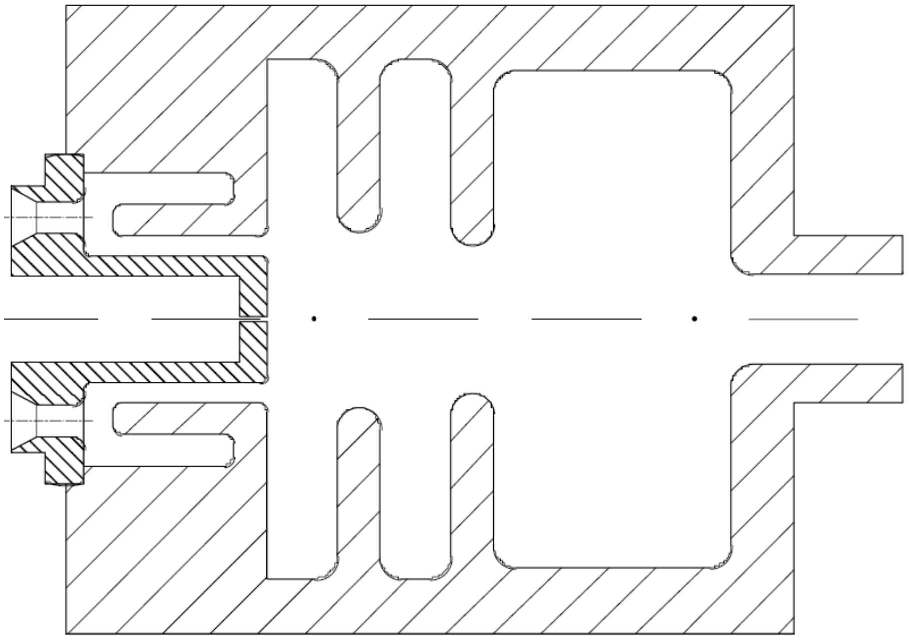




Taken from Linac and ring project report Part A

Gun Layout





Cross Section: overall length 100 mm, maximum inner radius ≈ 40 mm

Taken from Linac and ring project report Part A

Gun Performance

Power dissipation	2.02			MW @ 81.4 MV/m on axis
Q	15030			
Shunt impedance	60.6			MOhm/m
Maximum electric field on axis	81.4			MV/m
Maximum electric field on boundary	97.4			MV/m @ 81.4 MV/m on axis
Frequency	2999.15			MHz (dependent of mesh size)
Beam kinetic energy	2.3			MeV (kinetic $\Rightarrow$ 2.8 total)
Rise time	0.42			μs
Input coupling	3			
Coupling between cavities	2.64			
	0 mA	**100 mA**	**600 mA**	
Beam power	0	0.23	1.38	MW (@ dE=2.3 MeV)
Energy spread (nucleus of bunch)	0.13	1.1	18	KeV (RMS)
Bunch length (nucleus of bunch)	0.06	0.08	0.26	ps (RMS) ≈ deg (RMS)
Emittance	0.03	0.85	1.8	π mm mRad (@ E=2.8 MeV) (RMS)
Emittance, norm	0.16	4.6	9.8	π mm mRad (RMS)

Taken from Linac and ring project report Part A

Simulations (MAXLAB) with Superfish and Parmela

Maximum Performance: 10 μs RF pulses, 100 pps
→ I_{av} = 600 μA, E_{kin} = 2.3 MeV (2.8 MeV total)

