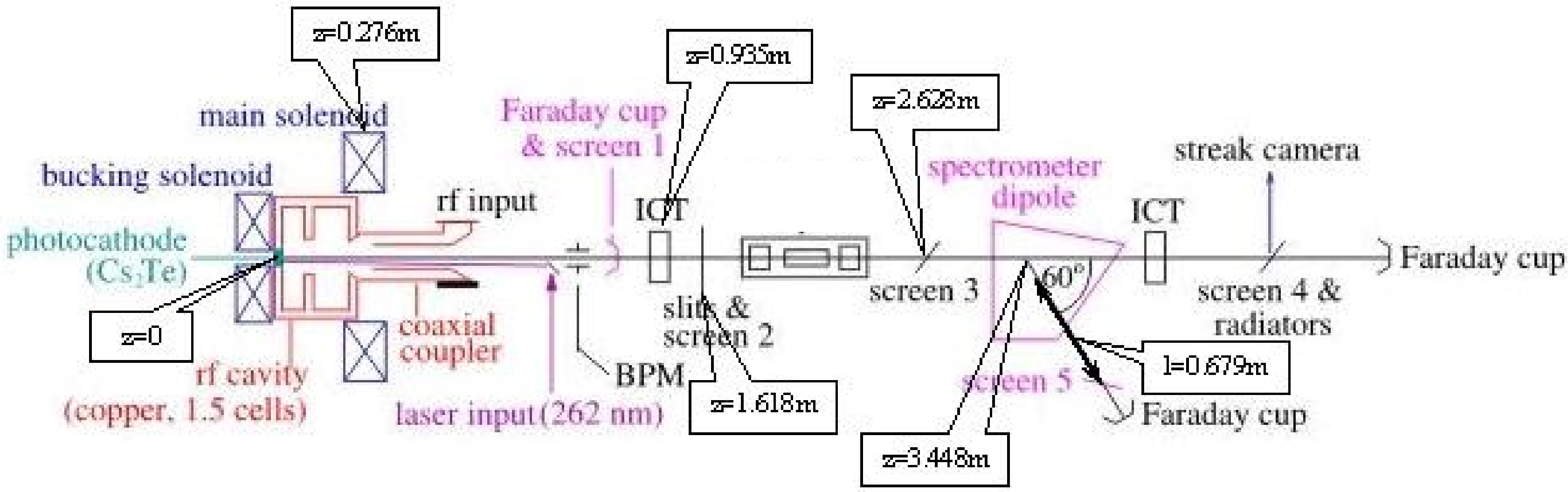
Working Group 4:
Low emittance electron sources

- Benchmark problem
- Talks

WG4 Benchmark problem (PITZ1)

