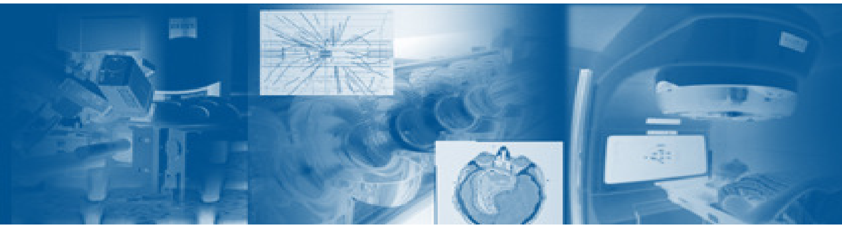


PT1: SC RF Technologies

Superconducting Photo Injectors for cw Operation

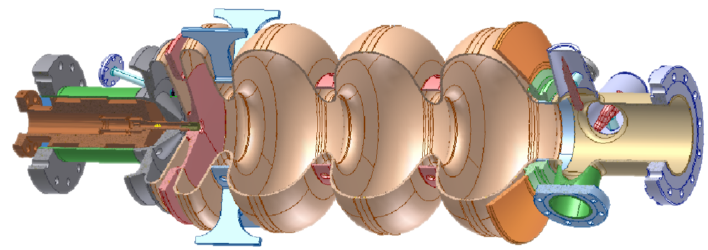
P.Michel/HZDR

ARD review meeting 21./22. November 2011, GSI

Many thanks to
J.Secutowic/DESY, T.Kamps/HZB, J.Teichert/HZDR, I.Will/MBI

Motivation:

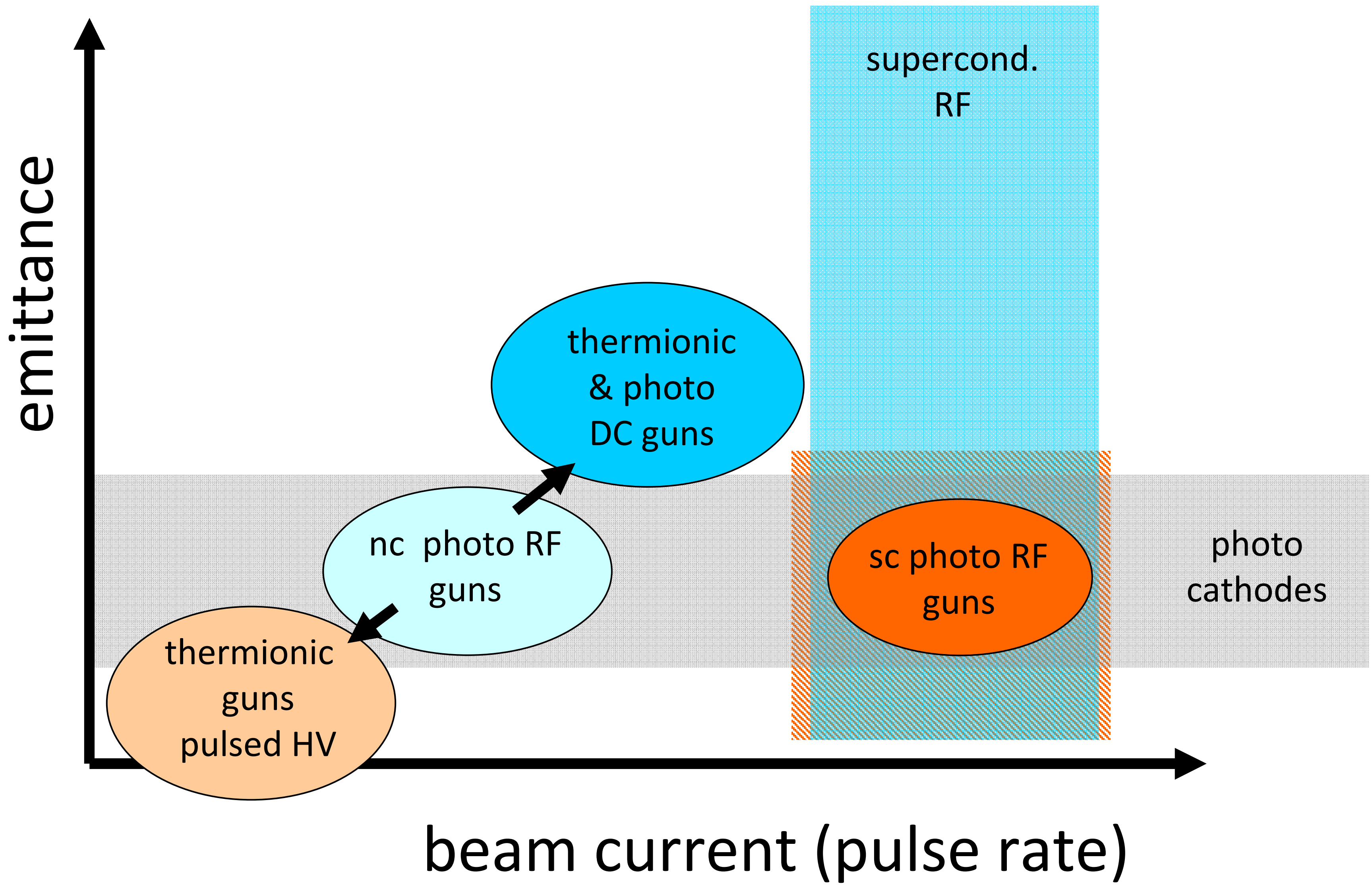
- missing puzzle in high power accelerator technology (cw, high brightness, ERL)
- compact accelerators and radiation sources



Challenges:

- combination of low emittance and high average power beams (4th generation LS)
- combination of specific requirements of sc RF and photo cathode technology
- high acceleration fields on photo cathode and high voltage
- development of dedicated photo cathode lasers for low emittance cw beams
- emittance compensation in sc RF guns (TE mode in coupling, sc solenoids…)
- RF coupling and HOM damping
- dedicated gun diagnostics
- pushing sc RF injector technology from „proof of principle“ to routine application

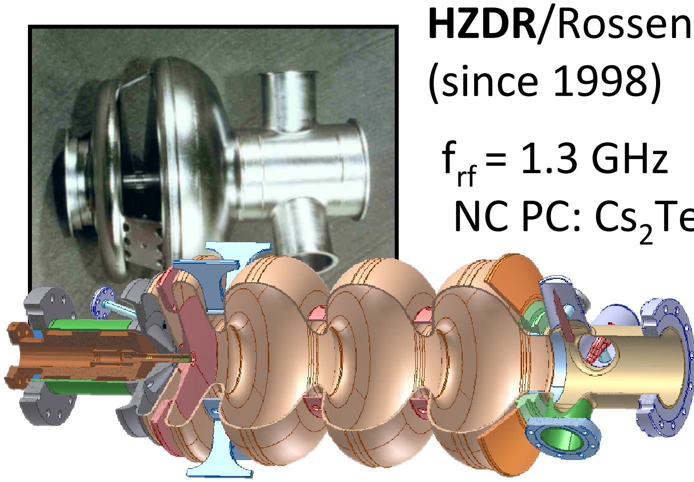
Why sc RF injectors ?