Gun Performance

Taken from Linac and ring project report Part A

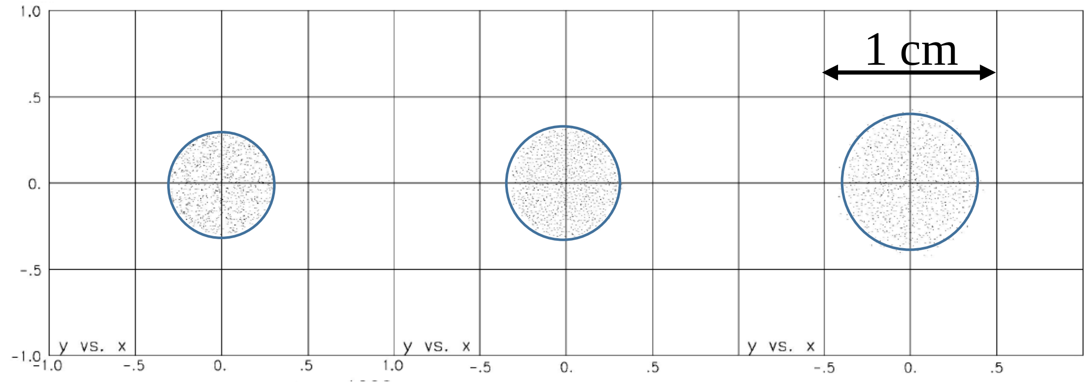


Fig. 4-11 Beam size (cm) at gun exit. (I = 0 / 100 / 600 mA, E_k = 2.3 MeV)