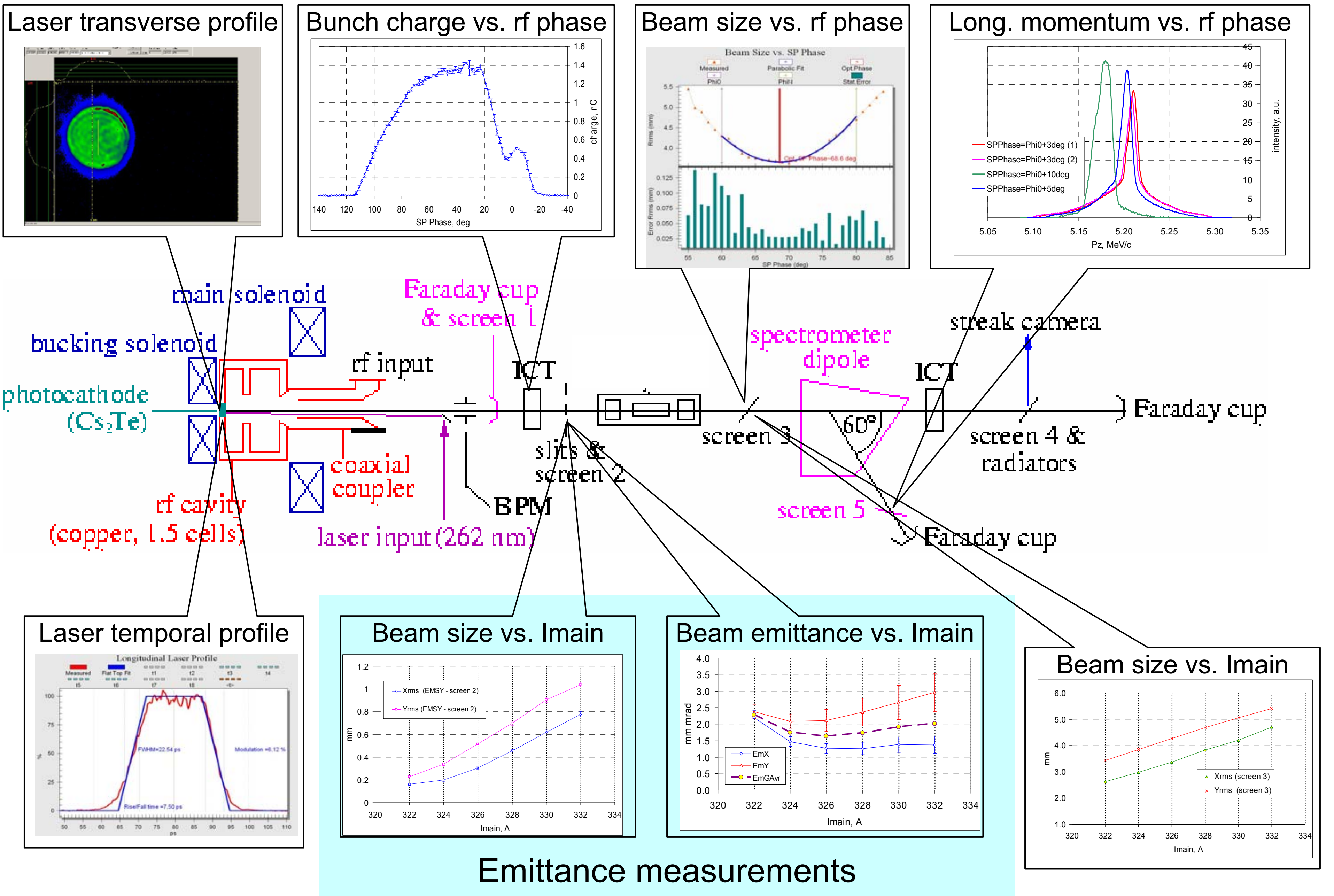


Simultaneous simulations of a set of the consistent beam measurements

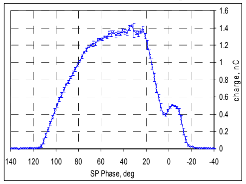
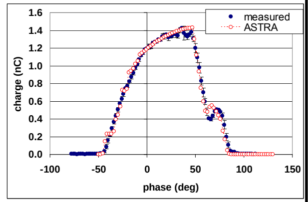
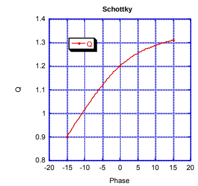
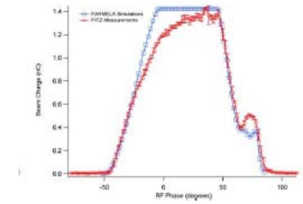
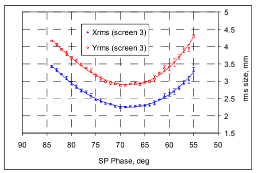
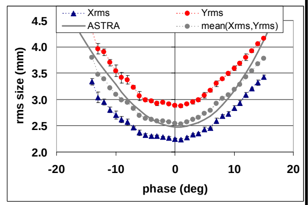
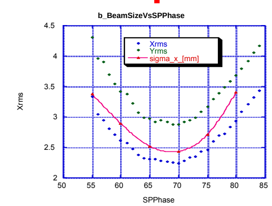
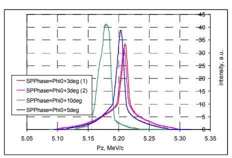
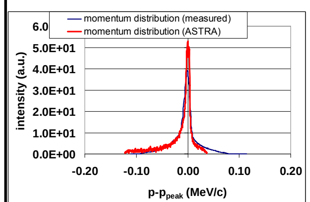
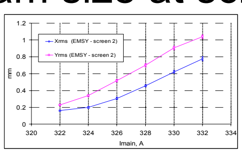
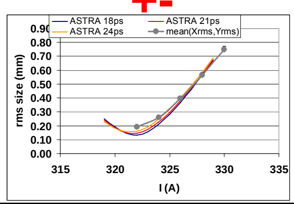
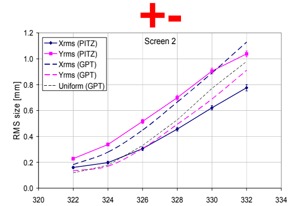
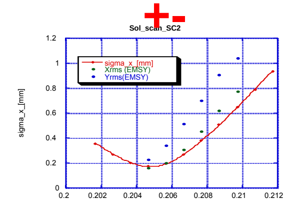
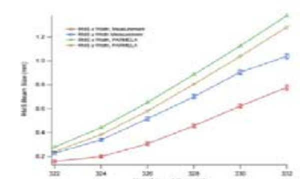
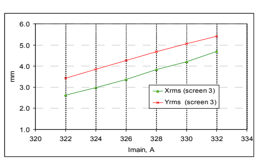
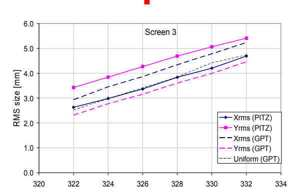
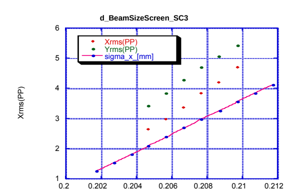
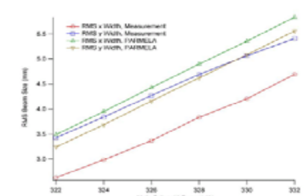
Measurements (laser+electron beam) have been performed:

- Phase scan ~1nC, ICT1
- Phase check (beam size measurements at screen 3 vs. SP Phase)
- Momentum measurements for
  - ✓SPPhase=Phi0+10 deg,SPPhase=Phi0+3 deg (x2),SPPhase=Phi0+5 deg
- Emittance measurements for
  - ✓(SPPhase=Phi0+3 deg, SPPhase=Phi0+5 deg) ×(Imain=322;324;326:328;330;332A)
- Some stability studies (charge,position)
- Cathode laser measurements

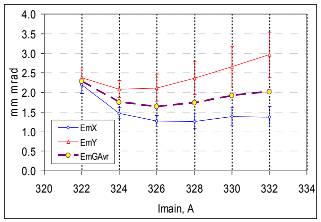
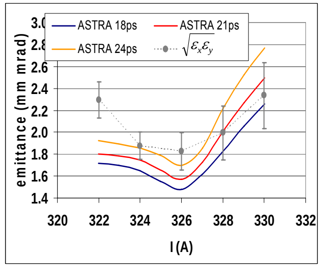
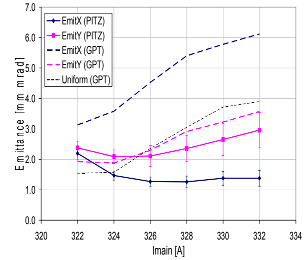
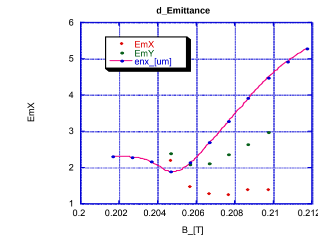
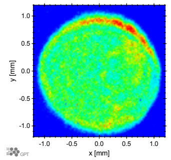
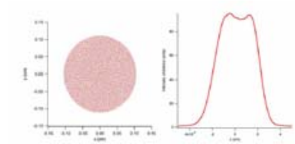
WG4 Benchmark problem



WG4 Benchmark simulations

Benchmark task	V.Miltchev (ASTRA)	B.v.d.Geer (GPT)	M.Ferrario (HOMDYN)	S.Russel (PARMELLA)
Phase scan Q(rf phase) 	+ 			
Ref.phase check 	+ 		+ 	
Long. Momentum 				
Beam size at screen2 	+- 	+- 	+- 	
Beam size at screen3 		+ 		