Superconducting RF Photo Guns

HELMHOLTZ GEMEINSCHAFT

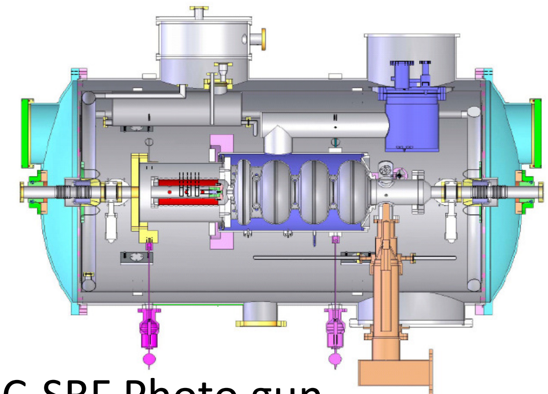
SRF guns with TESLA-style elliptical cavities



HZDR/Rossendorf
(since 1998)

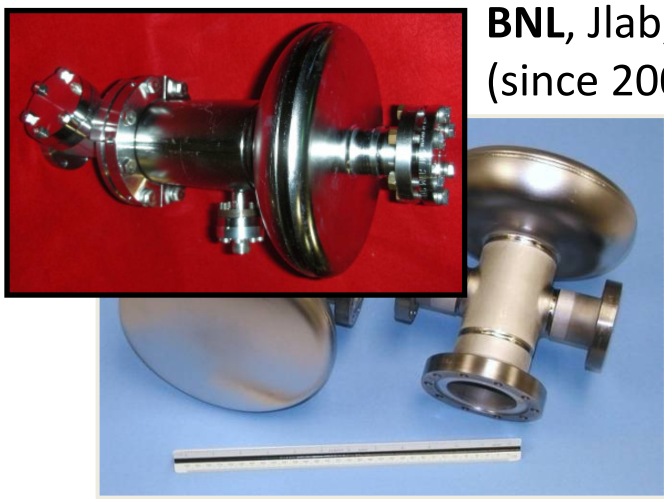
f_{rf} = 1.3 GHz
NC PC: Cs_2Te

IHEP Peking University (since 2001)



DC-SRF Photo gun

f_{rf} = 1.3 GHz
NC PC: Cs_2Te



BNL, Jlab, DESY
(since 2002)

f_{rf}=1.3 GHz
SC PC:
Nb, Pb

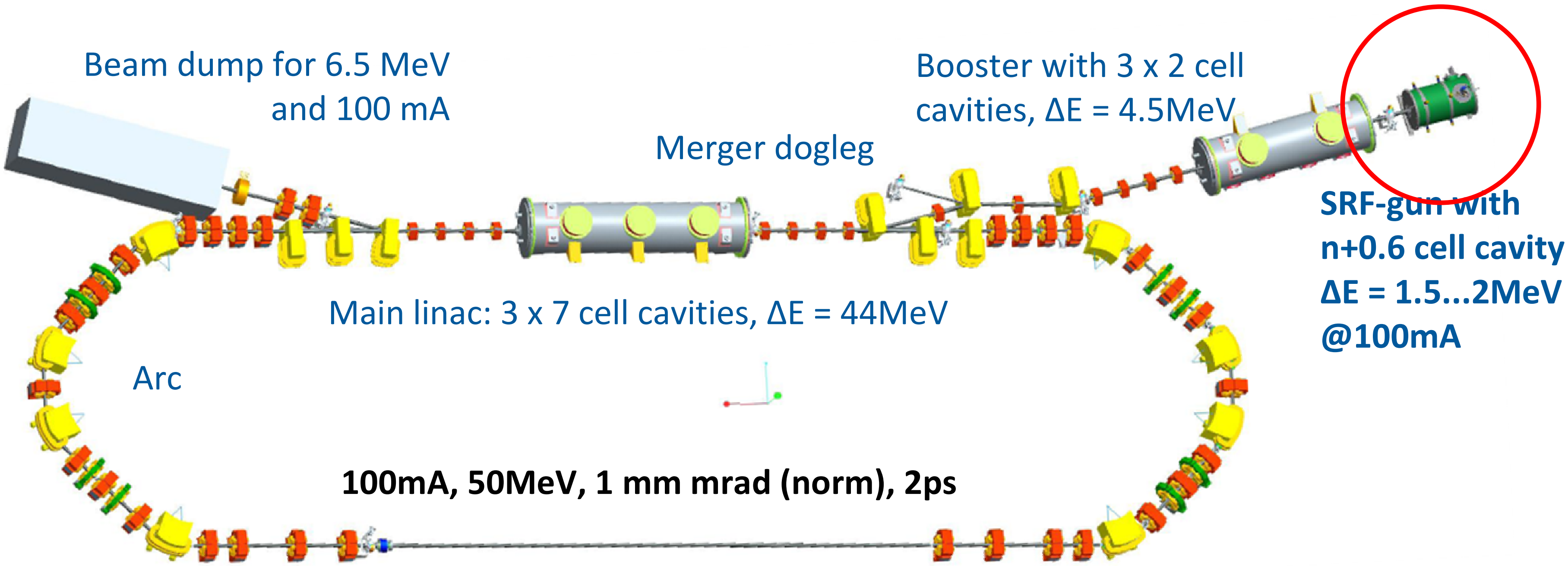
NC PC:
GaAs

HZB, DESY, Jlab, Soltan Inst.
(since 2008)

