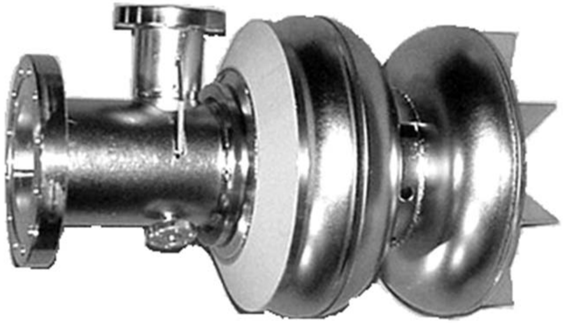


HZB Helmholtz Zentrum Berlin

First results of the SRF gun development for the BERLinPro ERL project at HZB

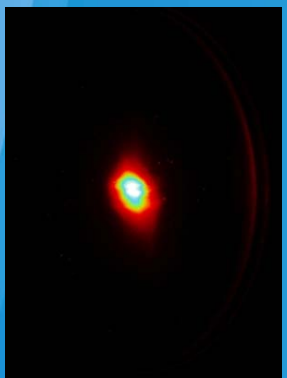
ERL 2011 Tsukuba

T. Quast

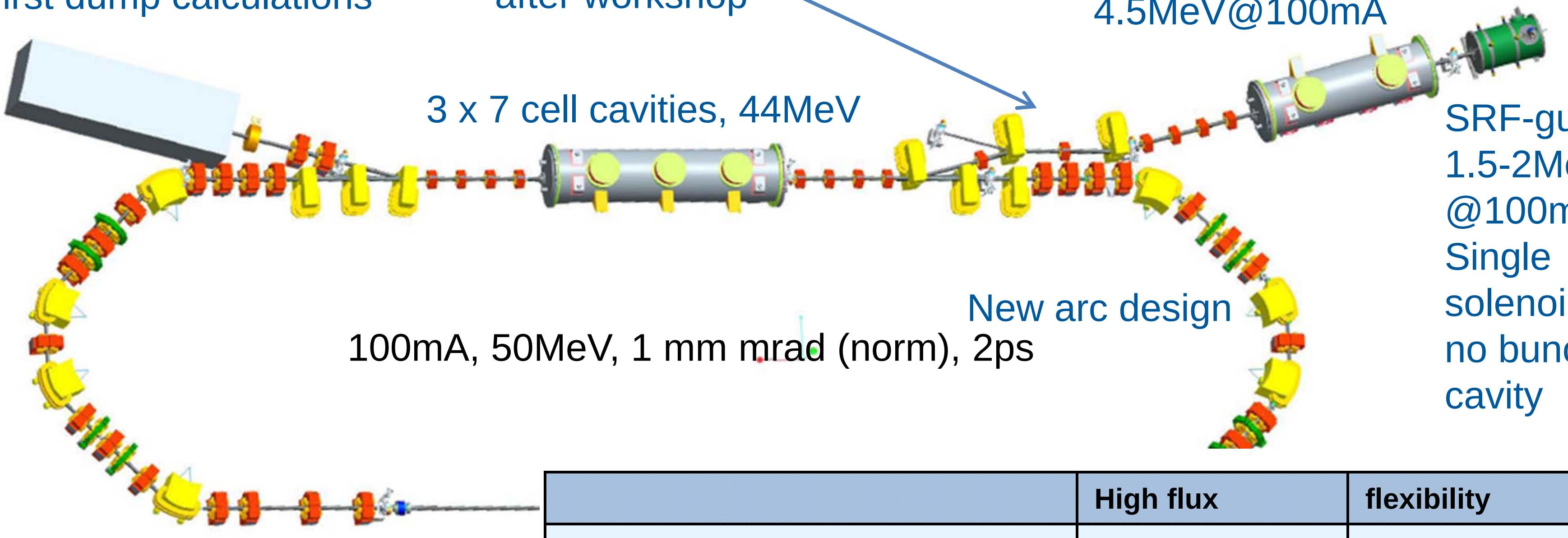
for a collaboration by

Jefferson Laboratory, DESY, A. Soltan Institute,

Brookhaven National Lab., Max-Born-Inst. and HZB



BERLinPro: General Machine Parameters / Layout



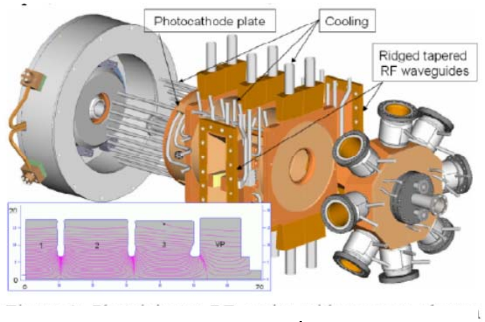
	High flux	flexibility
max. beam energy	50MeV	50MeV
max. current	100mA	
nominal bunch charge	77pc	up to ~10pC
pulse length	2ps	down to ~ 100fs
Rel. energy spread	$\sim 10^{-4}$ range	$\sim 10^{-2}$
rep. rate	1.3GHz	variable
normalized emittance	< 1mm mrad	some mm mrad

Minimal machine design / work on new cost estimates in progress
No space for second turn, experiment / no up-grade options

Workshop in 2008: evaluation of possible concepts – and decision for SRF gun

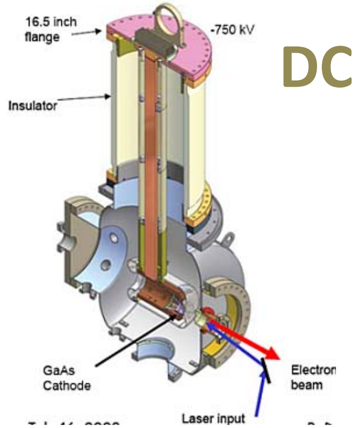
NC RF Gun and DC Gun: mature techniques, but seem already reached limit (?)

NCRF



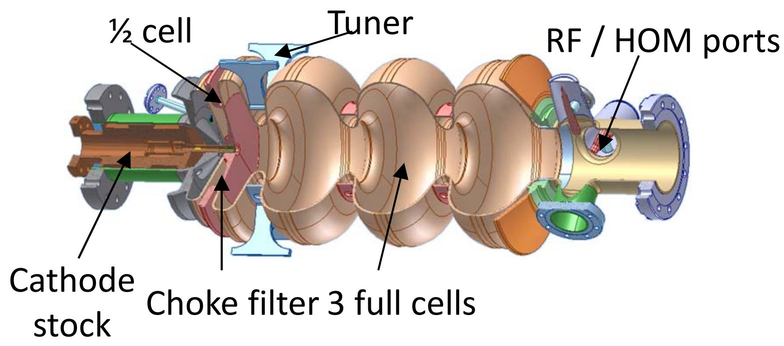
Courtesy S. S. Kurennoy / LANL

DC



Courtesy B. Dunham / Cornell

SRF



From J. Teichert, see NIM A 577 (2006)

HZDR/ELBE SRF gun

•1mA of average current from normal-conducting Cs2Te cathode at 77K

• No degradation in cavity performance due to cathode stock and material

HZDR/ELBE gun shows feasiblity of the SRF gun concept
→ SRF cavity with normal-conducting cathode works!

1. For our application, we need different performance:

1. Beam dynamics: How can we have more control on the transverse and longitudinal beam parameters? Mainly determined by field on cathode and setup of any focusing elements.

