Status of HZB activities

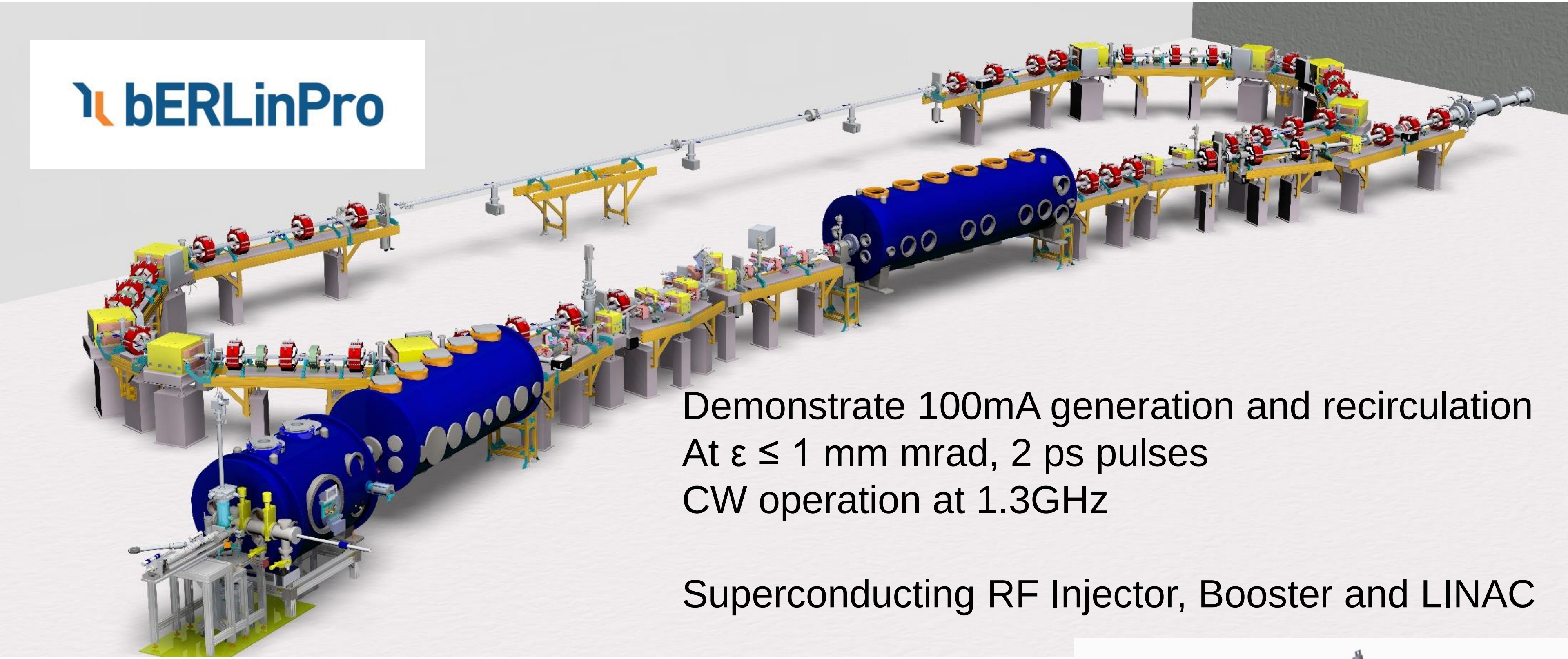
04.04.2016

Martin Schmeißer

Photocathode Preparation

Status of the Transfer System

Diamond Amplifier Cathodes

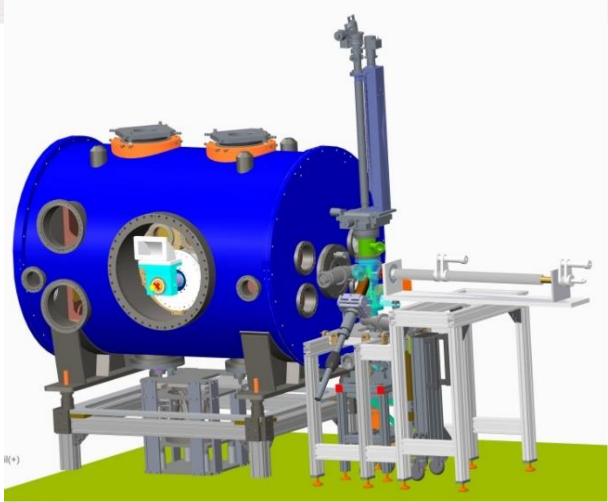


Demonstrate 100mA generation and recirculation
At ε ≤ 1 mm mrad, 2 ps pulses
CW operation at 1.3GHz

Superconducting RF Injector, Booster and LINAC

GunLab

Prototype of the SRF Photoinjector + Diagnostic Beamline



Photocathode Preparation

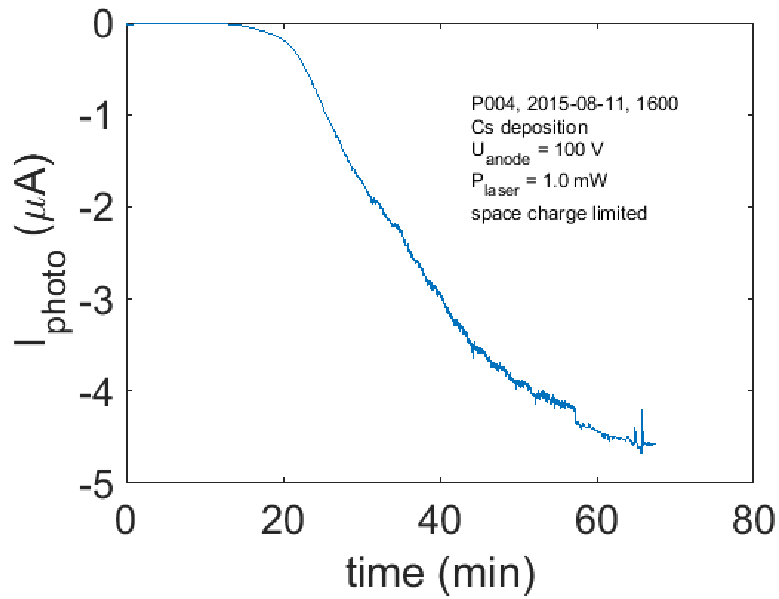
Status of the Transfer System

Diamond Amplifier Cathodes

Results P004 :

- Polished Mo substrate
- 10 nm Sb film evaporated at 100°C
- Surface composition KSb after K deposition
- zero QE for green light, small QE for daylight

- Surface composition Cs_2KSb after Cs deposition
- **~5% QE**
- 3.8% and 3.6% QE after 1 and 2 days