f_{rf} = 1.3 GHz
SC PC: Pb

BERLinPro stage one gun

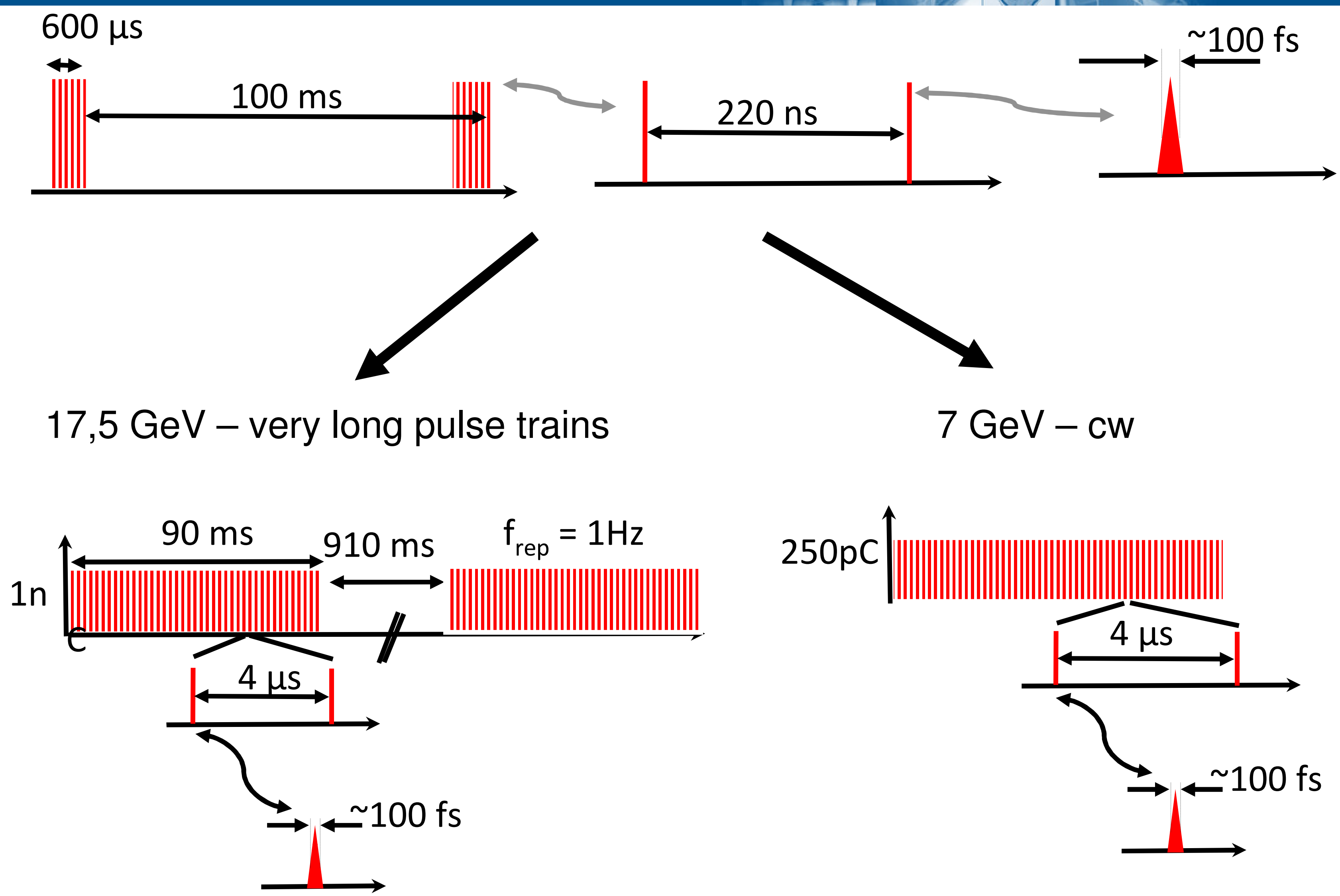
BERLinPro



Courtesy T. Kamps

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

XFEL cw upgrade



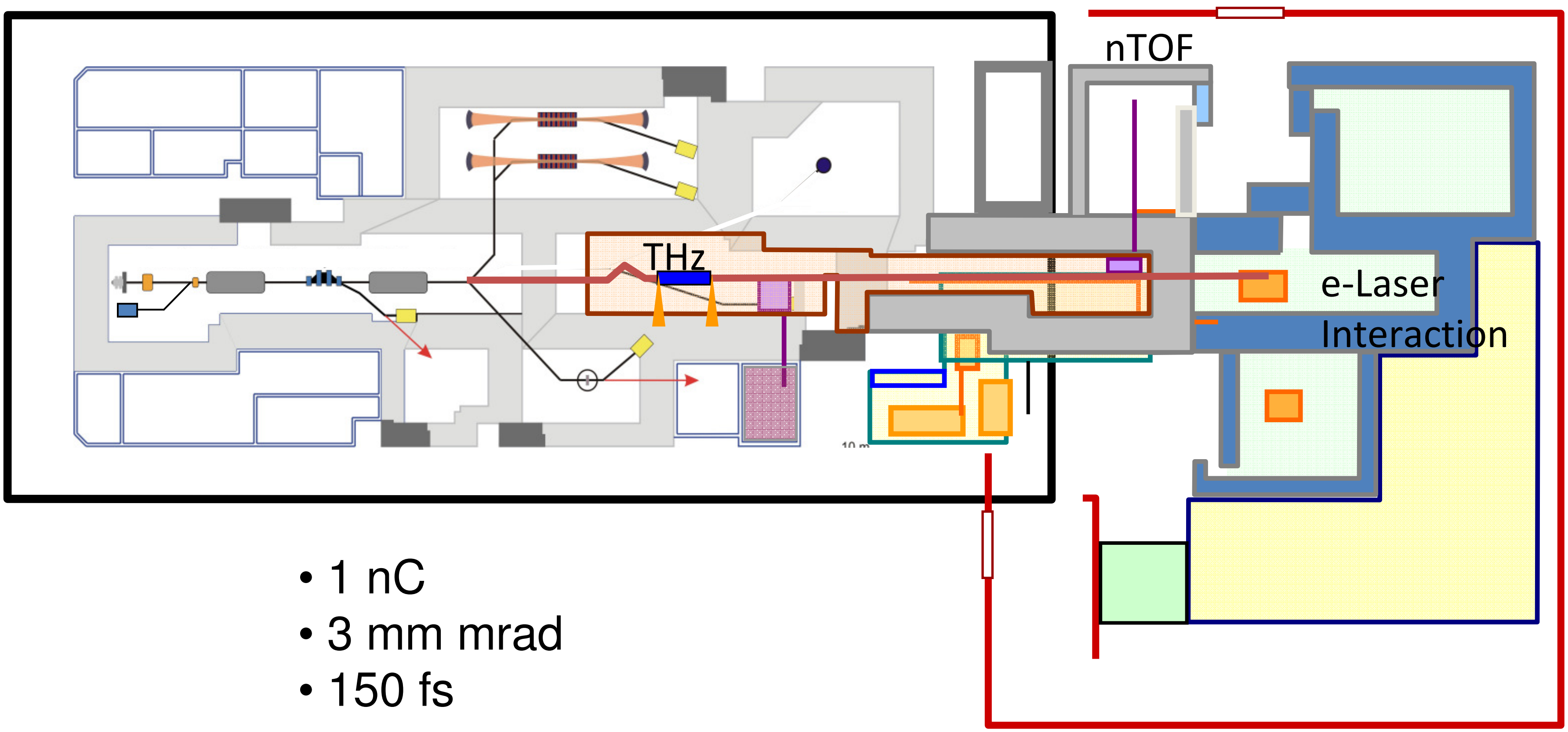
additional pulse structure will make the XFEL photon beam even more attractive

ELBE upgrade for new & improved secondary (user) beams

HELMHOLTZ GEMEINSCHAFT

high bunch charge / low emittance / ultra short pulses

- coherent THz generation
- neutron TOF
- electron beam – high power laser interaction (Thomson X‘rays)



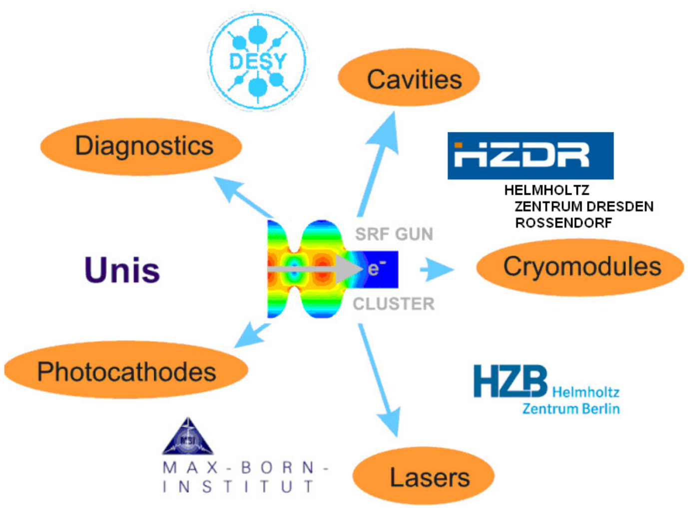
- 1 nC
- 3 mm mrad
- 150 fs

sc RF gun cluster

- there are at least three centers of expertise in sc RF gun technology
- german gun cluster was founded in 2010 (DESY, HZB, HZDR + MBI)
- different designs for different applications – using similar techniques
- find synergies – share infra structures – exchange experiences

	HZDR	HZB	DESY
Current/mA	1	100	0,18
Pulse charge/nC	1		0,02 - 1
Repetition rate/MHz	0,1- 13		0,18 - 9
Emittance/mm mrad	3	1	<1
Specific	3½ c	½ cell	1½ cells
Photo cathode	Cs_2Te	CsK_2Sb	nc or sc

complementary



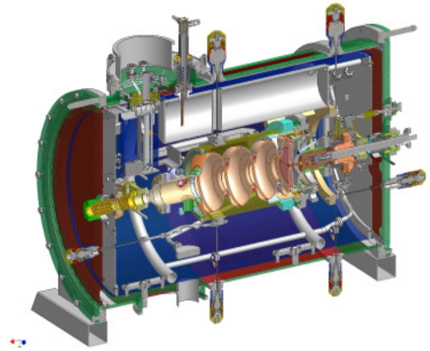
Common infrastructure & partners:

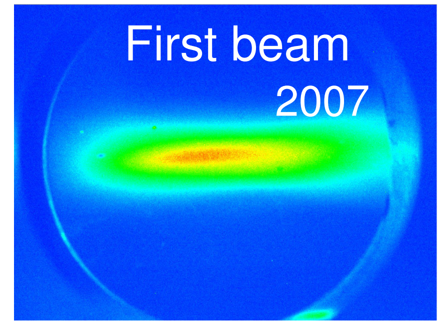
- HoBiCaT @ HZB
- Gun dignostic beamline @HZRD
- DESY clean room labs
- JLab
- laser expertise @ MBI
- photo cathode lab @ Uni Mainz

sc gun cluster status

- **worldwide first sc RF photo gun in routine operation since 2010 at HZDR**

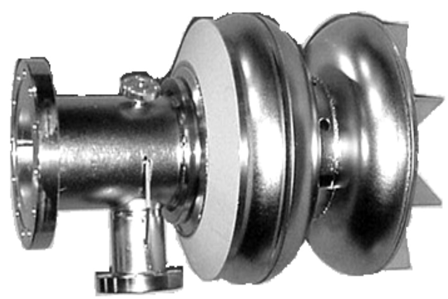
  + long operation time (>35C)
  + key components (Tuner, coupler..)
  - low acc field (limited bunch carge < 100pC)
  - moderate emittance (~ 5 mm mrad)
  - dark current + multipacting

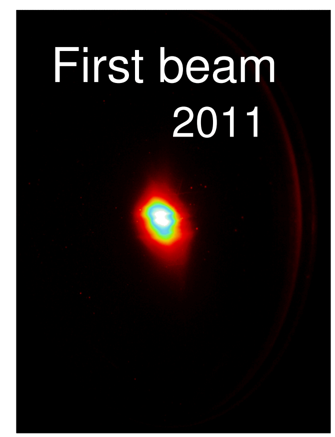




- **first test measurements with 1+1/2 cell cavity with Pb cathode at HZB**

  + proof of principle with Pb cathode
  + extremely fast development , using HoBiCaT test facility
  - missing crucial components
  (tuner, HOM coupler, high QE photo cathode…)





- **first 1+1/2 cell test cavity for XFEL cw p**

  + development of Pb cathode technology
  + vertical tests without/with Pb cathode coating
  - acc gradient degradation after Pb coating

Challenges

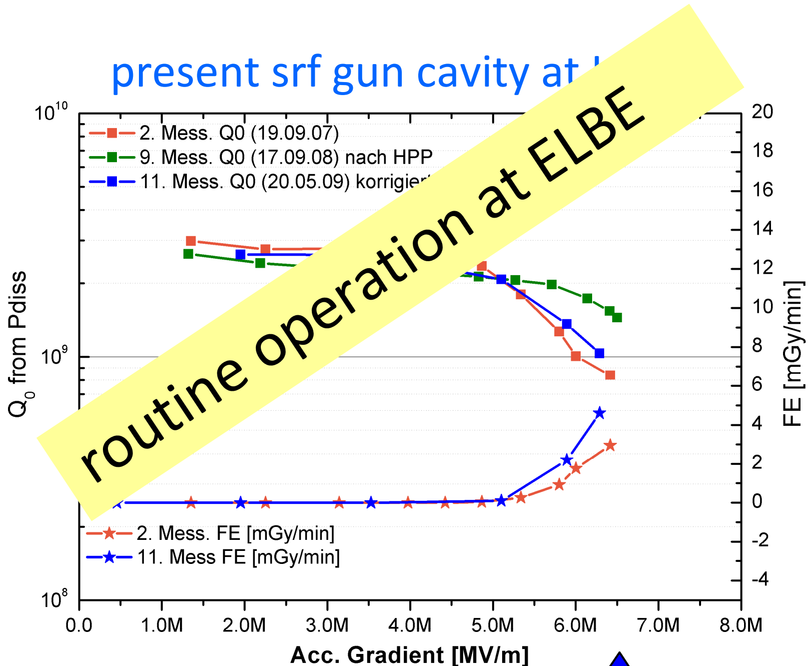
high acceleration gradients on photo cathode