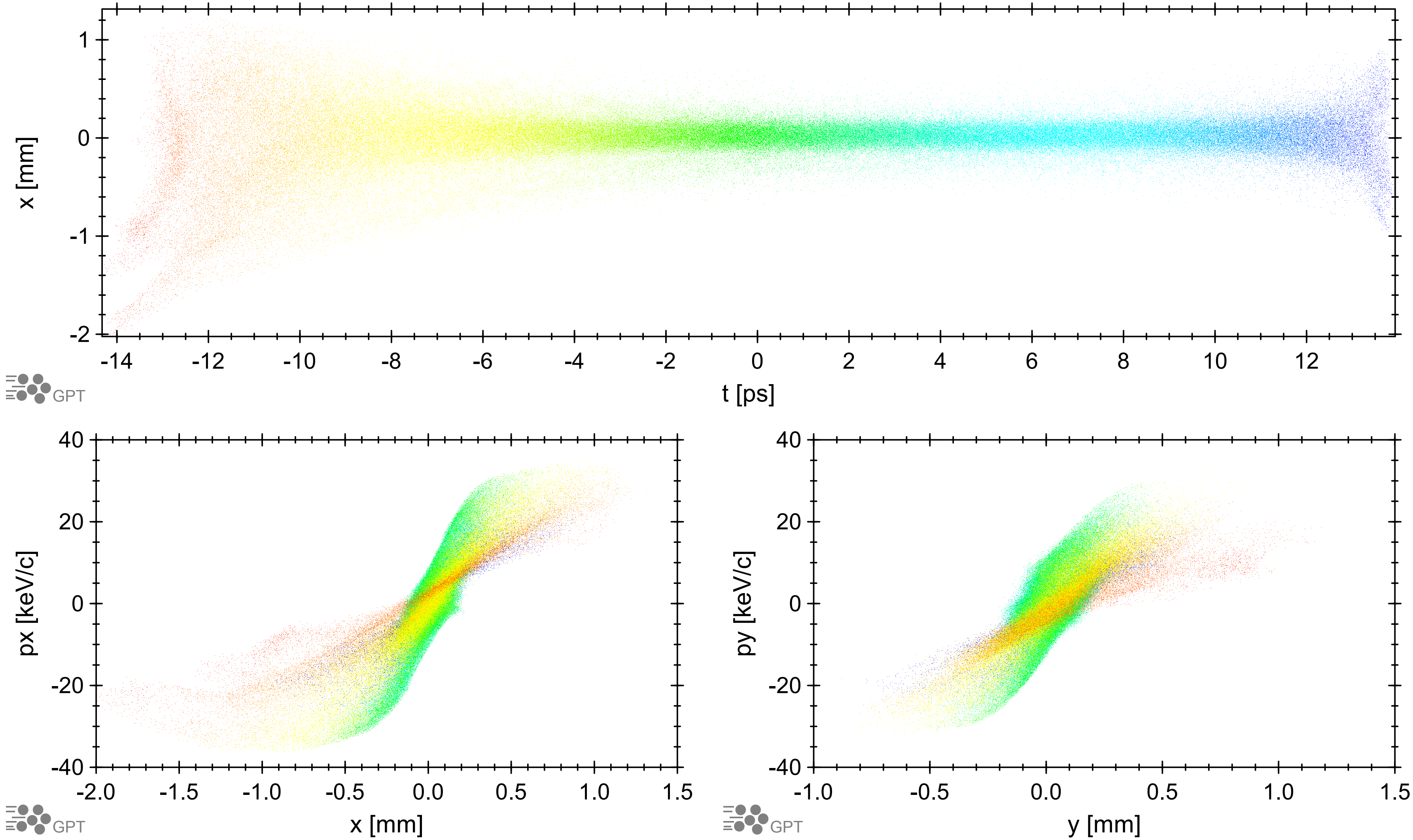
WG4 Benchmark simulations

Benchmark task	V.Miltchev (ASTRA)	B.v.d.Geer (GPT)	M.Ferrario (HOMDYN)	S.Russel (PARMELLA)
Emittance 				
Cathode laser Transverse Temporal	Homog., round Flat-top, ideal	**Real 3D** Flat-top, ideal 	Homog., round Flat-top, ideal	Homog., round **Flat-top, real** 
Varied parameters	Schottky effect, rf field beam energy +1%, cath.laser sizes, solenoid calibration	X<->Y	Solenoid calibration and z-position	RF field, X<->Y

- Principle agreement has been demonstrated
- Further improvements are ongoing
- One more contribution – TREDI (Luca Giannessi) is promised
- Further participants are welcomed

http://www-zeuthen.desy.de/~kras/PITZProblem.html/PITZbenchmark.html

WG4. Benchmark: Phase-space at Screen2, GPT Simulations



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Low emittance electron sources