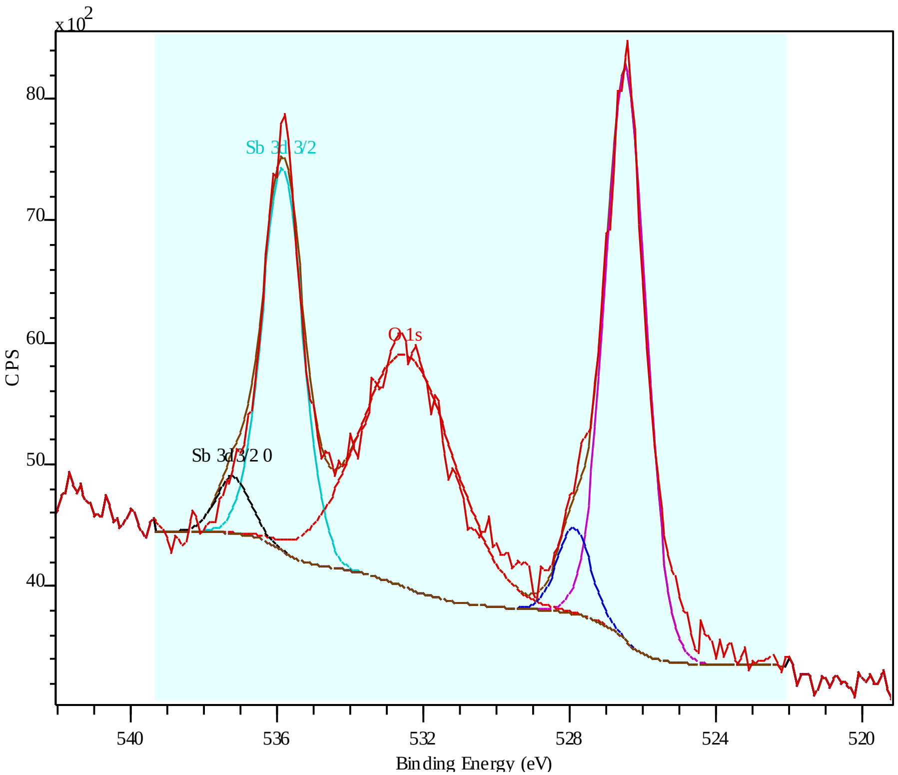
Results P005 :

- < 10nm Sb film evaporated at 100°C
- $K_{2.4}Sb$ surface composition after K deposition, strong Oxygen impurities
- K rich composition after Cs deposition, strong Oxygen impurities
- 0.175% QE

The difference between a good and a bad cathode :

- Same substrate, same cleaning, low contaminations confirmed by XPS
- Same growth procedure, same type of sources

- P005 Sb layer not as thick
- Water and Oxygen partial pressure worse by 10^2



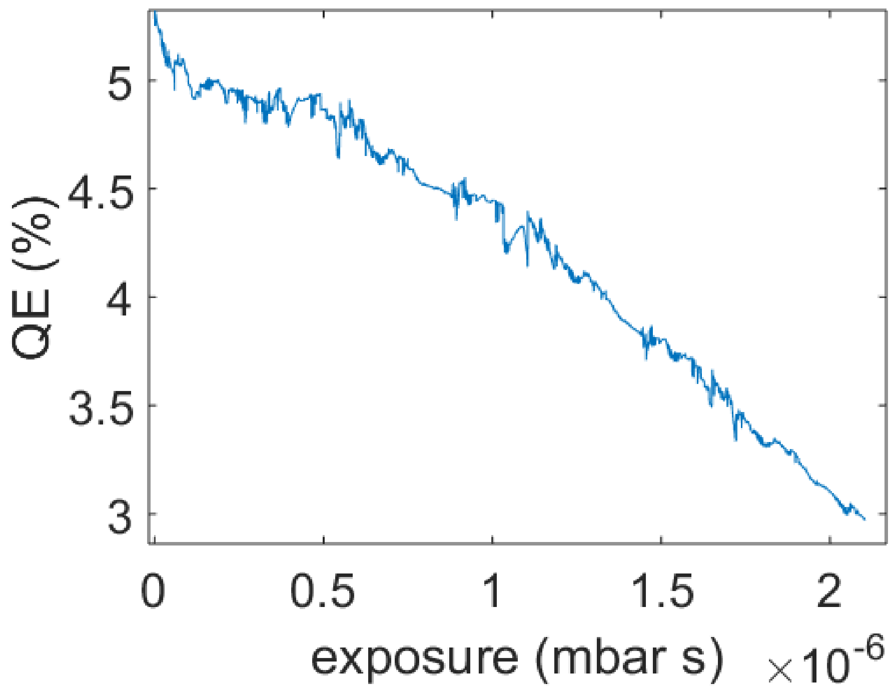
Strong degasing of K source due to first use
→ Need to degas at higher temperatures

Control over vacuum conditions is essential. Mass spectrometer allows to ensure low residual gas pressures.

Results P006 :

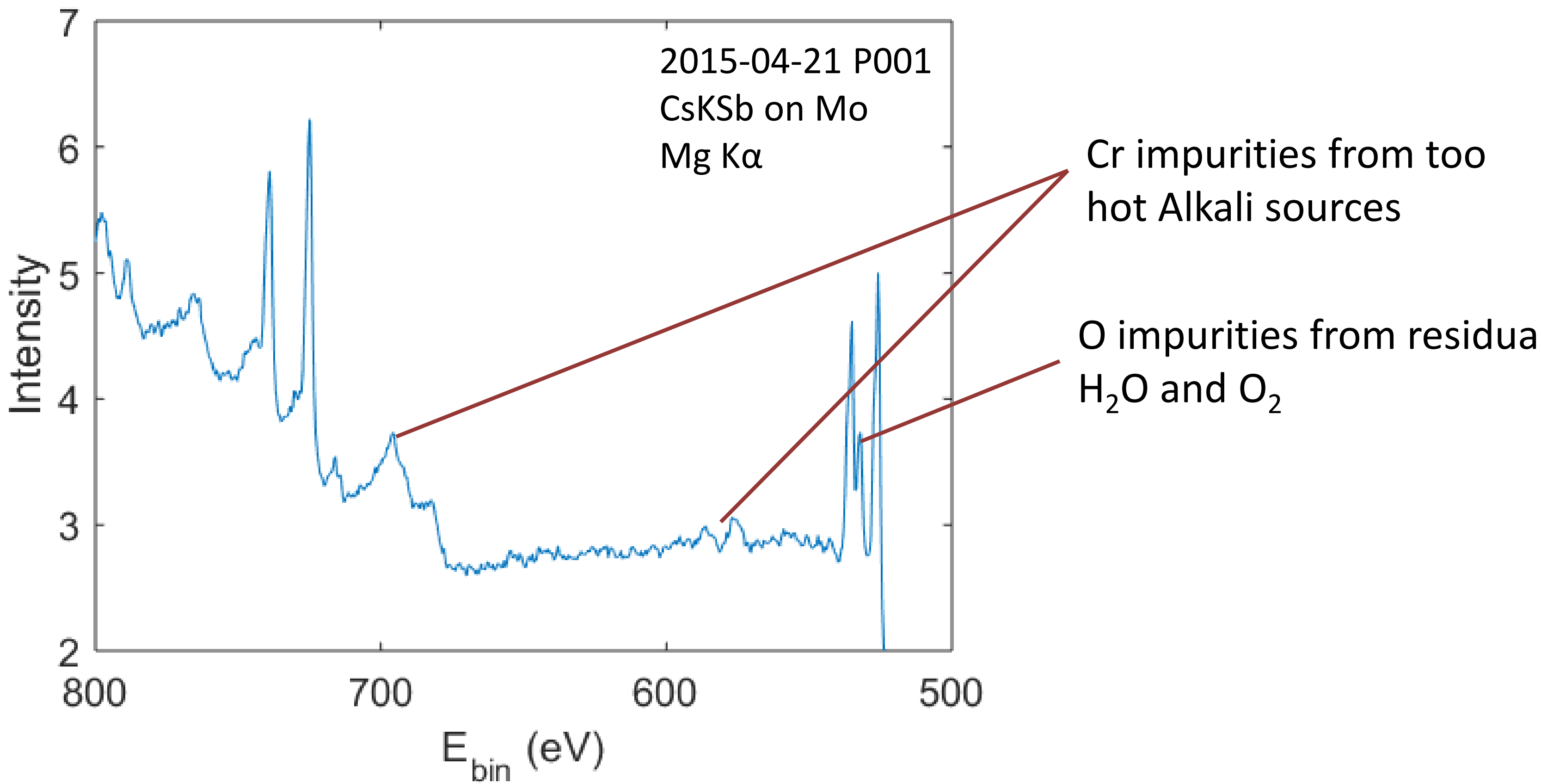
- 10nm Sb film evaporated at 100°C
- $K_{1.7}Sb$ surface composition after K deposition
- Not all Sb reacted, some still in metallic state
- 0.05% QE for green light