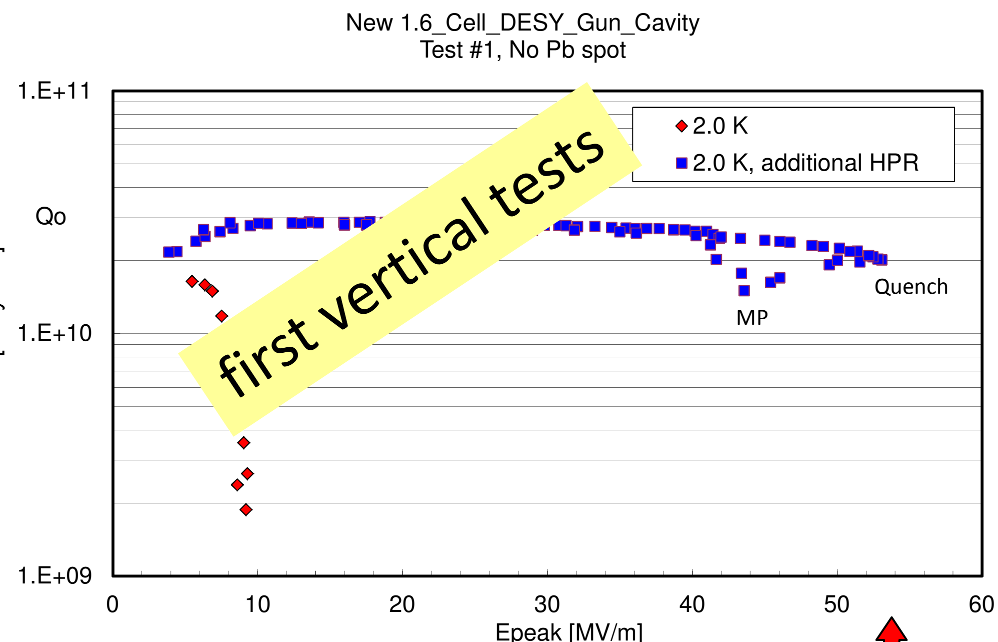
new fine-grain c

HELMHOLTZ GEMEINSCHAFT

- space charge caused emittance growth
- limitation in accelerable charges

present srf gun cavity at





E_{acc}= 6 MV/m

E_{peak} = 16 MV/m

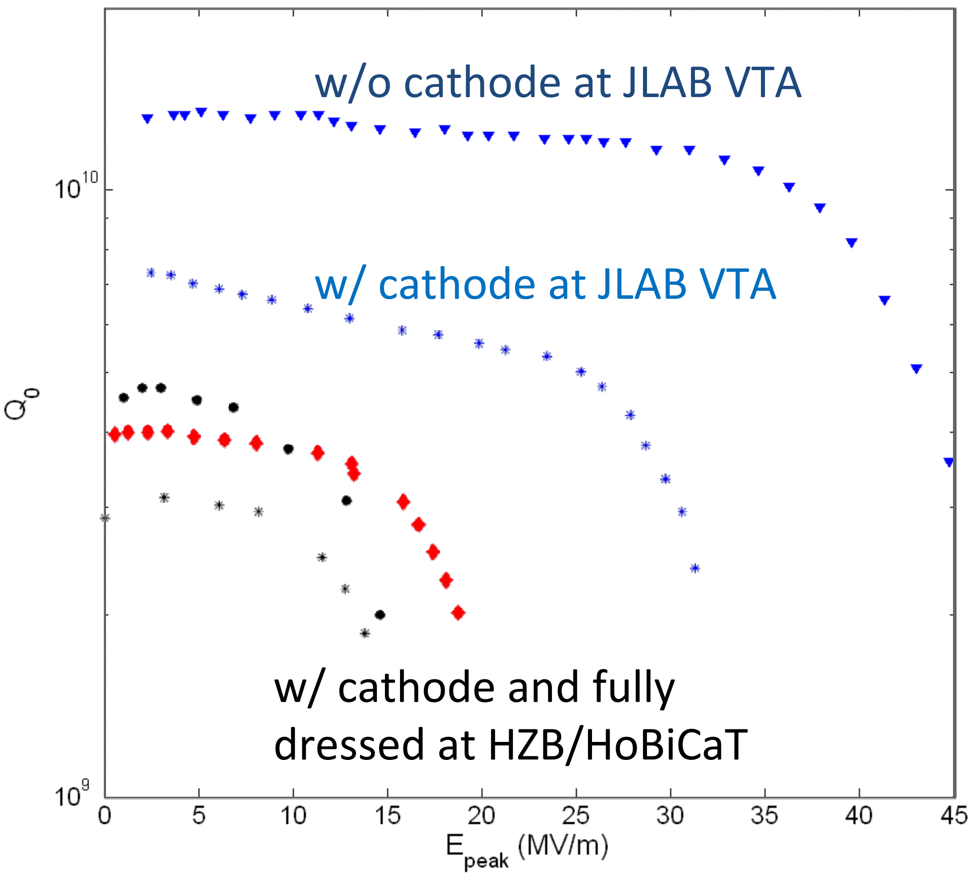
maximum bunch charge: ~ 100 pC

Epeak > 50 MV/m

Challenges

high acceleration gradients on photo cathode

A. Neumann et al, Proc. of SRF 2011



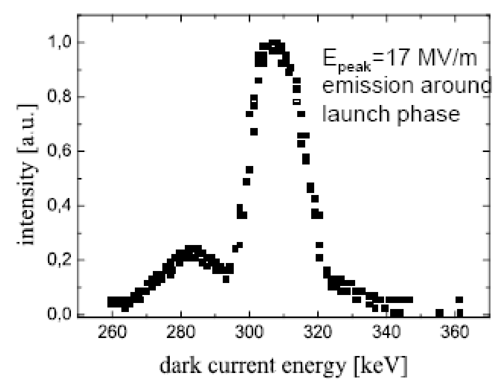
Courtesy T. Kamps

Vertical tests after fabrication showed excellent performance with $Q_o > 1*10^{10}$ and $E_{pk} < 35$ MV/m.

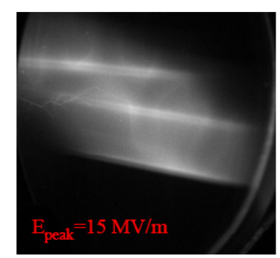
After two rounds of Pb film deposition Q_o drops significant and field emission (FE) onset lowered.

At HZB HoBiCaT even worse after installation and cool/warm cycles.

Lasercleaning and field processing helped to move FE onset up.



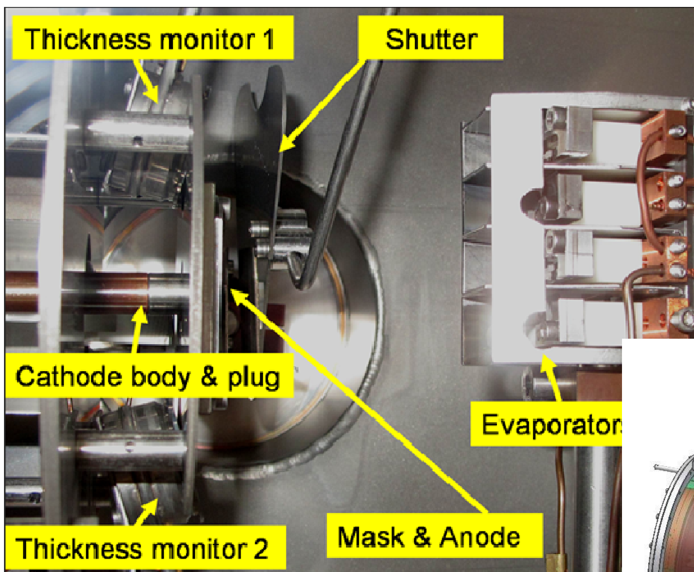
R. Barday et al, Proc. of PST 2011



Challenges

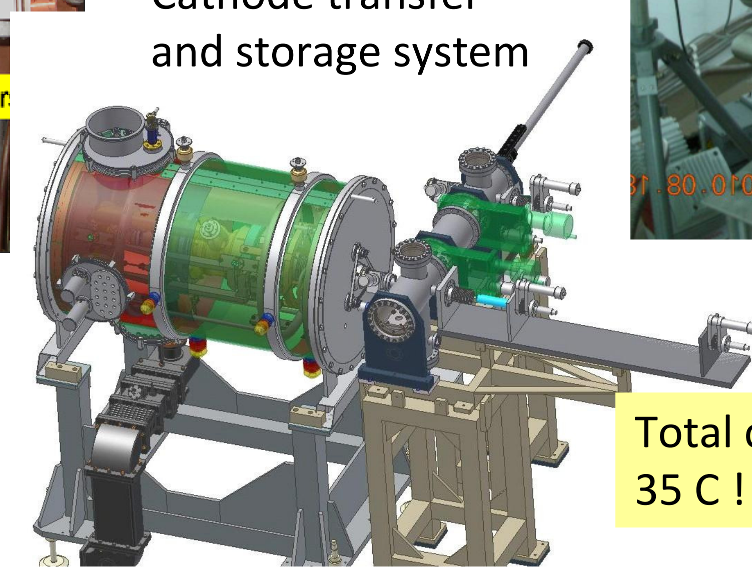
photo cathode preparation and handling

- contamination from photo cathode layers ?
- cathode life time
- coating technology ?
- alternative photo cathode materials CsK_2Sb, GaAs …
- photo cathode insertion and transport technology