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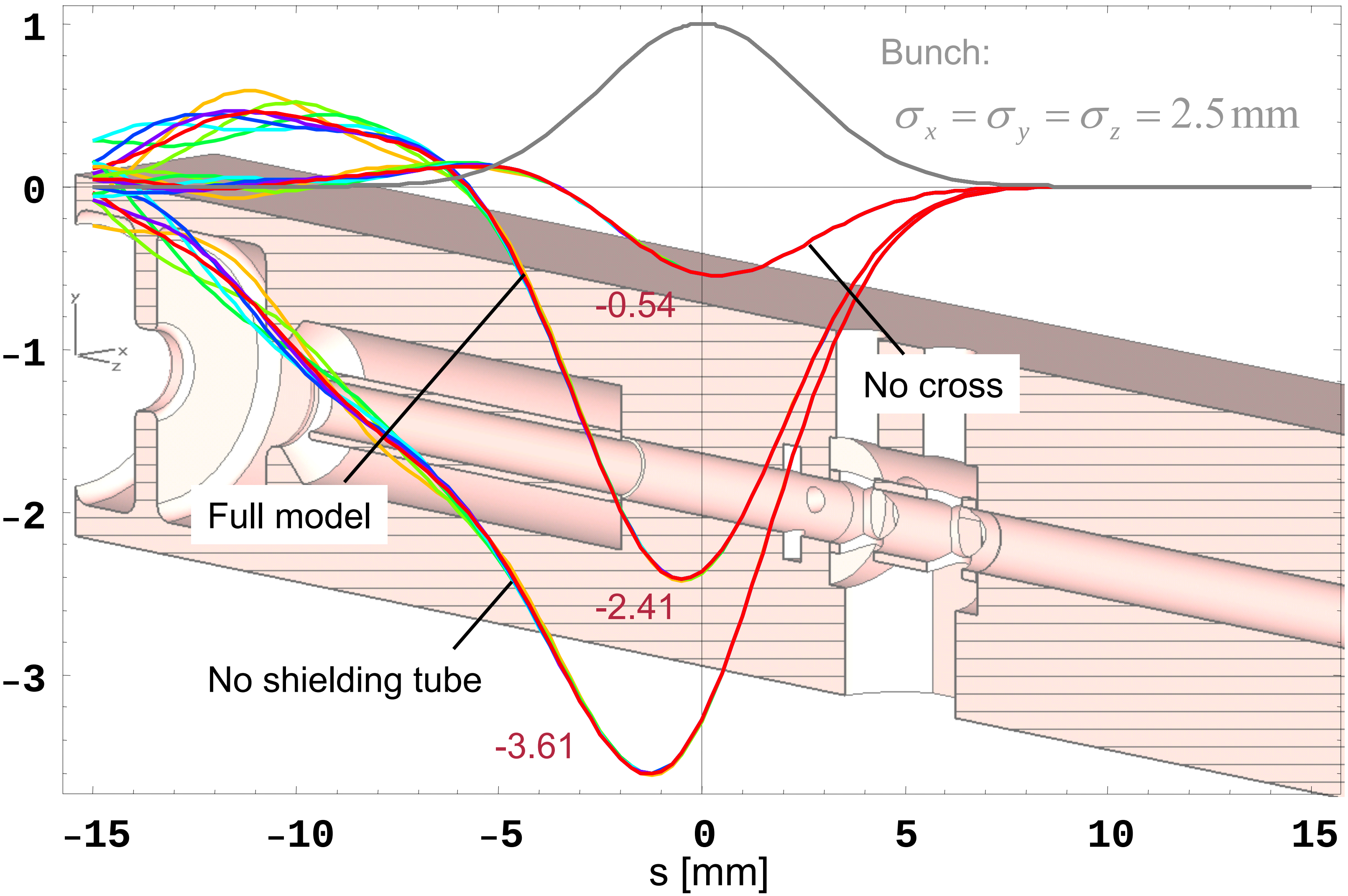
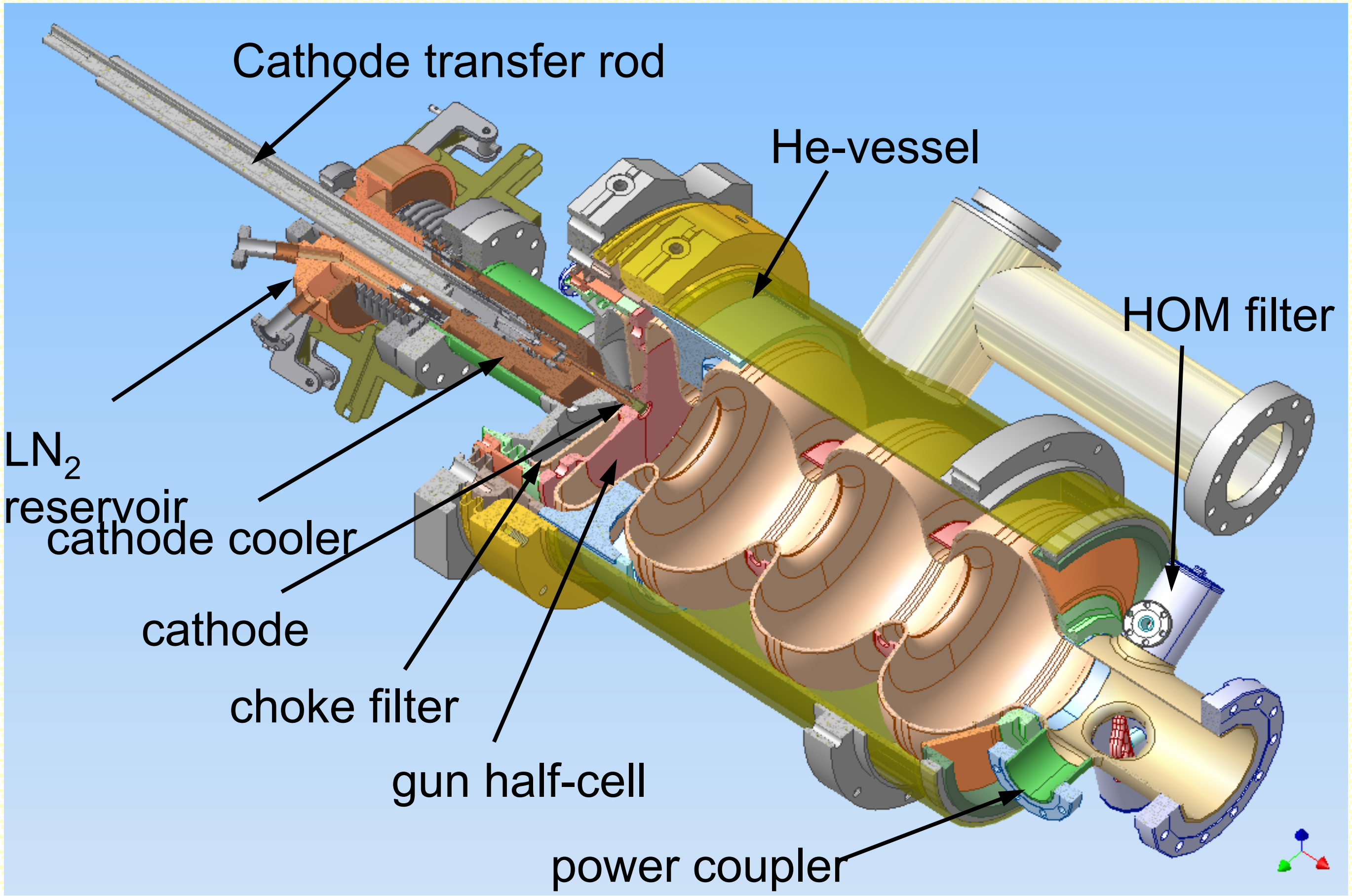
- Talks