   → **Cavity Design..**

2. Average current: How can we generate 100 mA? Need cathode with high QE at VIS, which can operate in SRF environment.

   → **Cathode preparation and handling.. (CsK_2Sb & green Laser)**

3. Average power: How can we couple P_{avg} = 100 mA x E_b power into the SRF cavity?

   → **Coupler, HOM Damper..**

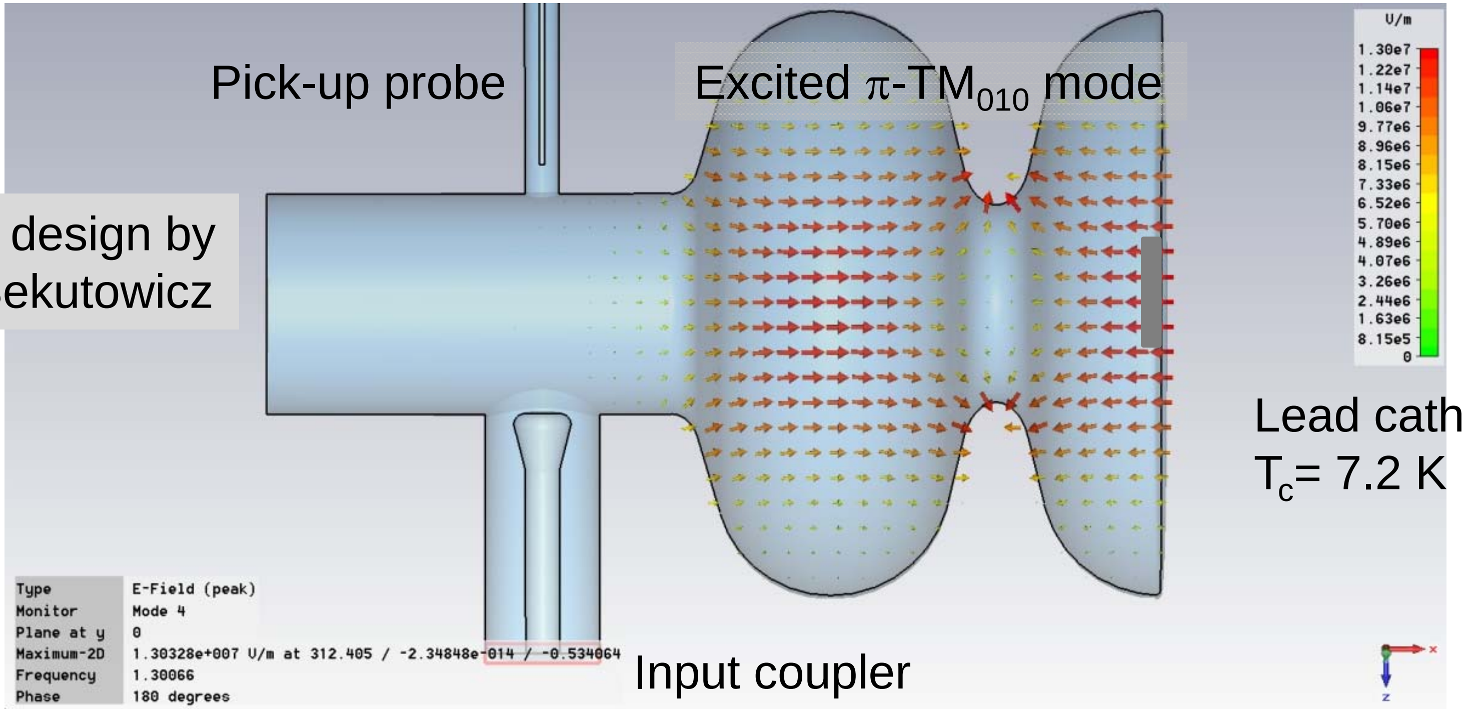
Demanding goals! - 3 stage approach – 3 injectors

a. **Full SC** injector for beam dynamics studies → ***This talk***

b. **Peak brightness** injector, study NC cathode insert

c. **High average current** injector

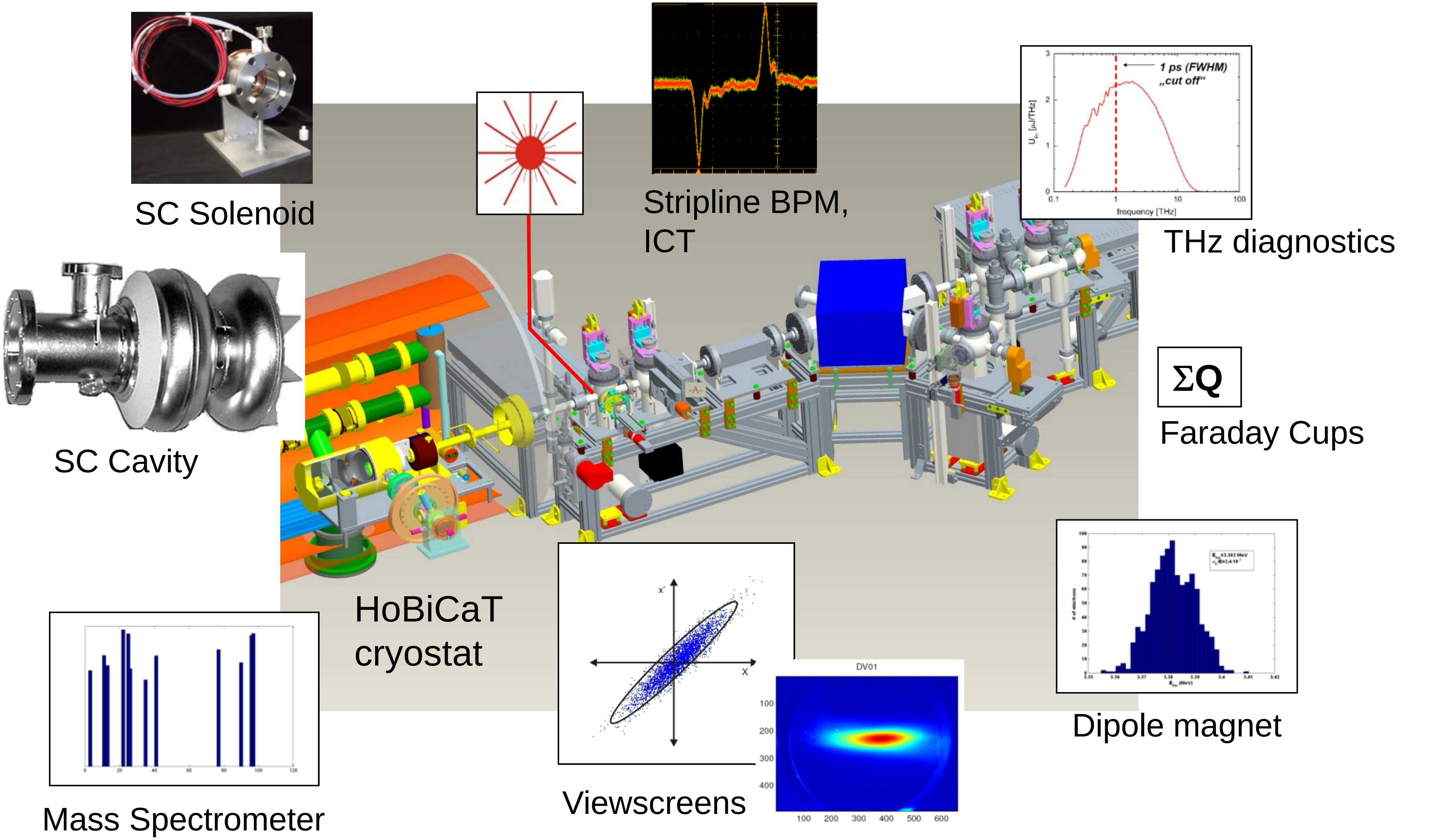
First step: SC RF Gun0



Frequency π-mode	1300 MHz
E_{peak}/E_{acc}	1.86
H_{peak}/E_{acc}	4.4 mT/(MV/m)
Geometry factor	212.2 Ohm
R/Q (linac, b=1)	190 Ohm