- $Cs_{2.7}K_{1.7}Sb$ composition after Cs deposition
- All Sb reacted, Alkali rich surface
- **5.2% QE**



QE decays from 5 to 3% in about 4 days

Combined exposure of H_2O and O_2 in $3*10^{-10}$ mbar vacuum



XPS allows quick assessment of chemical composition, quantification.

It teaches us to work accurately and carefully.

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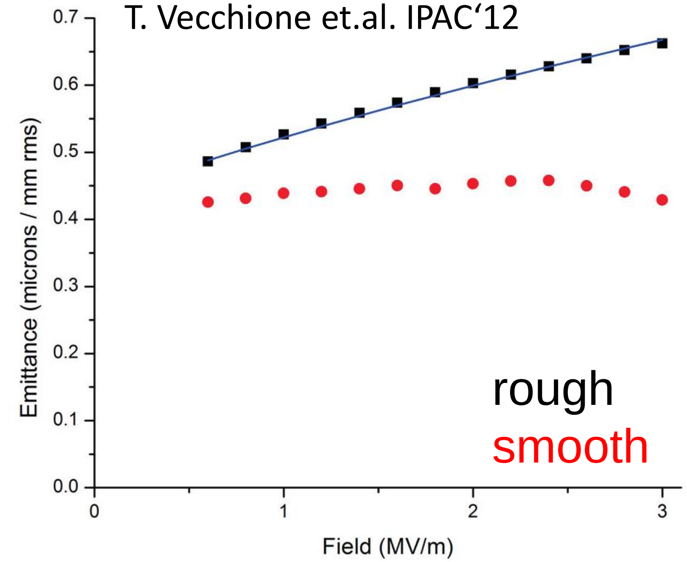
Roughness introduces an increase in emittance :

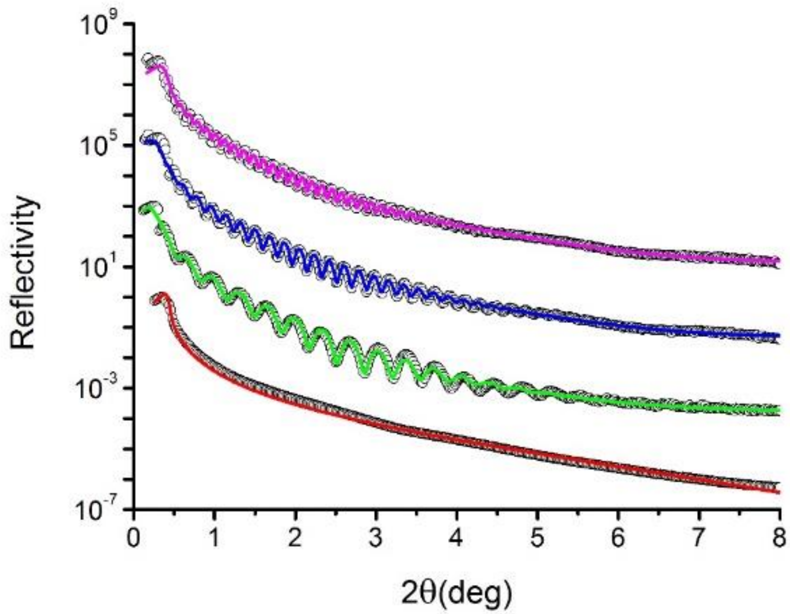
$$\varepsilon_{rough} = \sigma_{x,y}\sqrt{\frac{\pi^2 a^2 Ee}{2m_0 c^2 \lambda_{rough}}}$$

Qian, H. J. et al. (2012). *PRSTAB*, *15*(4)

→ We need to be better than 10 nm!



Roughness and crystal structure can be resolved in-situ using **XRR** and **XRD**



M. Gaowei, BNL
XRR results for sputtered layers on Si

Layer	Roughness (nm)	Thickness (nm)
3rd layer	0.69	51.2
2nd layer	0.62	22.6
1st layer	0.60	17.8
Substrate	0.24	

For cathode research:

polished Mo sheets, 10x10x1 mm
from sintered material
Roughness : ~10 nm rms, can be 1-3 nm rms

For photoinjector operation:

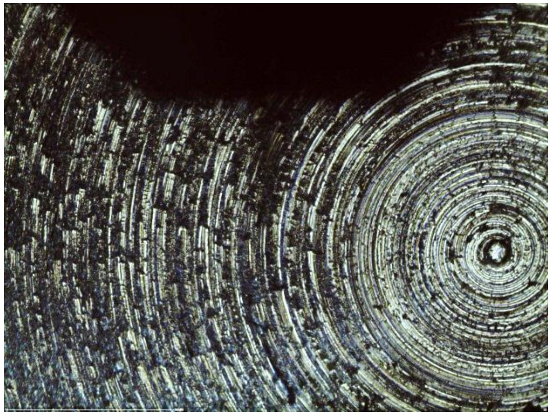
„Plugs“
Ø 10 mm x 6 mm from Mo or Cu rods
machined to surface roughness Ra = 10 µm

Mo plugs from sintered material
polished samples have roughness ~ 8nm rms

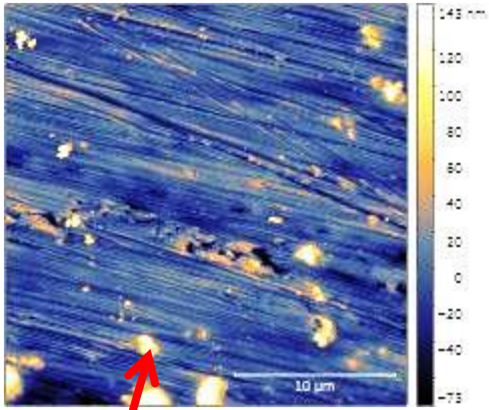
Cu plugs from OFHC copper
20nm rms roughness after polishing

The roughness in numbers looks promising, but :