Cs_2Te deposition
HZDR

Cathode transfer
and storage system

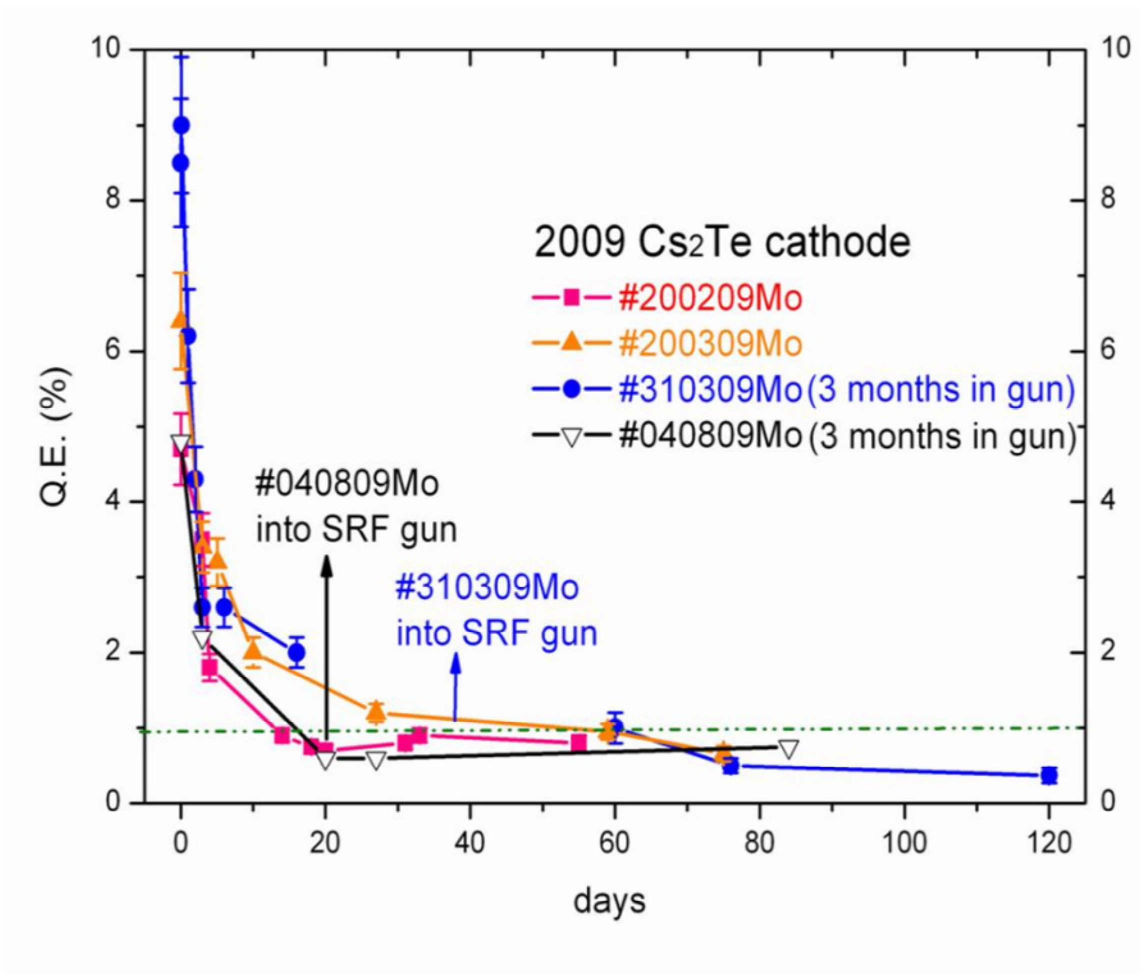


Pb coating
Swierk/Poland

Total charge at HZDR gun:
35 C !!

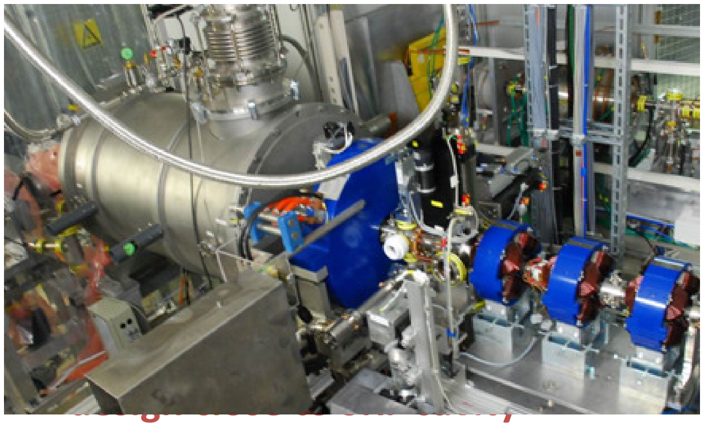
Challenges

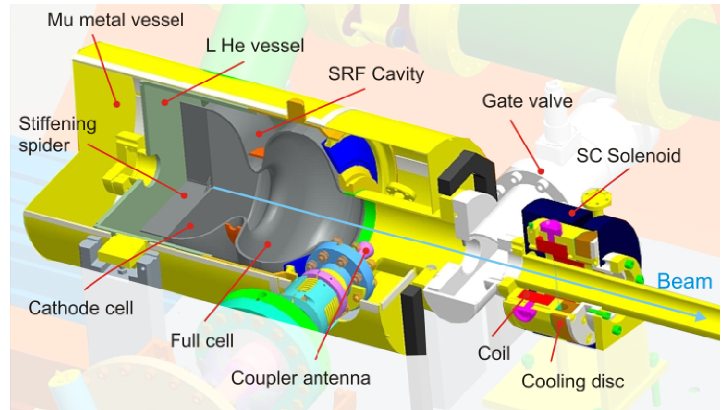
photo cathode preparation and handling



Challenges
low emittance technologies

- superconducting solenoids inside cryostat



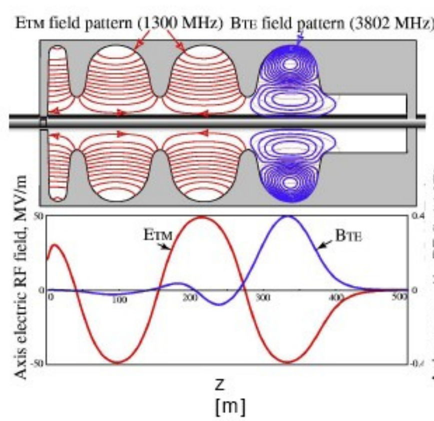


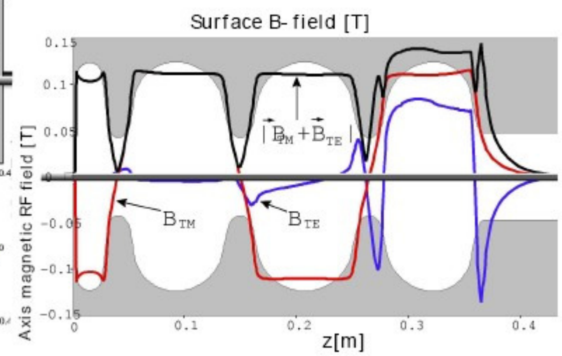
- TE mode induces additional magnetic fiel inside RF cavity

EMITTANCE COMPENSATION IN A SUPERCONDUCTING RF PHOTOELECTRON GUN BY A MAGNETIC RF FIELD

Dietmar Janssen, Forschungszentrum Rossendorf, Germany
Vladimir Volkov#, BINP SB RAS, Novosibirsk, Russian Federation

Proceedings of EPAC 2004, Lucerne, MOPKF014.