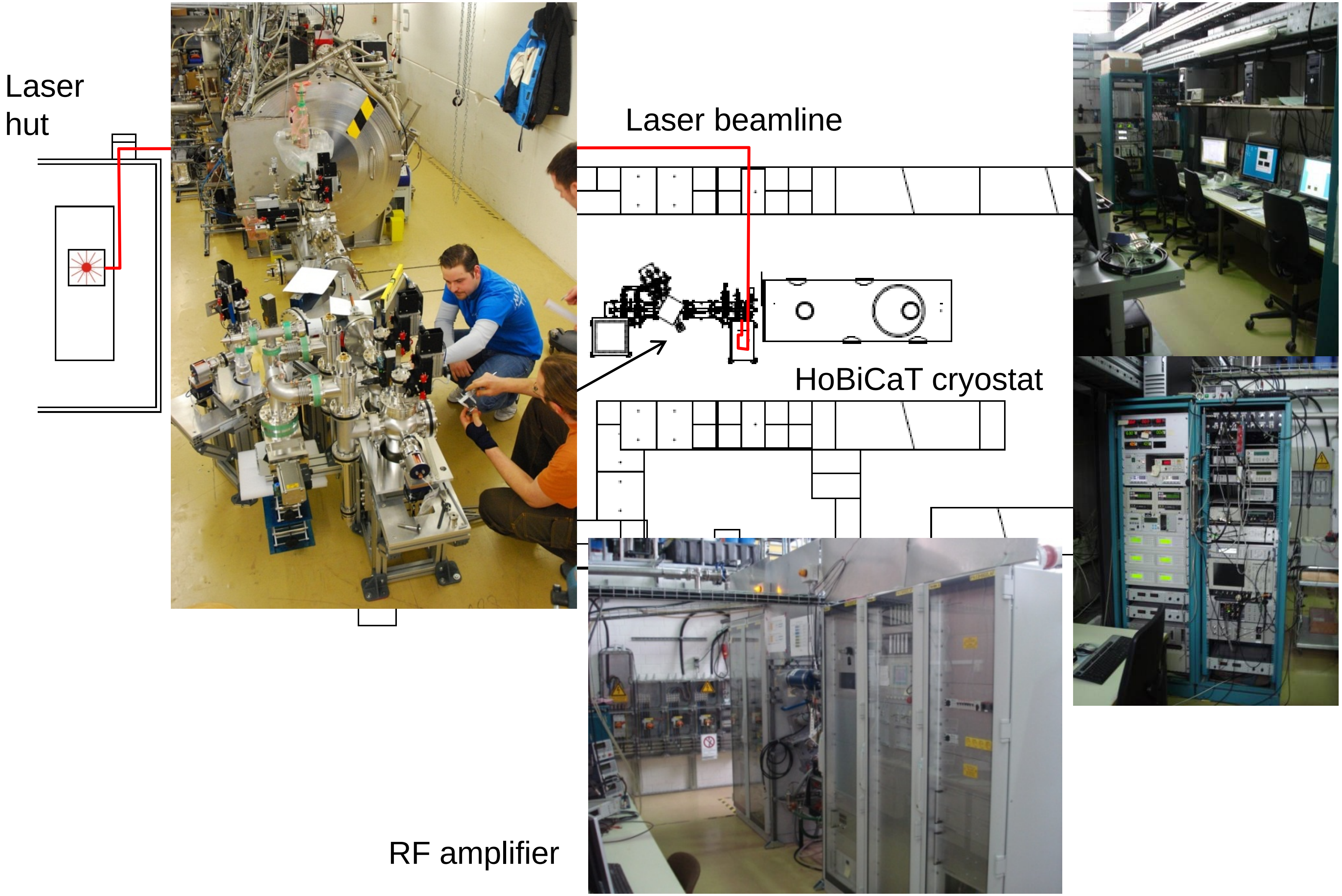
- EM design: Highest fields at cathode region
- SC lead cathode on half-cell backwall: $QE_{Pb} \sim 10 \cdot QE_{Nb}$
- Study beam dynamics at short pulses, ERL parameter range

Gun with Diagnostic beamline at HZB

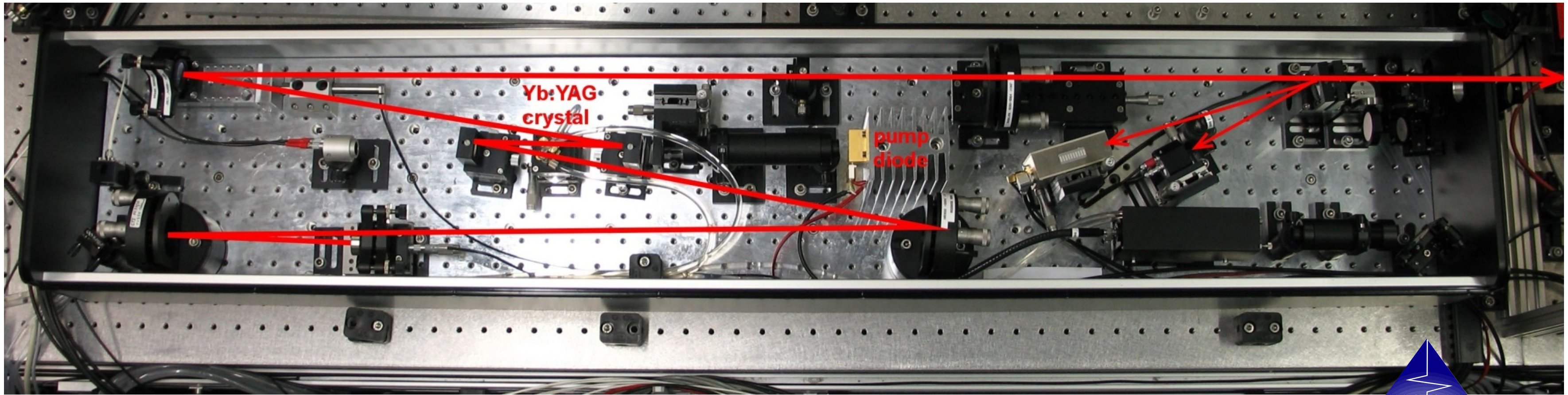


First time operated fully SC photoinjector ensemble (SC Cathode, Cavity, Solenoid)
Source/upgrade for CW low current machines (POLFEL, XFEL)