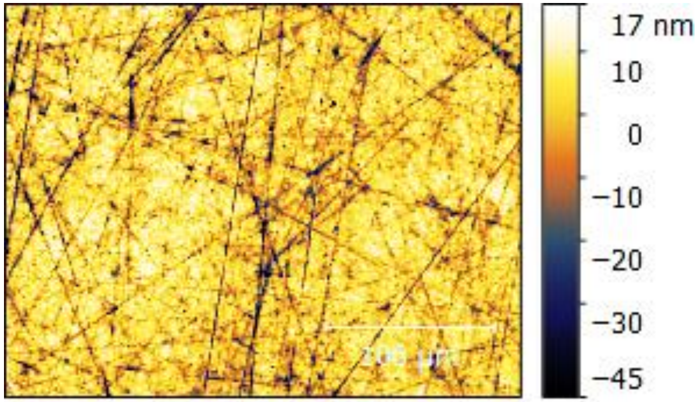
Mo after turning



AFM : Cu after polishing

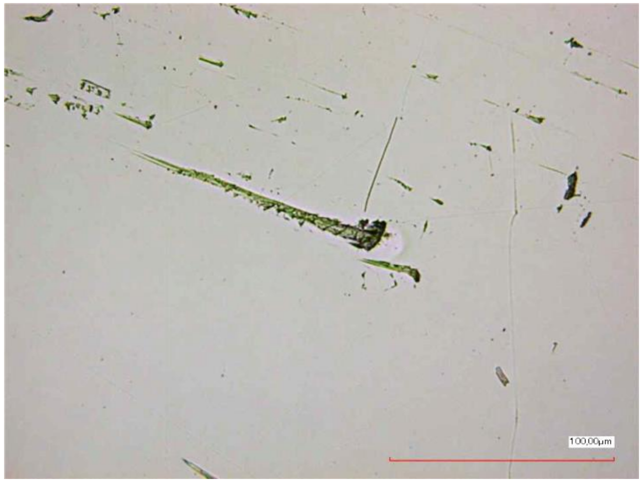


WLI : Mo after polishing



Grzegorz Gwalt

Protrusions in the AFM images for Mo and Cu



Sven Lederer

White light interferometry of Mo samples shows scratches, boundaries

Loose grains break from sintered Mo and create new scratches

→ Forged Mo material preferable?
→ Single crystals can be obtained

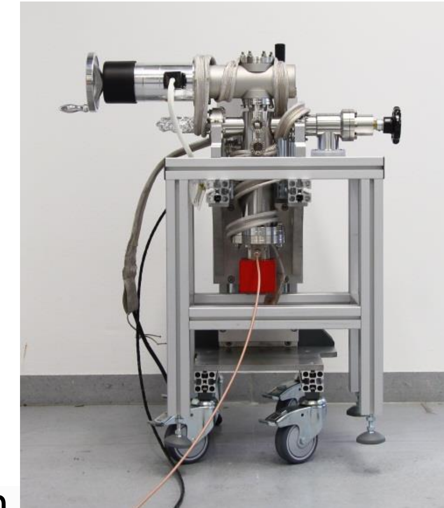
Photocathode Preparation

Status of the Transfer System

Diamond Amplifier Cathodes

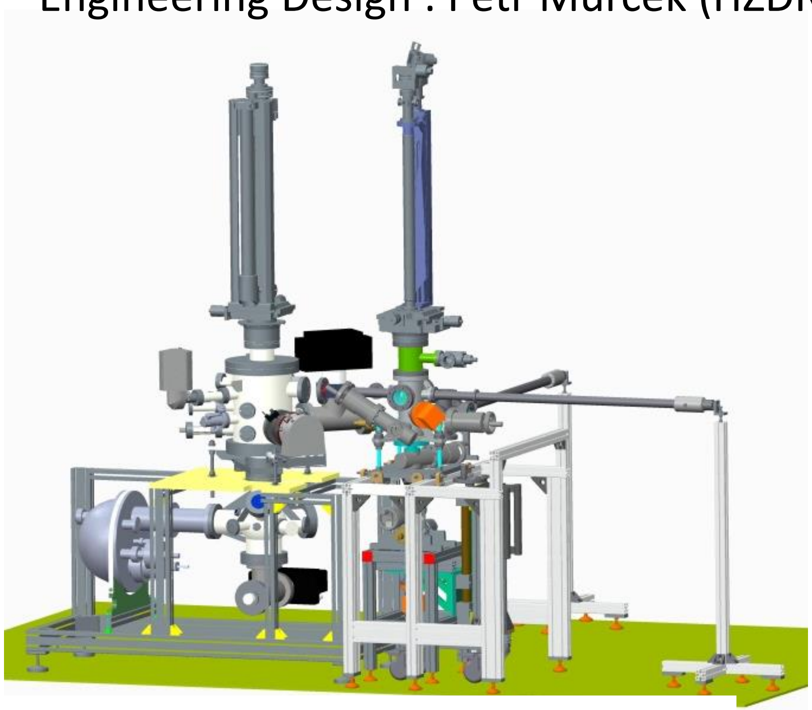
PHOTOCATHODES – TRANSFER SYSTEM

Cathodes must be stored and handled in < 10^{-10} mbar UHV

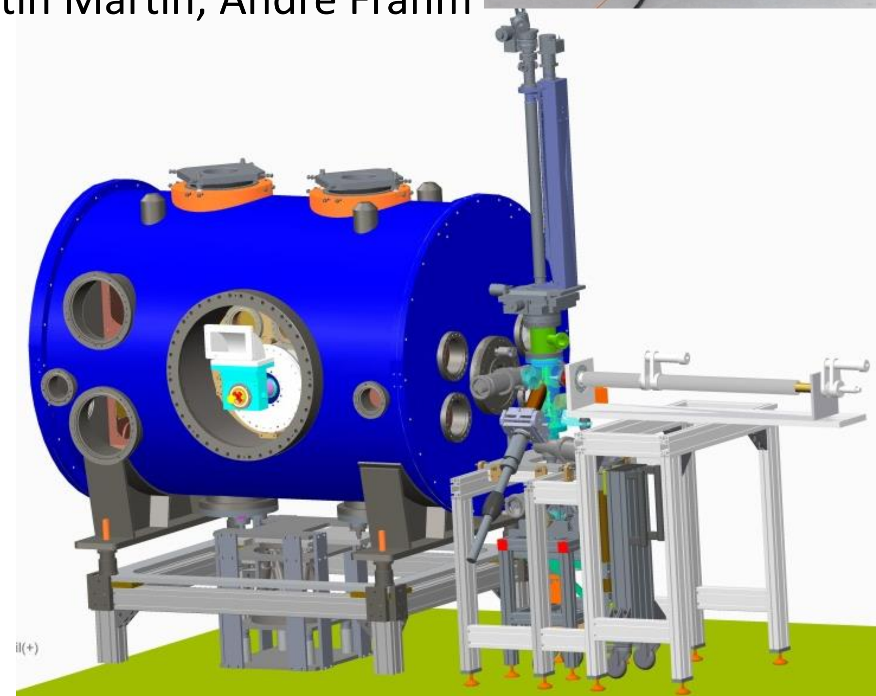


- Vacuum suitcase is available. Vacuum ~ $1*10^{-11}$ mbar
- Stability with NEG + getter pump is good for >3 months
- All parts : cleaning and assembly in ISO 5 clean room conditions

- Transfer system 1 is being comissioned
- Transfer system 2 engineering done, parts are manufactured
- Engineering Design : Petr Murcek (HZDR), Kerstin Martin, Andre Frahm