Wake Field Calculations

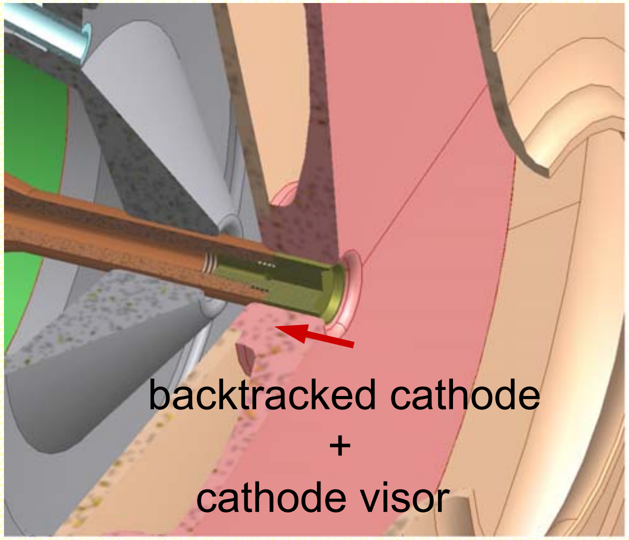
- Summary

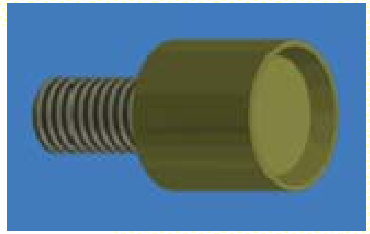


Friedrich Staufenbiel: Rossendorf 3½ cell SRF gun



transverse emittance with a flat top laser profile (ASTRA simulation)