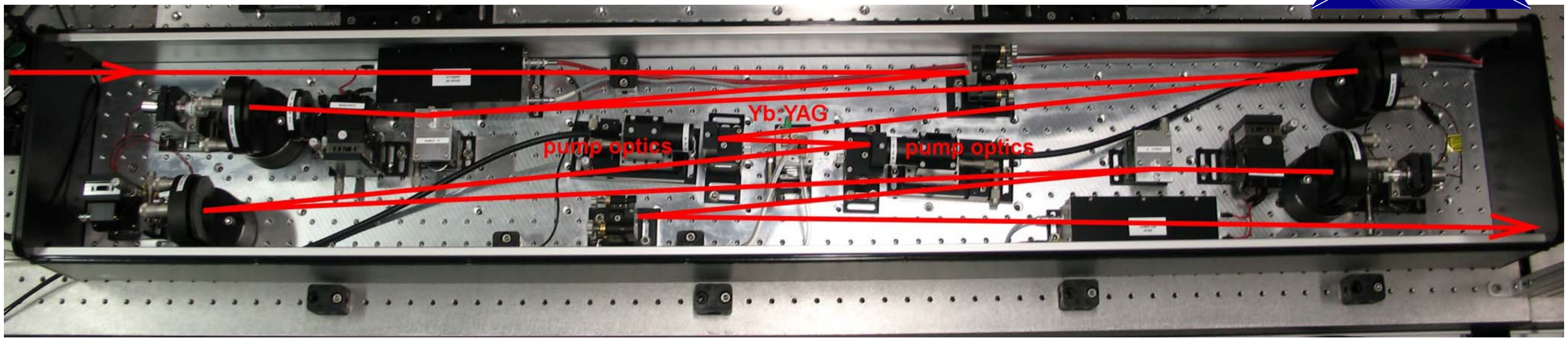
Extension of the HoBiCaT Cavity Test Facility



The drive laser: cw with short pulses in UV to do beam diagnostics experiments with the Pb/Nb system



SESAM modelocked oscillator

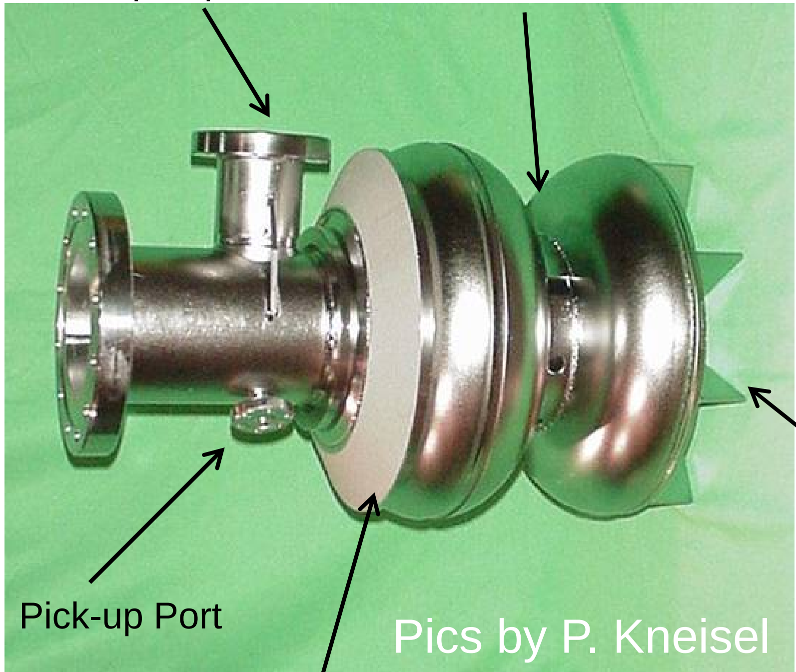


Regenerative amplifier

Cavity fabrication at Thomas Jefferson Lab (P. Kneisel, PAC 2011)

Fundamental power coupler port

Stiffening ring



Pick-up Port

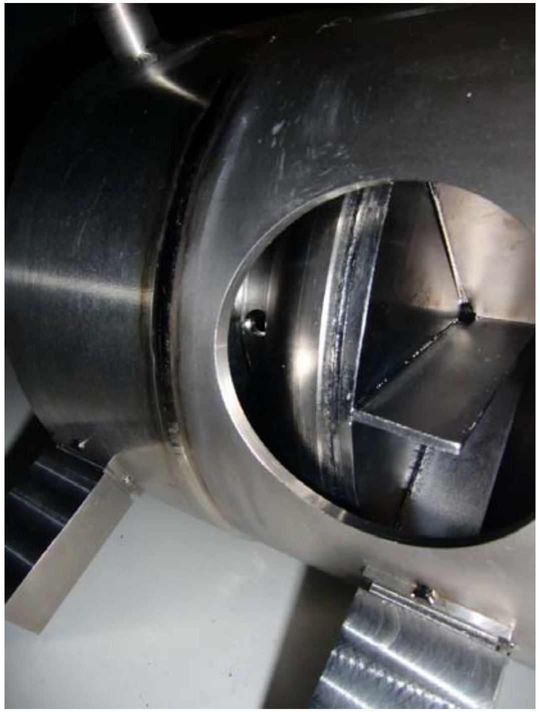
Passive stiffening System: “Spider“

„Helium vessel endplate“

Large grain cavity backwall for cathode

Cavity half-cells

TTF-III FPC: $Q_L = 1\cdot10^9 - 6\cdot10^6$
including 3-stub tuner

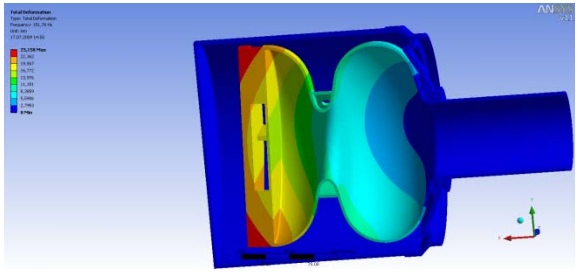


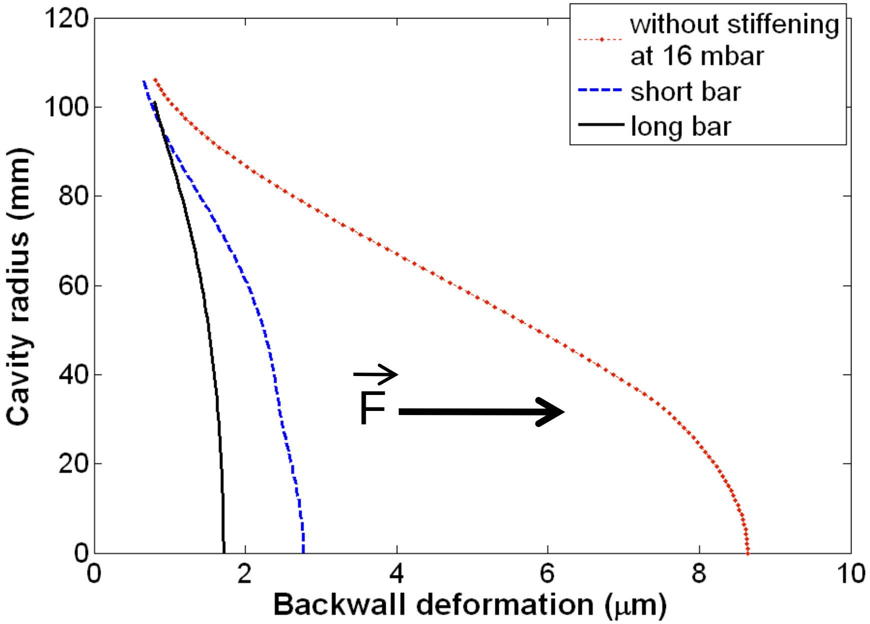
Cavity in helium vessel

Mechanical design: Countermeasures to increase field stability

- Beam quality dominated by field stability
- Field stability in SC cavity: Avoid detuning (deformation) of the cavity

Combined FEM mechanical and
Electro-magnetic field simulations
→ low deformation (detuning) design