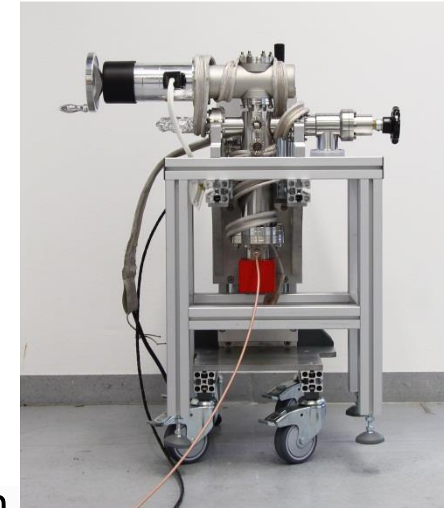
Transfer System #1 at Prep Chamber



Transfer System #2 at Gun Module

PHOTOCATHODES – TRANSFER SYSTEM

Cathodes must be stored and handled in < 10^{-10} mbar UHV



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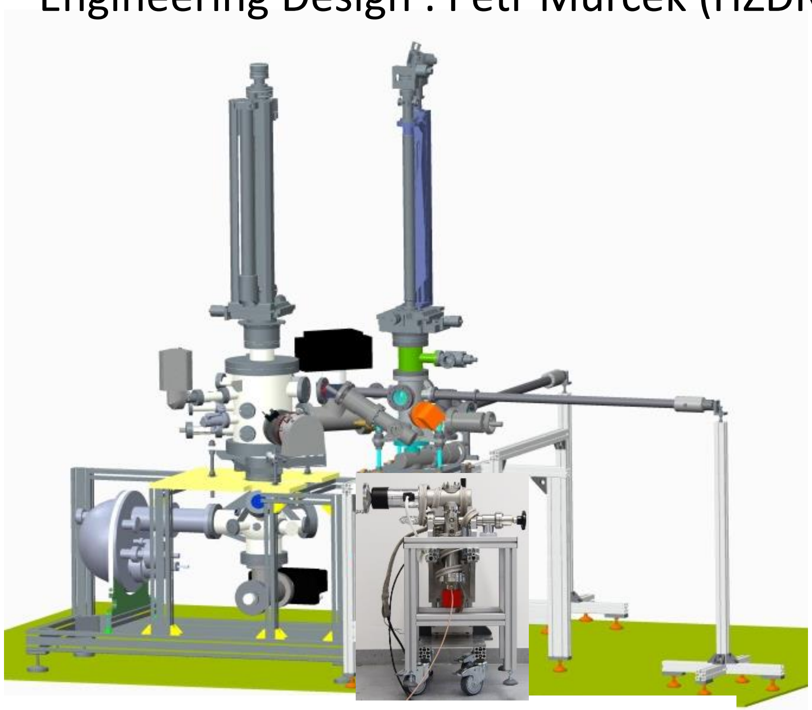
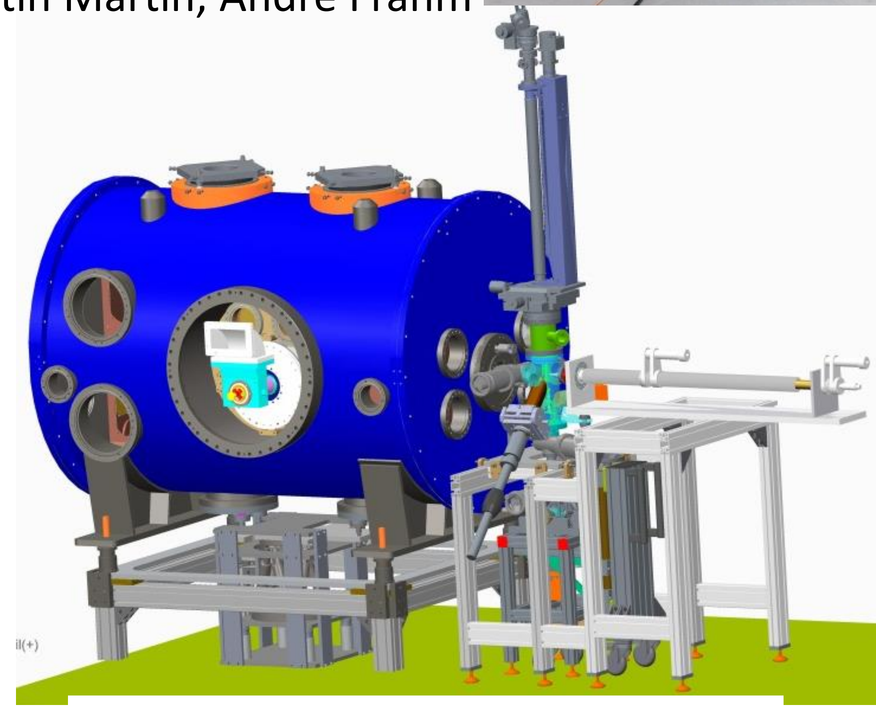
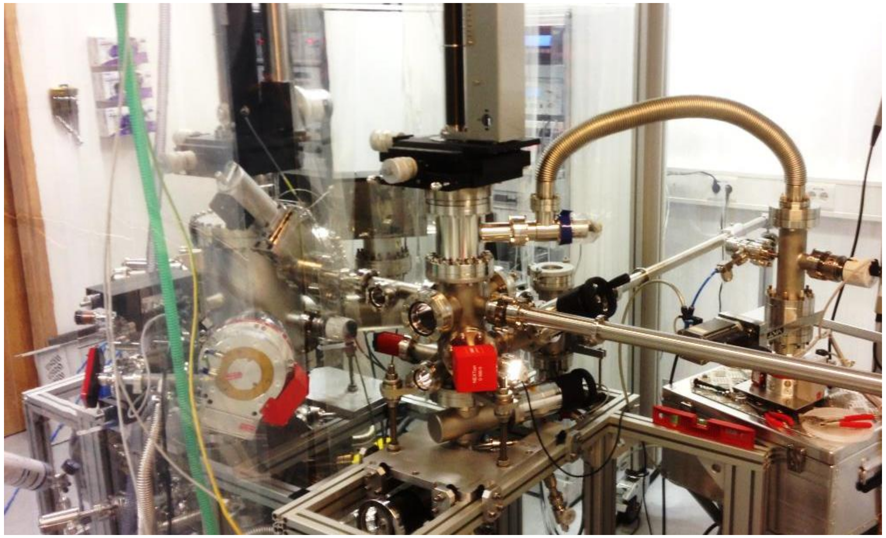


Transfer System #1 at Prep Chamber



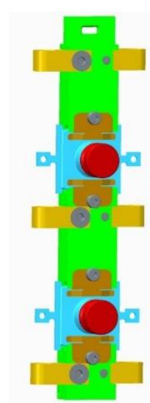
Transfer System #2 at Gun Module

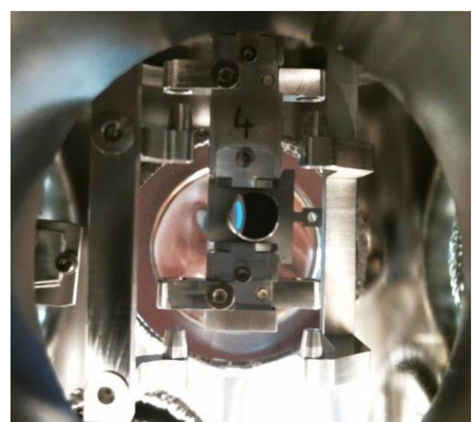


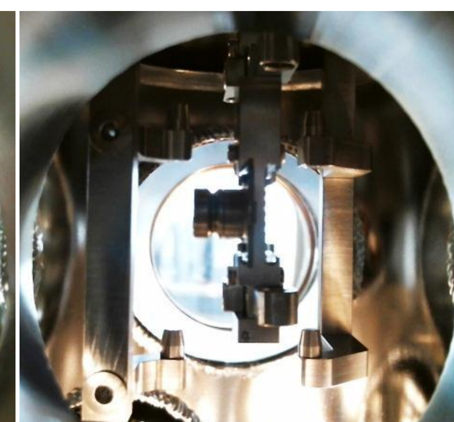
TS #1 is assembled and under vacuum
Some alignment still neccessary

Space for 3+1 cathodes in a cartridge:

The cartdridge travels in the suitcase and can be moved in both transfer systems.