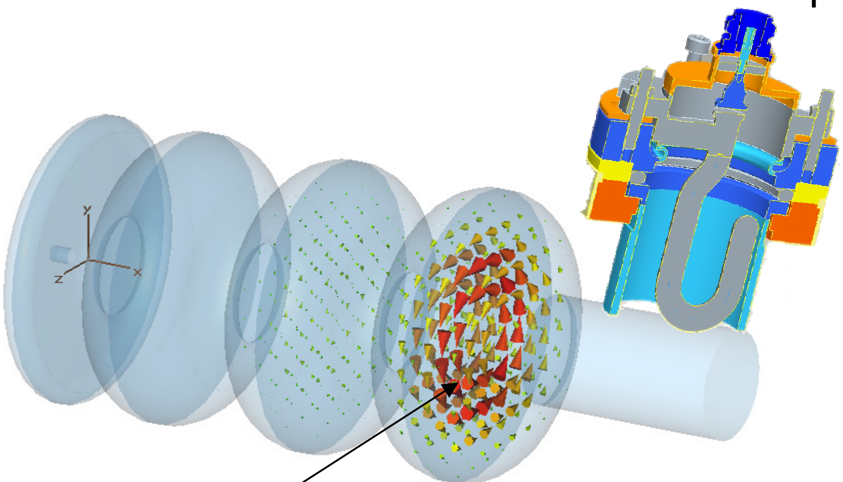




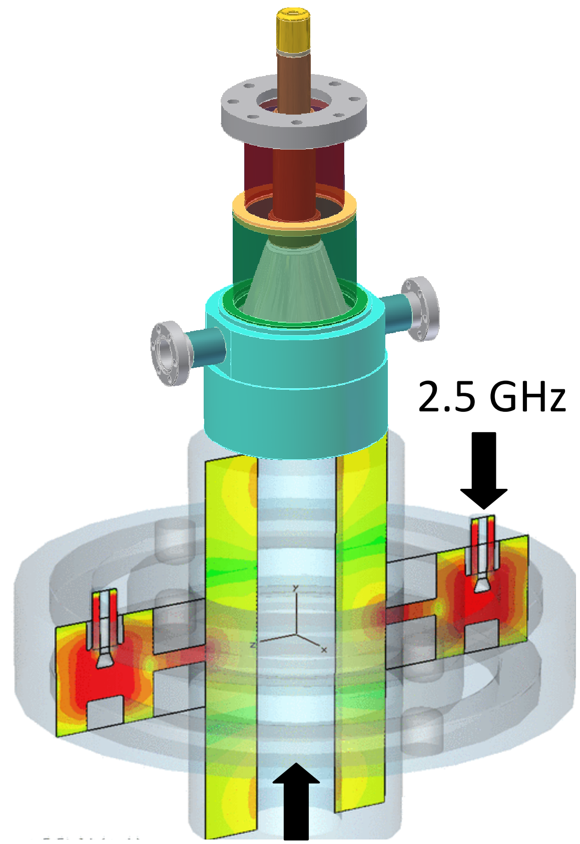
Challenges
low emittance technologies

Patent registered by A.Arnold/HZDR
DE 10 2009 046 463.A1

Saclay hook coupler



H-Field of TE_{011}-Mode measured @ 2.5 GHz

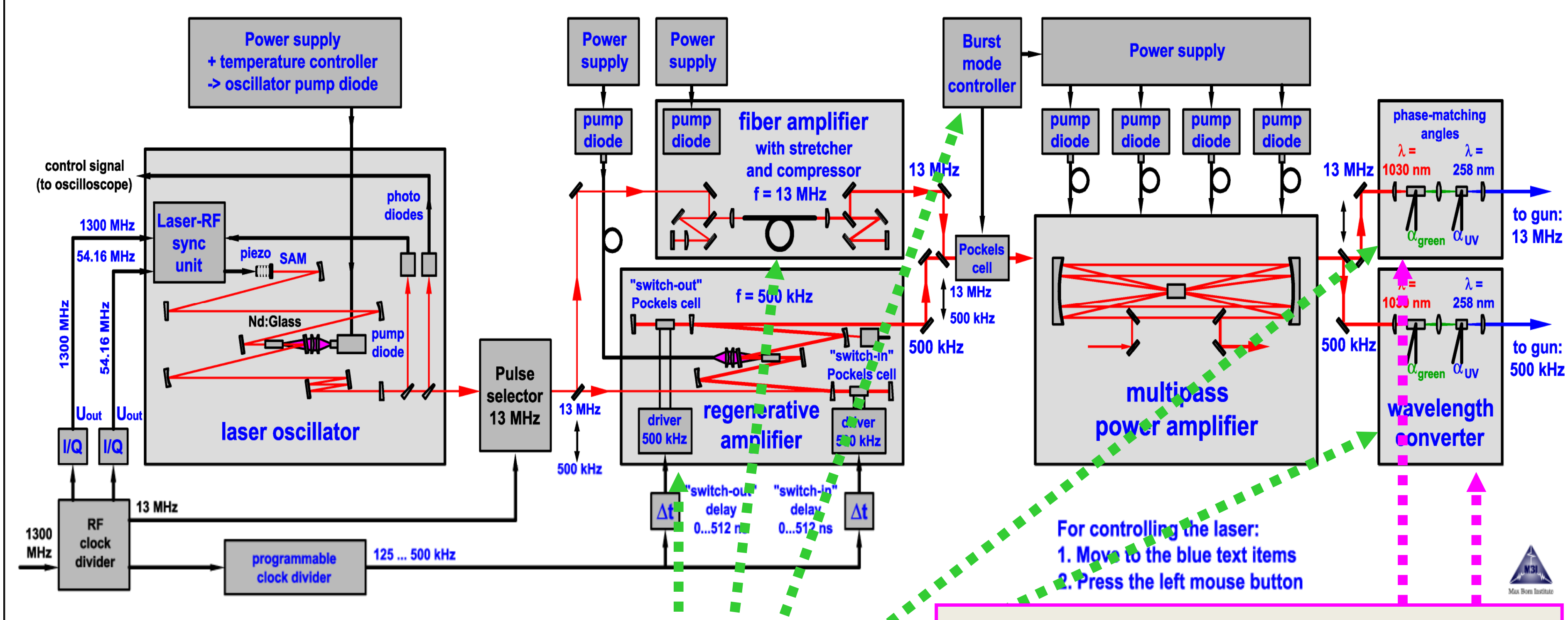


fundamental mode power coupler using special diplexer

Challenges
photo cathode lasers for cw

HELMHOLTZ GEMEINSCHAFT

Photoinjector drive laser for the HZDR SRF gun



Challenges:

- Large flexibility in repetition rate
- Conversion to UV
- Synchronisation ... full remote control
- Optional: pulse shaping

Large flexibility in repetition rate

- **13 MHz** ("standard" operation)
- **100/250/500 kHz**
- **Burst mode** for special use

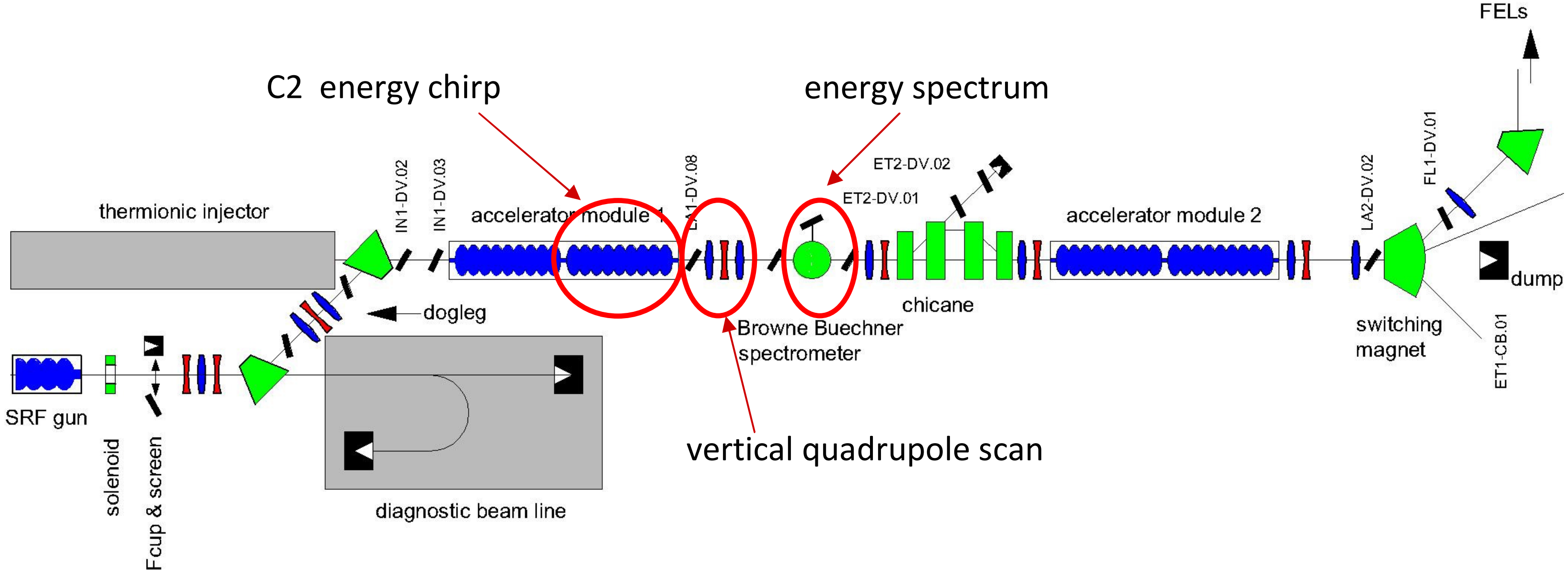
Generation of UV pulses (λ ~ 260nm)