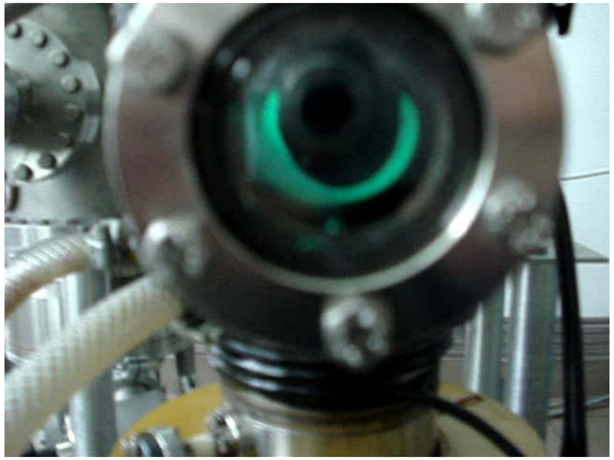
Detuning in Hz/mbar

Type	SuperFish	CST MWS	Measured
Without	527	615	-
Short bar	200	-	474
Long bar	130	-	-
“Spider”	-	-	114

Cathode deposition at IPJ Andre Soltan Swierk

Cavity with helium vessel

Plasma arc
depositon setup
in 30° configuration

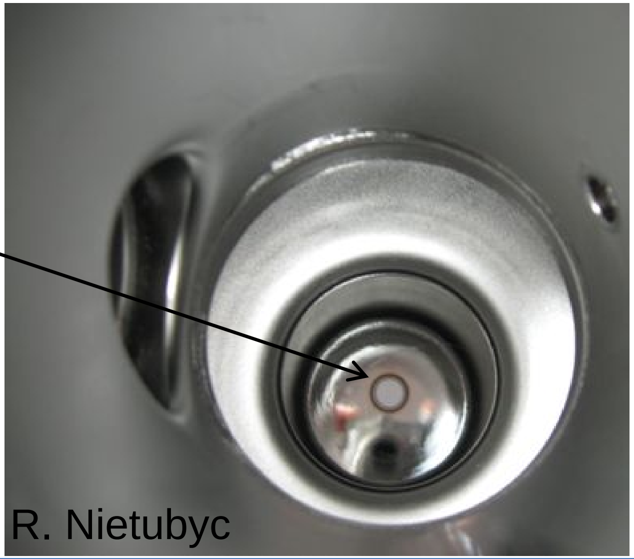


16 x 5min depositions result
in a few hundred nm thick
Pb cathode film

Mask to protect cavity

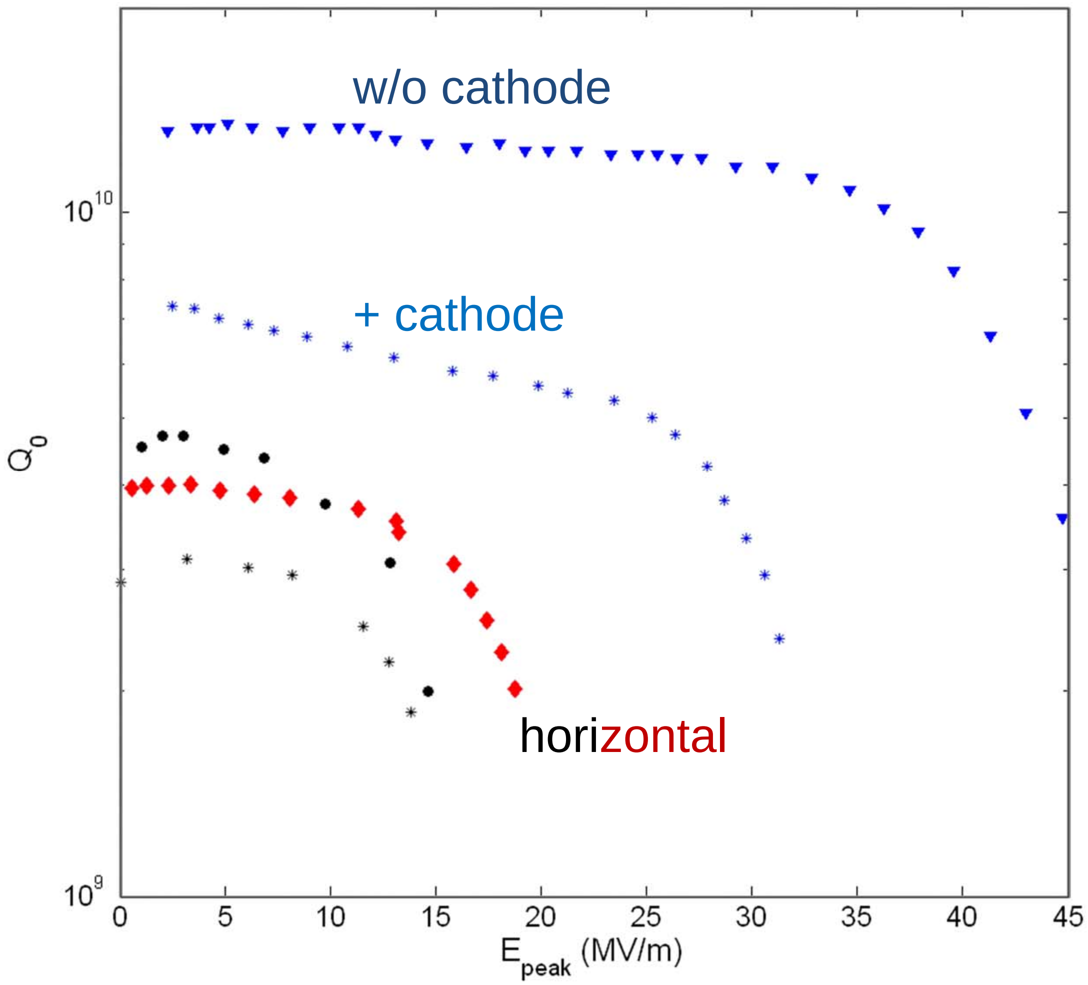
Pb cathode film

Final diameter
by BCP + special
mask: 5 mm



R. Nietubyc

Quality factor measurements: Vertical and Horizontal tests (JLab and HZB)