Photocathode Preparation

Status of the Transfer System

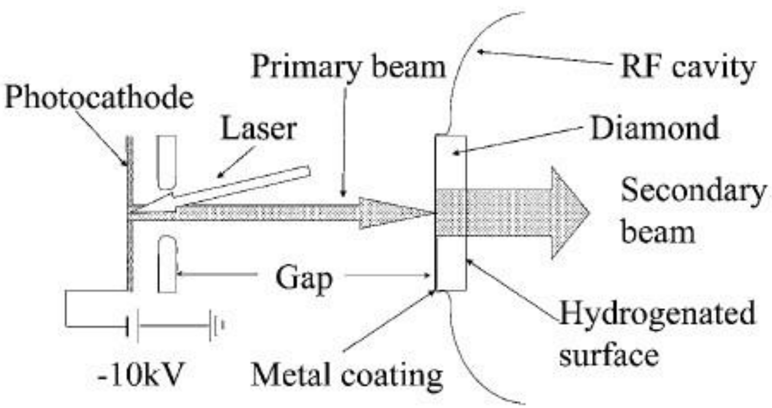
Diamond Amplifier Cathodes

Diamond Amplifier Cathodes

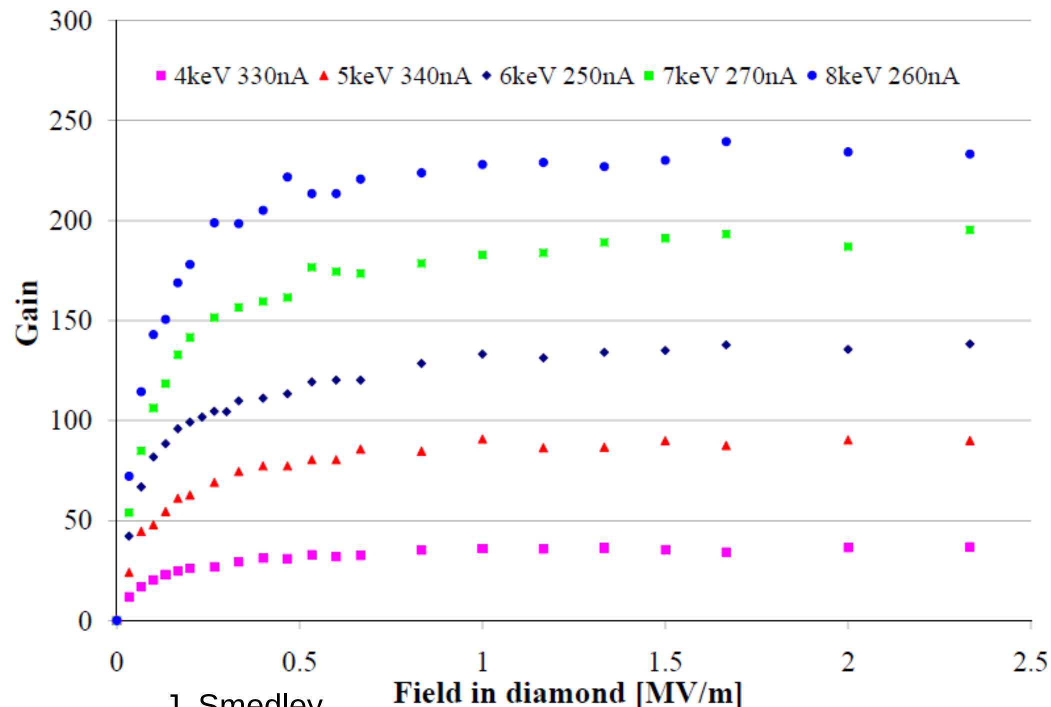
Motivation:

Generation of very high average current (>100 mA) well above what is currently achievable with high QE multi-alkali photocathodes

- DAC is a promising option.
- Diamond is very robust wrt. radiation, current density, thermal load
- very linear response
- H coated or (111) surface has negative electron affinity



X. Chang et al, PRL 105, 164801 (2010)



J. Smedley

Diamond Amplifier Cathodes

HZB Helmholtz Zentrum Berlin

Motivation:

Generation of high average current (>100 mA) well above what is currently achievable with high QE multi-alkali photocathodes

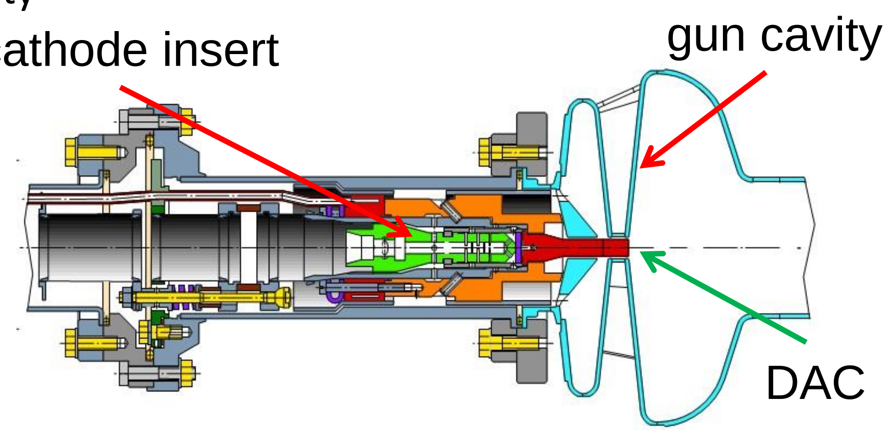
- DAC is a promising option.
- Diamond is very robust wrt. radiation, current density, thermal load
- H coated or (111) surface has negative electron affinity
- moderate vacuum requirements

Challenges:

Implications of the DAC for

- operation inside the insert of an SRF gun
- beam properties (thermal emittance, response time)
- unwanted beam production, field emission

Trapped charge in NEA well and surface states



SRF gun cold mass: insert and cavity

Courtesy V. Volkov/ D. Janssen/ HZDR

Steps towards a DAC in an SRF gun

- collaboration with BNL on DAC
- physics and engineering design of a suitable cathode cell which contains the DAC
- laboratory tests on wanted and unwanted beam properties
- engineering design for operation of DAC in SRF gun at ELBE/HZDR and BERLinPro/HZB

Task	2013	2014	2014	2015	2015	2016	2016	2017
Improvement of field emission (FE) setup for cathode substrate characterization								
First test of DFEA cell with FE setup								
Setup and Comissioning of photocathode prep and analysis system for primary cathode								
Development of plug handling system for SRF gun								
Feasibility study for DAC implementation into SRF gun cathode insert								
Engineering design of DAC plug on cathode insert								
Report writing for EuCARD2 (D12.13)								