- Conversion efficiency ~5...15%
- Avoid degradation of beam quality due to heat in the final crystal
- Present limits in the UV power:
  P_{UV} ~ 0.7 W (long-term operation)
  P_{UV} ~ 2 W (short-term operation)

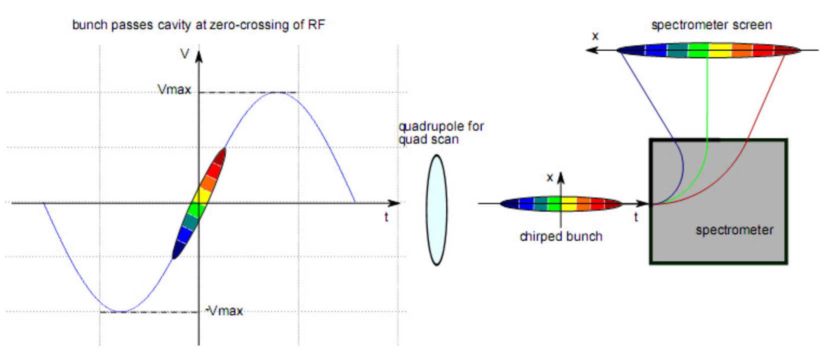
Courtesy I.Will

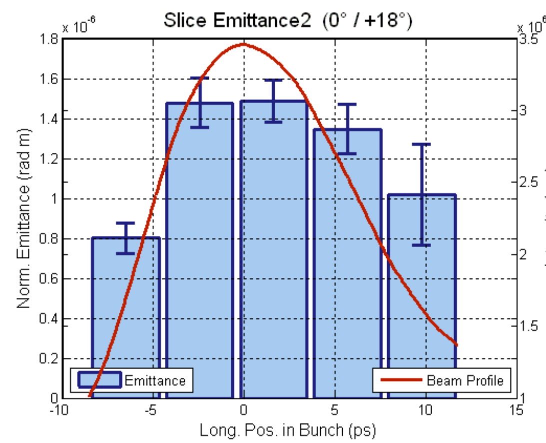
Challenges

advanced gun diagnostics



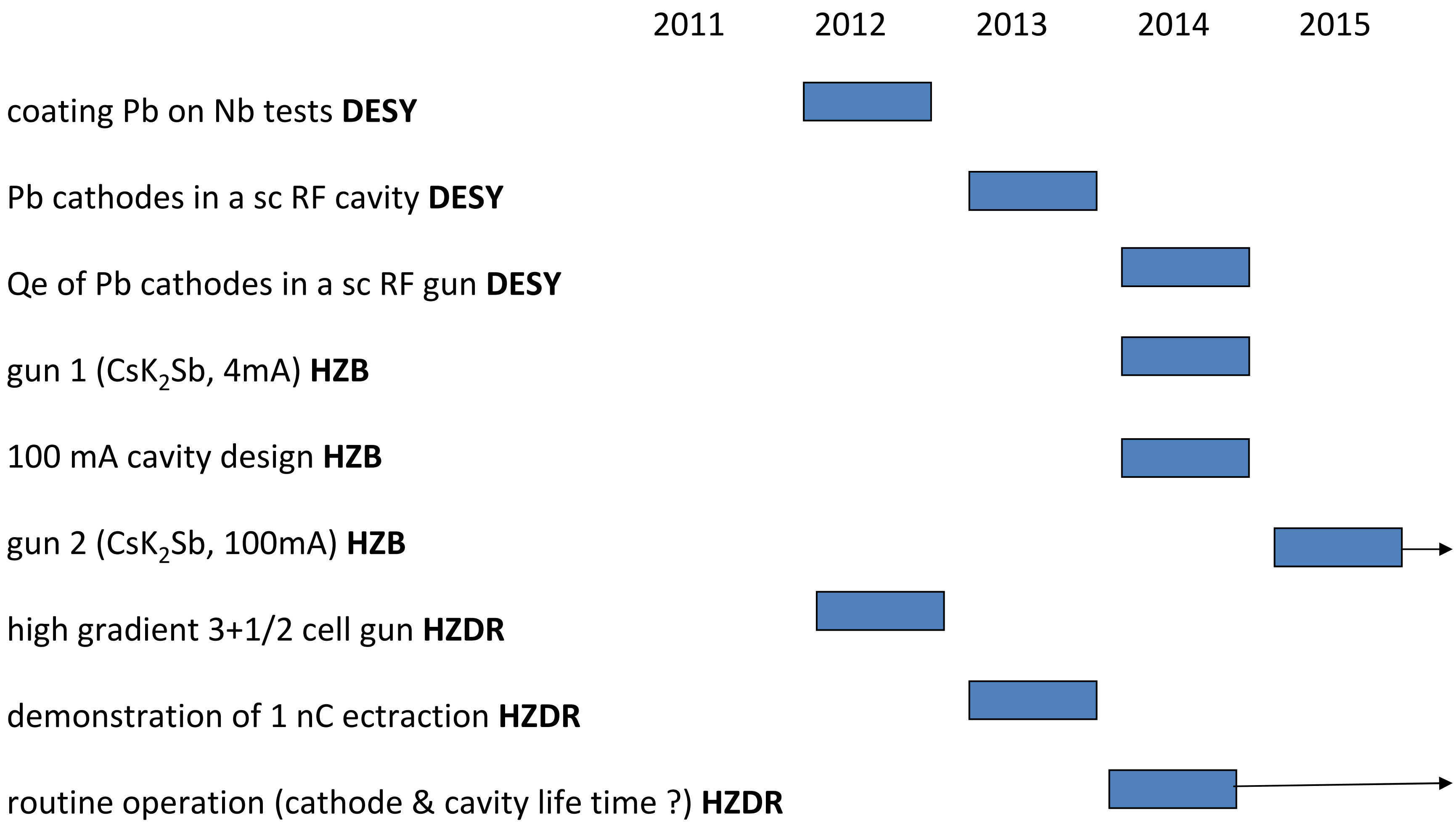
- **Phase scan technique for longitudinal phase phase**
- **Slice emittance measurement**





First result: J.Rudolph/HZB + J.Teichert/HZDR

Milestones



2011
2012
2013
2014
2015
coating Pb on Nb tests **DESY**
Pb cathodes in a sc RF cavity **DESY**
Qe of Pb cathodes in a sc RF gun **DESY**
gun 1 (CsK_2Sb, 4mA) **HZB**
100 mA cavity design **HZB**
gun 2 (CsK_2Sb, 100mA) **HZB**
high gradient 3+1/2 cell gun **HZDR**
demonstration of 1 nC ectraction **HZDR**
routine operation (cathode & cavity life time ?) **HZDR**

Thank you