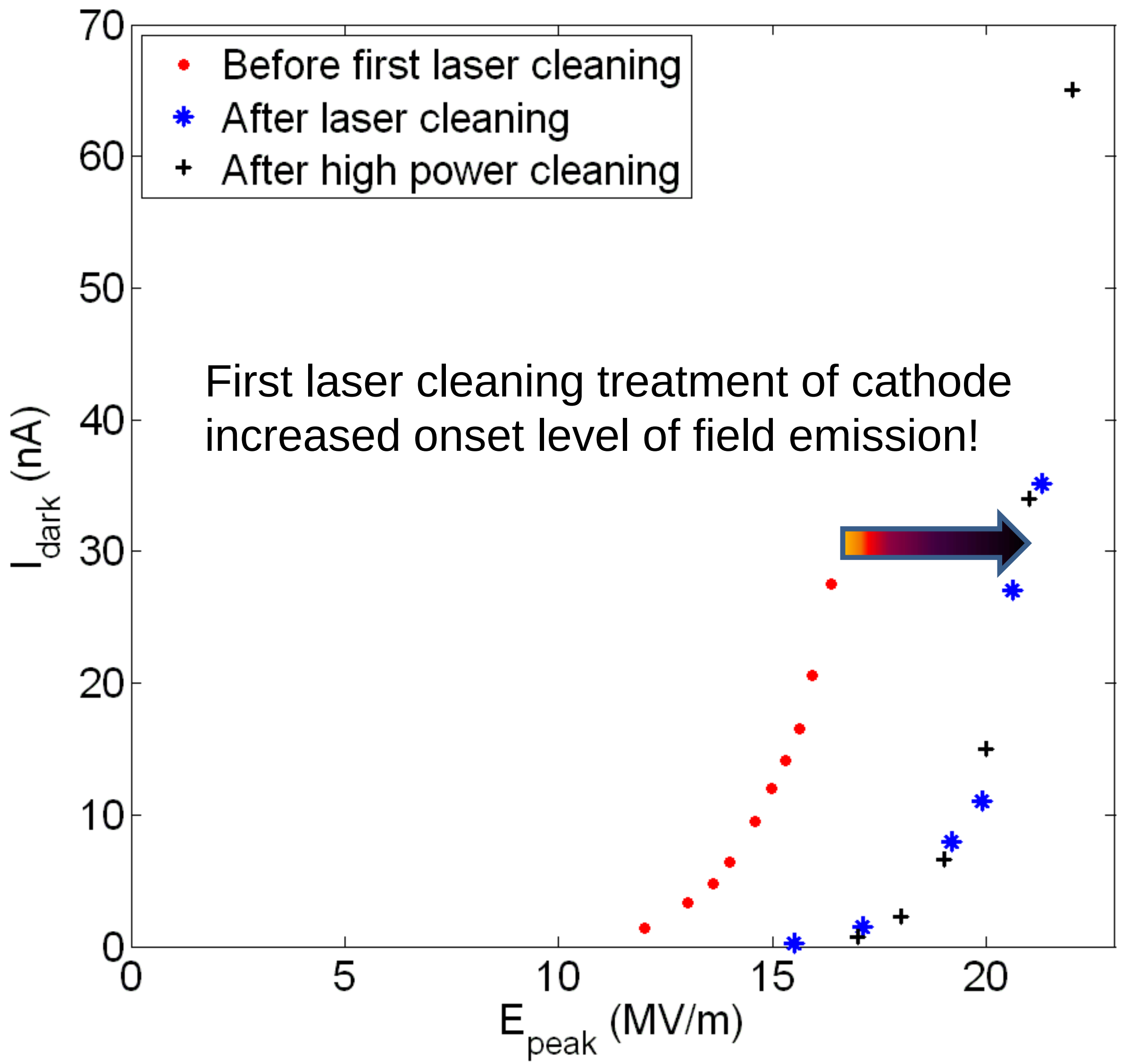
Note: Horizontal RF tests at β_c~3-4, error bar!

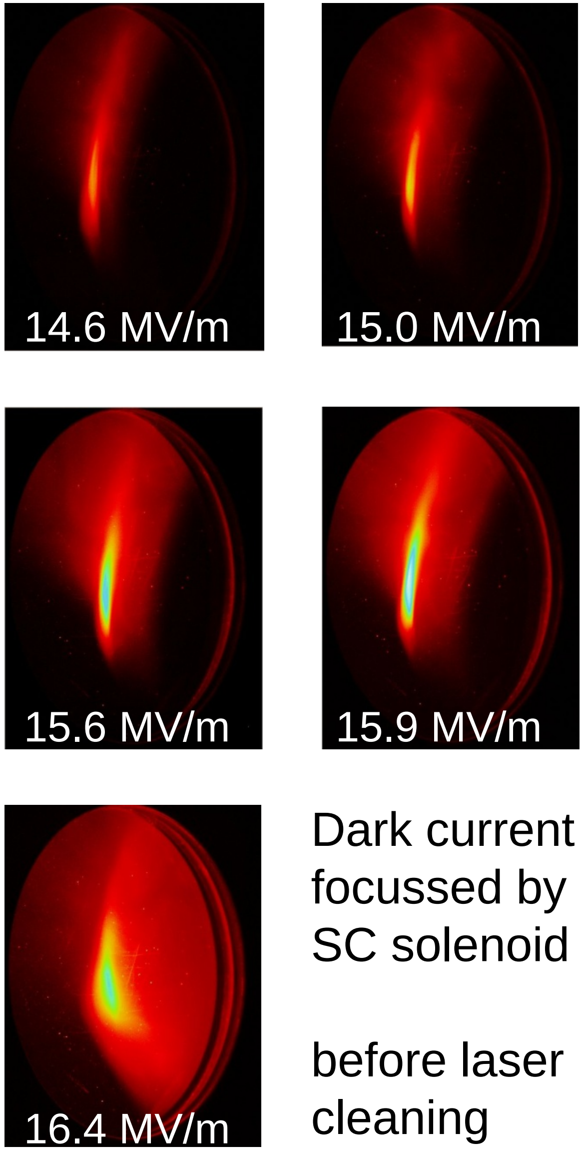
- Vertical test after fabrication, treatment and mounting $Q_0>1\cdot 10^{10}$ for $E_{peak}<35$ MV/m
- After lead deposition Q drops significantly and field emission (FE) onset lowered
- Installation in HoBiCaT further Q degradation, FE onset 12 MV/m
- After additional cooldown cycle even worse, cavity collects residuals