Acknowledgement

W. Anders, R. Barday, A. Jankowiak, T. Kamps, G. Klemz, J. Kühn,
J. Knobloch, O. Kugeler, A. Matveenko, A. Neumann, T. Quast, J. Völker,
HZB

J. Teichert, HZDR
J. Smedley, BNL
R. Nietubyc, NCBJ
J. Sekutowicz, DESY
P. Kneisel, JLAB

EuCARD²

EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

CAPACITIES

Task	2013	2014	2015	2016	2017
Personell 60.873 in 10 PM + 45.655 Overhead 27.392 in 4.5 PM + 20.545 Overhead EC 33.481 in 5.5 PM + 25.110 Overhead HZB			5 PM	5 PM	
Travel 9.000 total, 4.050 EC + 4.950 HZB		1.500	2.500	2.500	2.500
Consumables 45.000 total, 20.250 EC, 24.750 HZB		5.000	15.000	20.000	5.000

EuCARD2 - WP12 Innovative RF Technologies (RF) - Task 12.5: SRF Photocathodes

For input data, only fill the white areas below

Beneficiary short name ª	Average direct monthly salary * (€)	Rate for personnel indirect costs (%)	Rate for material and travel indirect costs (%)			
DESY	6.087	60	60	116875,888	Total EC requested funding for WP11:	2.199.207
HZB	6.087	75	0	127833,003	**Maximun EC funding for WP11 :**	**2.500.000**
HZDR	5.775	116	0	149688		
NCBJ	1.927	60	60	37007,648		
CERN						
CEA						
STFC	6.226	105	0			
INPG						
PSI						
ULANC						
UNIMAN						
UU						
UROS						

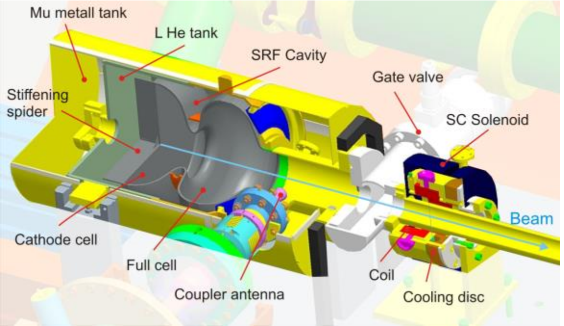
* To prevent rounding problems on the cost data, give the monthly salary as a multiple of 100 €

Beneficiary short name (all costs in €)	Person-Months	Personnel direct costs	Personnel indirect costs	Sub-contracting cost	Consumable and prototype direct costs	Travel direct costs	Material and travel indirect costs	Total direct costs	Toal indirect costs	Total costs (direct +indirect)	EC requested funding[1]	Funding rate
DESY	6	36.524	21.914	0	74.000	12.500	51.900	123.024	73.814	196.838	76.951	39%
HZB	**10**	**60.873**	**45.655**	**0**	**45.000**	**9.000**	**0**	**114.873**	**45.655**	**160.528**	**71.853**	45%
HZDR	14	80.850	93.786	0	0	10.000	0	90.850	93.786	184.636	78.025	42% *
NCBJ	36	69.389	41.634	0	69.000	18.500	52.500	156.889	94.134	251.023	98.134	39%
CERN		0	0	0			0	0	0	0		#DIV/0!
CEA		0	0	0			0	0	0	0		#DIV/0!
STFC	22	136.972	143.821	0	50.000	10.000	0	196.972	143.821	340.793	84.606	25%
INPG		0	0	0			0	0	0	0		#DIV/0!
PSI		0	0	0			0	0	0	0		#DIV/0!
ULANC		0	0	0			0	0	0	0		#DIV/0!
UNIMAN												
UU												
UROS		0	0	0			0	0	0	0		#DIV/0!
Totals:	88	384.608	346.809	0	238.000	60.000	104.400	682.608	451.209	1.133.818	409.569	

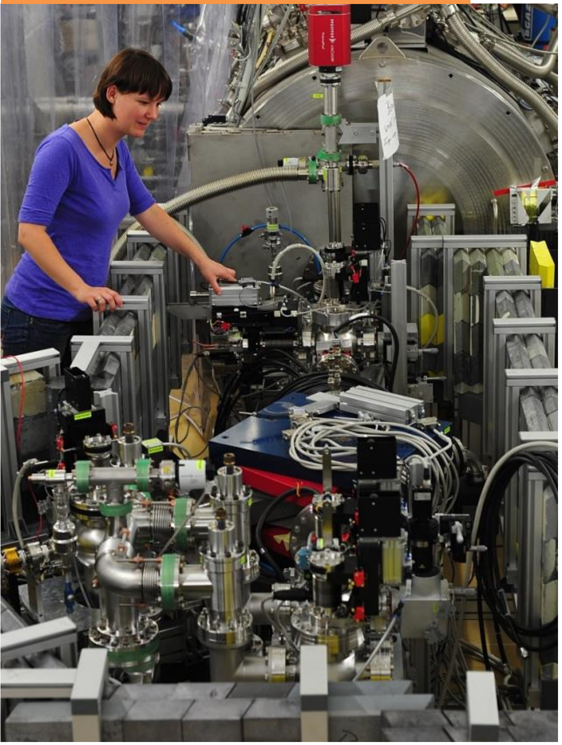
[1] In principle 50% of total costs but it could be less

* modifications (+ pm, - consumables, + travel and - salary) done following HZDR request on the 15 Nov. EC request not modified.

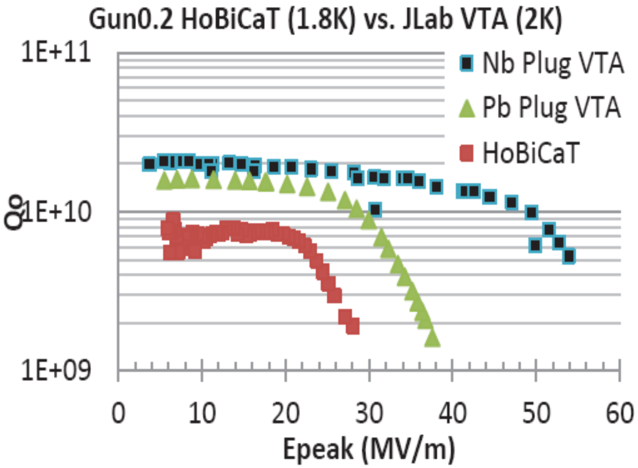
Material cost = consumable + prototype costs (assuming there are no durable equipment submitted to depreciation)
Personnel costs = person-months * monthly direct salary (inclusive contributions to social and other benefits)
Sub-contracting => note: subcontracted items do not give rise to reimbursement of overheads
Note: for TA and NA full-rate overheads have to be decalred according to the 1st table. EC nonetheless re-imburses 7% for these activities.
=> with the EU funding requested in the 2nd Table, it is possible to pay for more person-months than listed



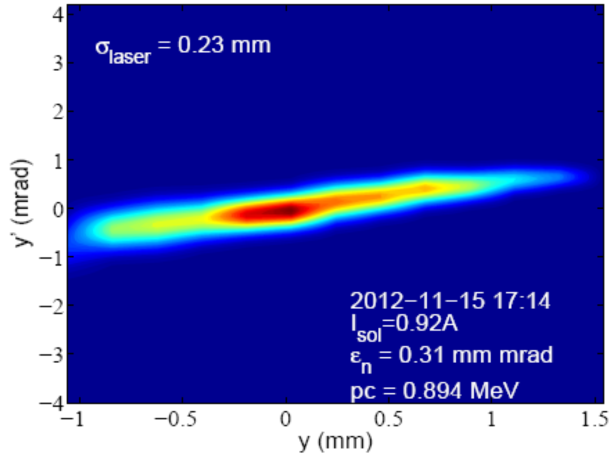
Collaboration between HZB, HZDR, DESY, JLAB, BNL, NCBJ, MBI, supported by EuCARD



Gun 0.1 directly Pb coated
Gun 0.2 removable cathode plug with Pb coating helps decoupling Nb cavity treatment (HPR, BCP) and cathode preparation.
Field processing increased achievable peak field from 20 to 28 MV/m, limited by field emission and quench.
Studied different techniques (electron back bombardment, long time laser exposure, laser cleaning with high power laser) to improve QE of metallic Pb cathode. Supported by XPS studies on Pb coated witness cathodes.
Measured transverse emittance with solenoid scan and slit mask methods. Emittance dominated by transverse fields due to protrusions on Pb surface.