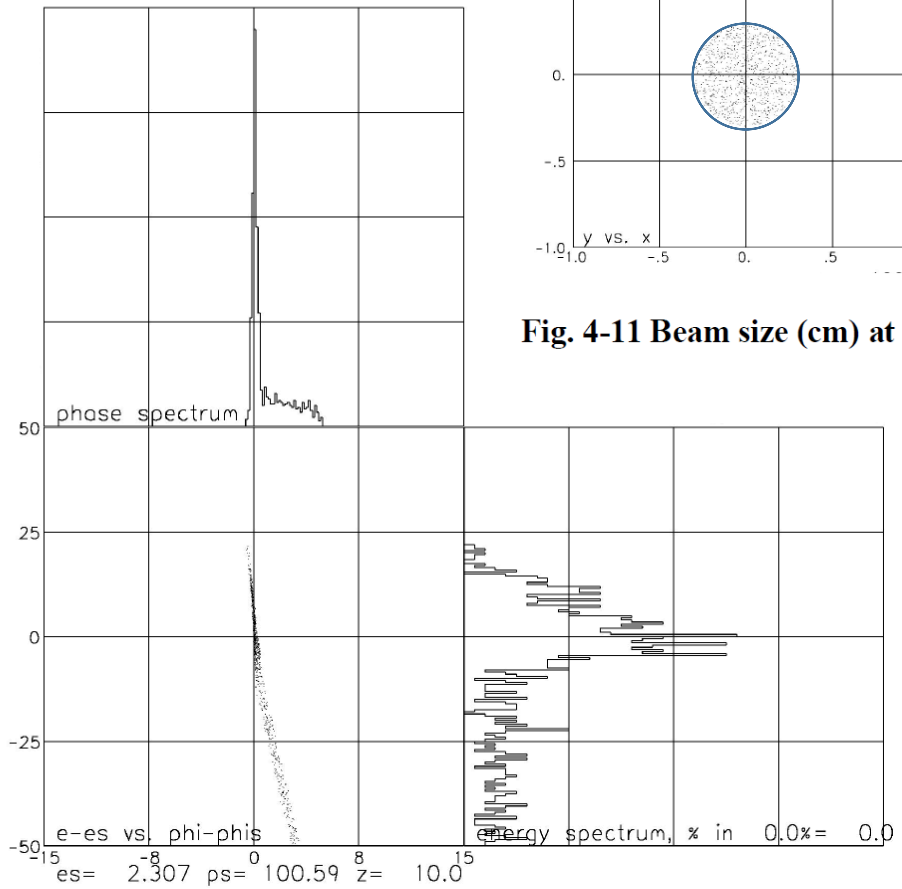
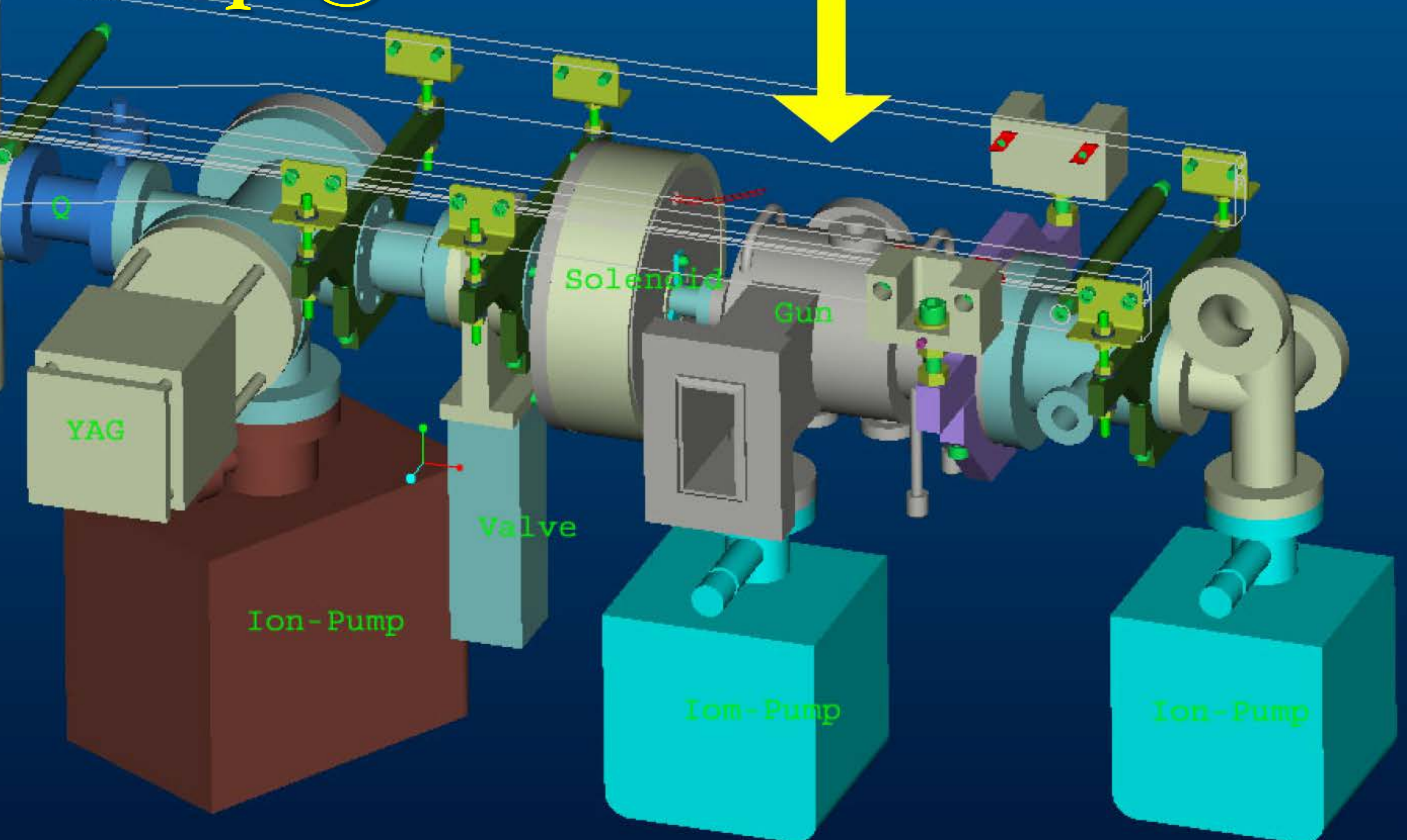


Fig. 4-10 Energy (KeV) and phase (deg.) (=length) distribution at the gun exit. (I = 600 mA, E_k = 2.3 MeV)

Set Up @ MAXLAB



Taken from Linac and ring project report Part A

Conclusions

- Still many ongoing tests at MAMI for our positron target
- New grant application submitted end of October!
  - looks promising,……..maybe
  - funding period:2018-2021
- Relevant for target, window, photon dump etc.

- allows further target tests at MAMI at 180 MeV *‘ex-situ’*
  - improved analysis via laser scanning + X-ray diffraction

- allows new target tests at DESY at 1-10 MeV *‘in-situ’*
  - X-ray diffraction technique

- *Stay tuned! …Lots of interesting results are going to happen!*