- Excimer Laser cleaning of lead cathode increased onset of FE to 18 MV/m

Operation of up to 20 MV/m, E_{acc} ~ 11 MV/m possible

Dark current studies

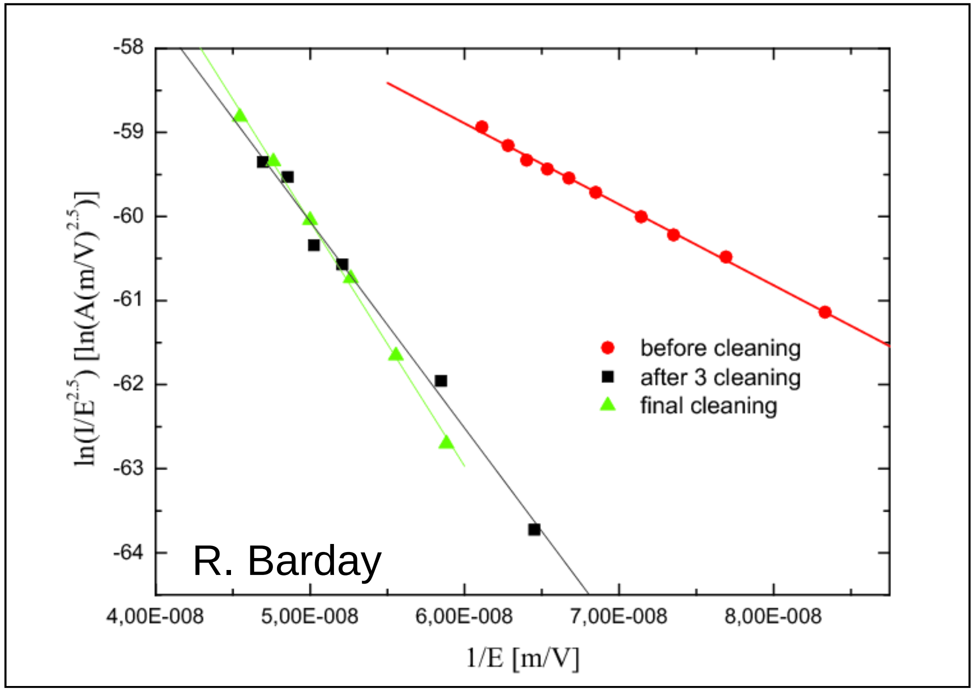




Dark current focussed by SC solenoid

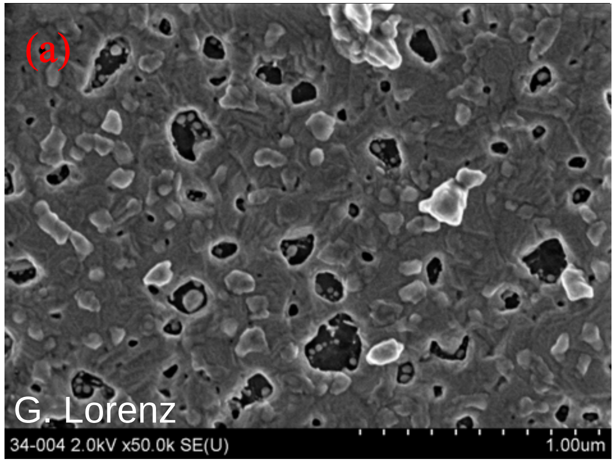
before laser cleaning

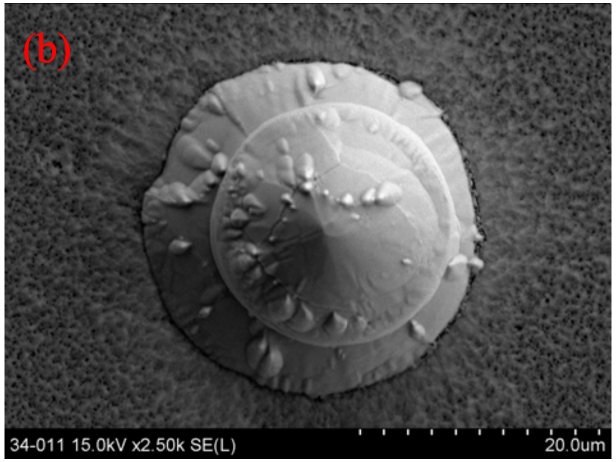
Dark current studies continued



Nordheim-Fowler fit of dark current/ field emission shows reduction of field enhancement factor β_{NF}.

Effectively emitting A_e area increases





Arc deposited lead samples sem image

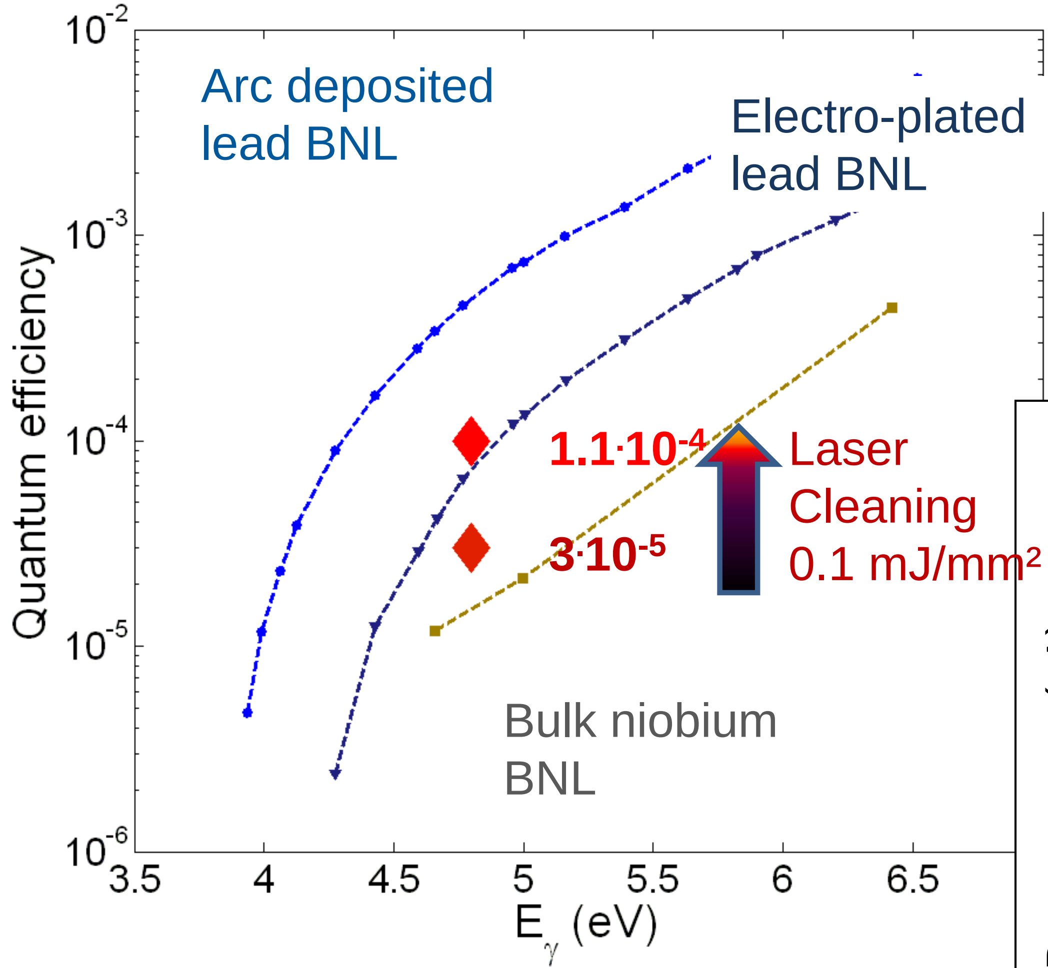
SEM images of comparable samples show droplets and tip on tip like structures

Laser cleaning levels small defects? (λ=248 nm, 0.1 mJ/mm²)

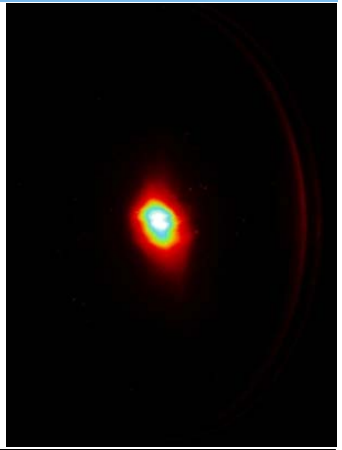
Tests with Niobium are planned

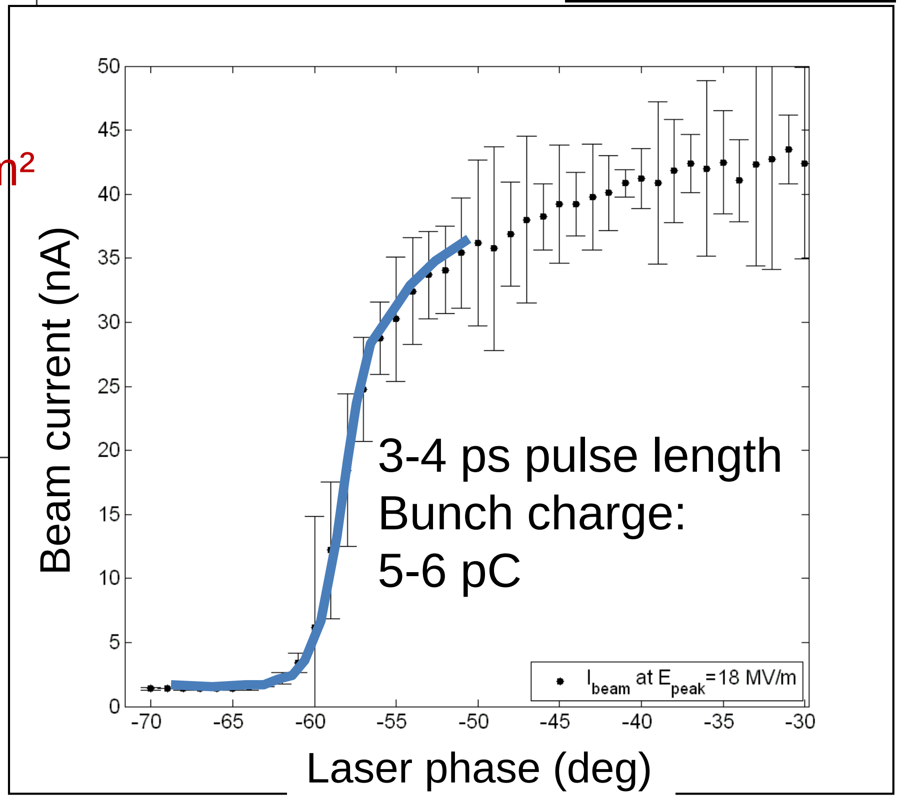
Quantum Efficiency and beam measurements