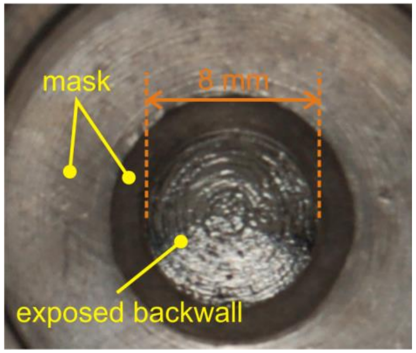
A. Burrill, et al., Proc. of IPAC 2013



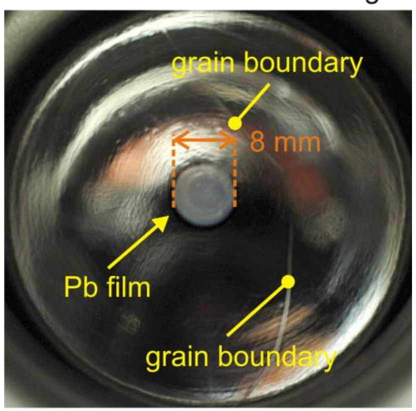
M. Schmeißer, et al., Proc. of IPAC 2013

Laser cleaning

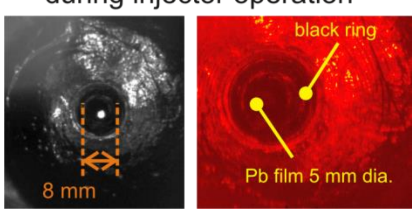
cathode mask on backwall

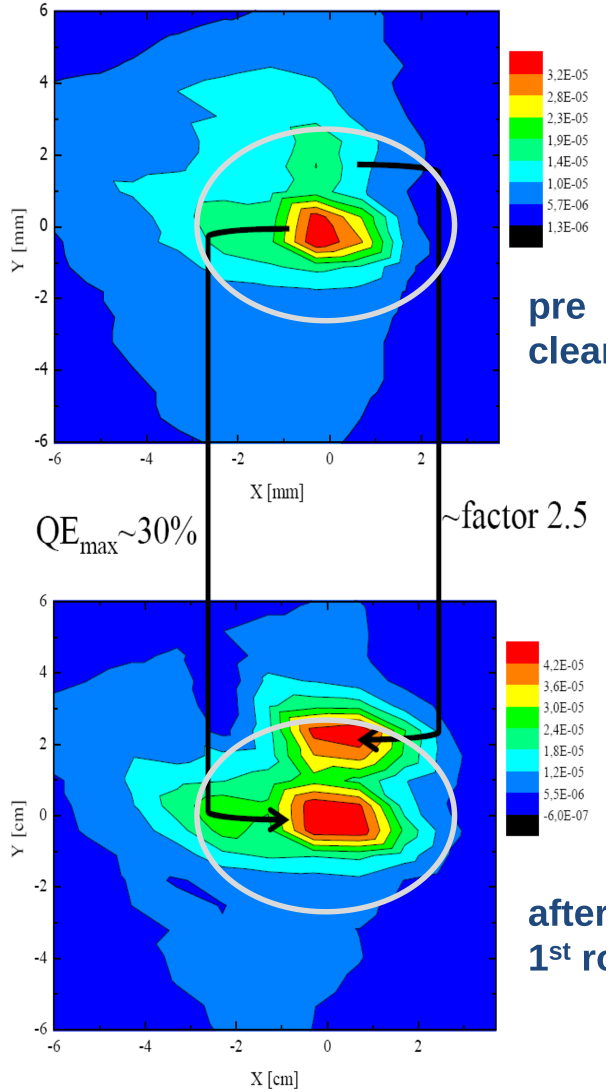


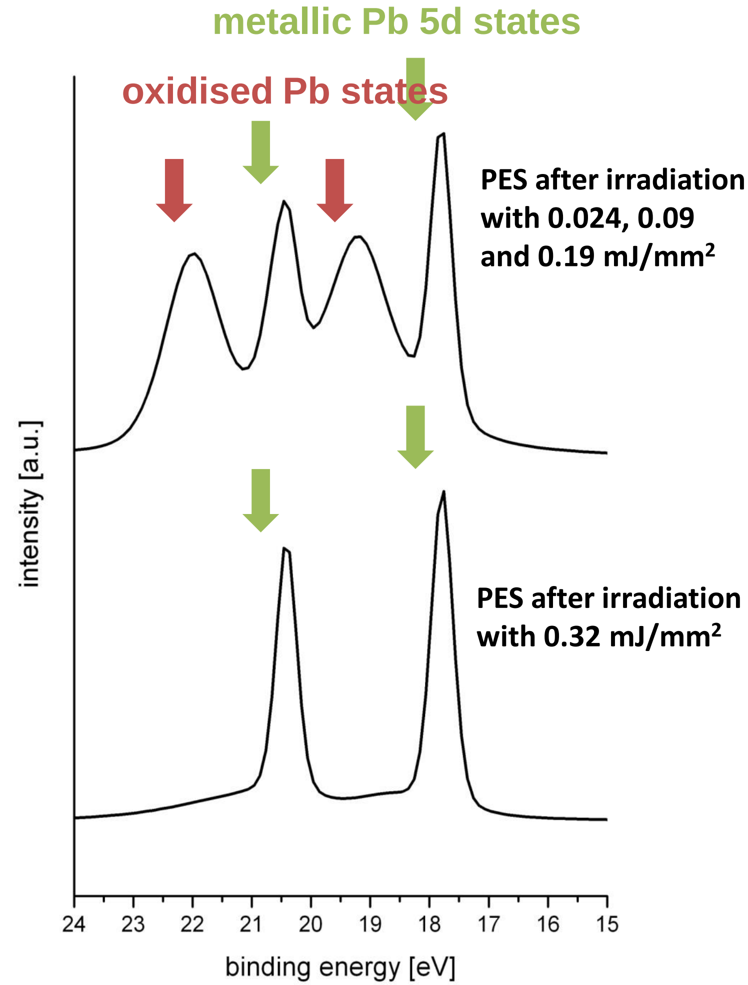
fresh Pb film after coating



during injector operation







S. Schubert, et al., Proc. of IPAC 2012
R. Barday, et al, Proc. of IPAC 2013
R. Barday et al., Proc. of PSTP 2011