J. Smedley, T. Kamps, T. Quast, A. Neumann, R. Barday



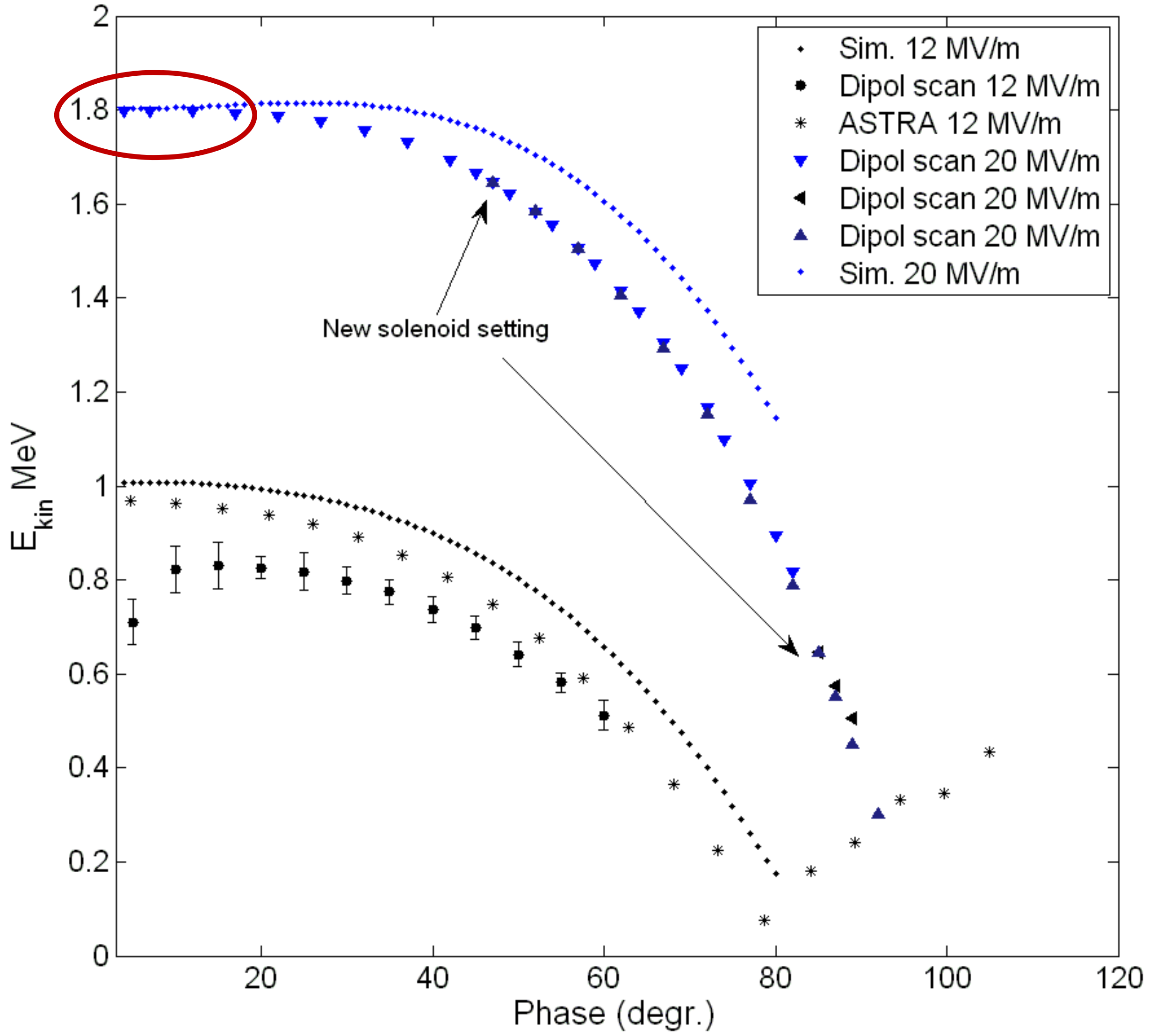
First beam
21st of April 2011
on YAG viewscreen





I_{beam}=50 nA at E_{cath}=20 MV/m
at 8 kHz Laser rep. Rate, λ=258 nm

Beam energy


Sim. 12 MV/m
Dipol scan 12 MV/m
ASTRA 12 MV/m
Dipol scan 20 MV/m
Dipol scan 20 MV/m
Dipol scan 20 MV/m
Sim. 20 MV/m
New solenoid setting
E_kin MeV
Phase (degr.)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
20
40
60
80
100
120

The three stage approach

Parameter	HoBiCaT Stage A	Gun lab Stage B	BERLinPro Stage C
Goal	Beam Demonstrator	Brightness R&D gun	Current Production gun
Electron energy	$\geq$ 1.5 MeV		
RF frequency	1.3 GHz		
Design peak field	$\leq$ 50 MV/m		
Operation launch field	$\geq$ 10 MV/m		
Bunch charge	$\leq$ 77 pC		
Repetition rate	30 kHz	54 MHz	1.3 GHz
Cathode material	Pb	Cu, CsK_2Sb	CsK_2Sb
Laser wavelength	258 nm	355, 526 nm	526 nm
Laser pulse energy	0.15 µJ	$\leq$ 1 µJ	4 nJ
Laser pulse shape	Gaussian	Gaussian, Flat-top	Flat-top
Laser pulse length	2.5 ps FWHM	$\leq$ 15 ps	15 ps
Average current	0.5 µA	$\leq$ 10 mA	100 mA

Stage A (Beam dynamics):

- Study beam dynamics of SC RF photoinjector:
  - Emittance
  - Field levels
  - Stability
- Fully SC design
- Starting point for design and operation of SRF gun

Stage B (Peak Brightness):

- Study + develop cathode insert into SC injector:
- Lifetime and QE of cathode materials
- Reliable cathode replacement scheme

Stage C (High avg. Current):

- SC design for ERL design current
- High power operation
- HOM damping
- Cathode lifetime

Started here

Outlook: Near future

- Measurements of beam emittance and thermal emittance of lead are in progress, data will be published at IPAC 2011(T. Kamps *et al.*)

- More detailed studies about laser cleaning, QE measurements, also XPS analysis will be published in the near future

- Further studies about the cavity trips will be done, improvement of Q_0 by helium processing is planned for

This work is a collaborative effort by:

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HZDR, Rossendorf
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