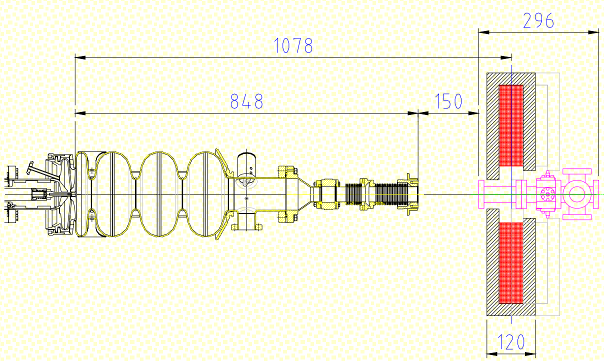


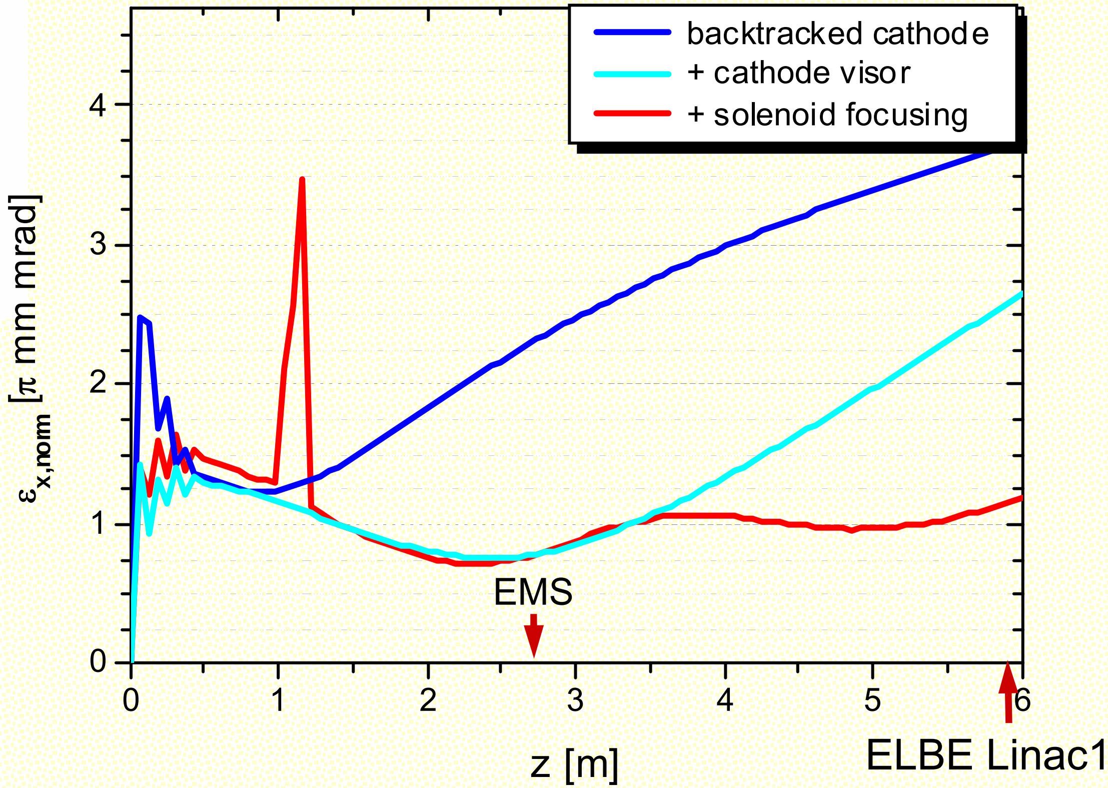


bunch charge : 1 nC
bunch length : 20 ps
σ_x : 1.5 mm

long. emittance :
≈ 70 π keV mm

backtracked cathode
+
cathode visor
+
solenoid focusing



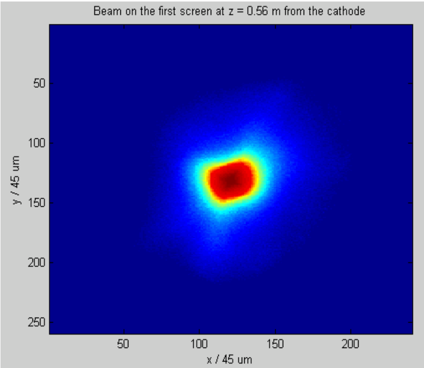


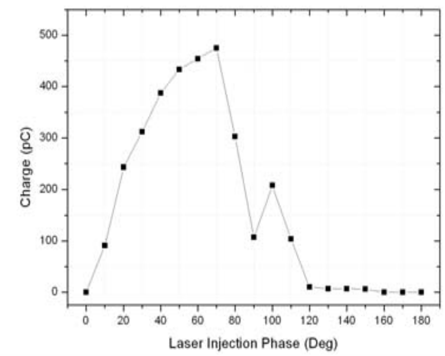
GTS Status

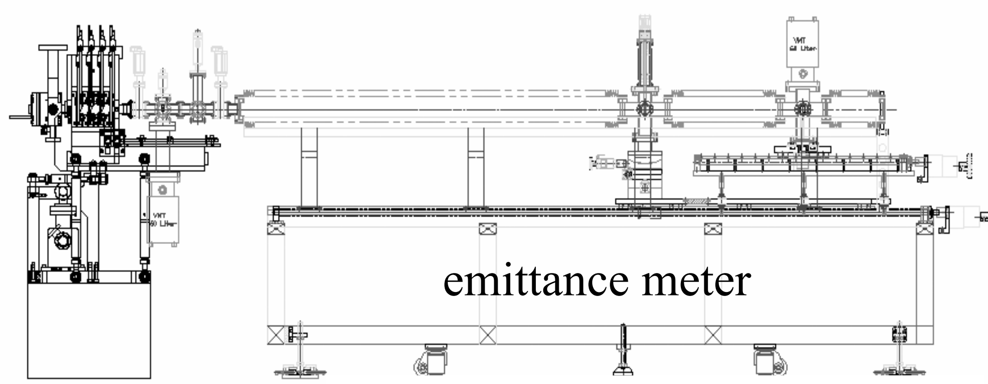
1. Construction started in December, 2004.

2. **First beam on November 1, 2005.**

3. Best beam achieved as of **May 10, 2006**:
   - **Energy ~ 2 MeV** (not exactly measured yet)
   - Initial phase = 30^{o}
   - **Q = 320 pC** (maximum ~500 pC at higher initial phase)
   - **Laser pulse length = 5 ps (FWHM)**
   - Peak current = 64 A
   - Beam size at 1.46 m from cathode = 500 μm rms
   - Laser spot diameter at the cathode = 3 mm (hard edge)
   - **Normalized rms emittance ~ 4 mm mrad**

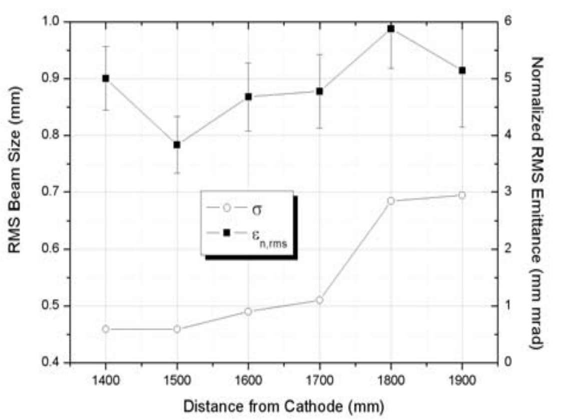




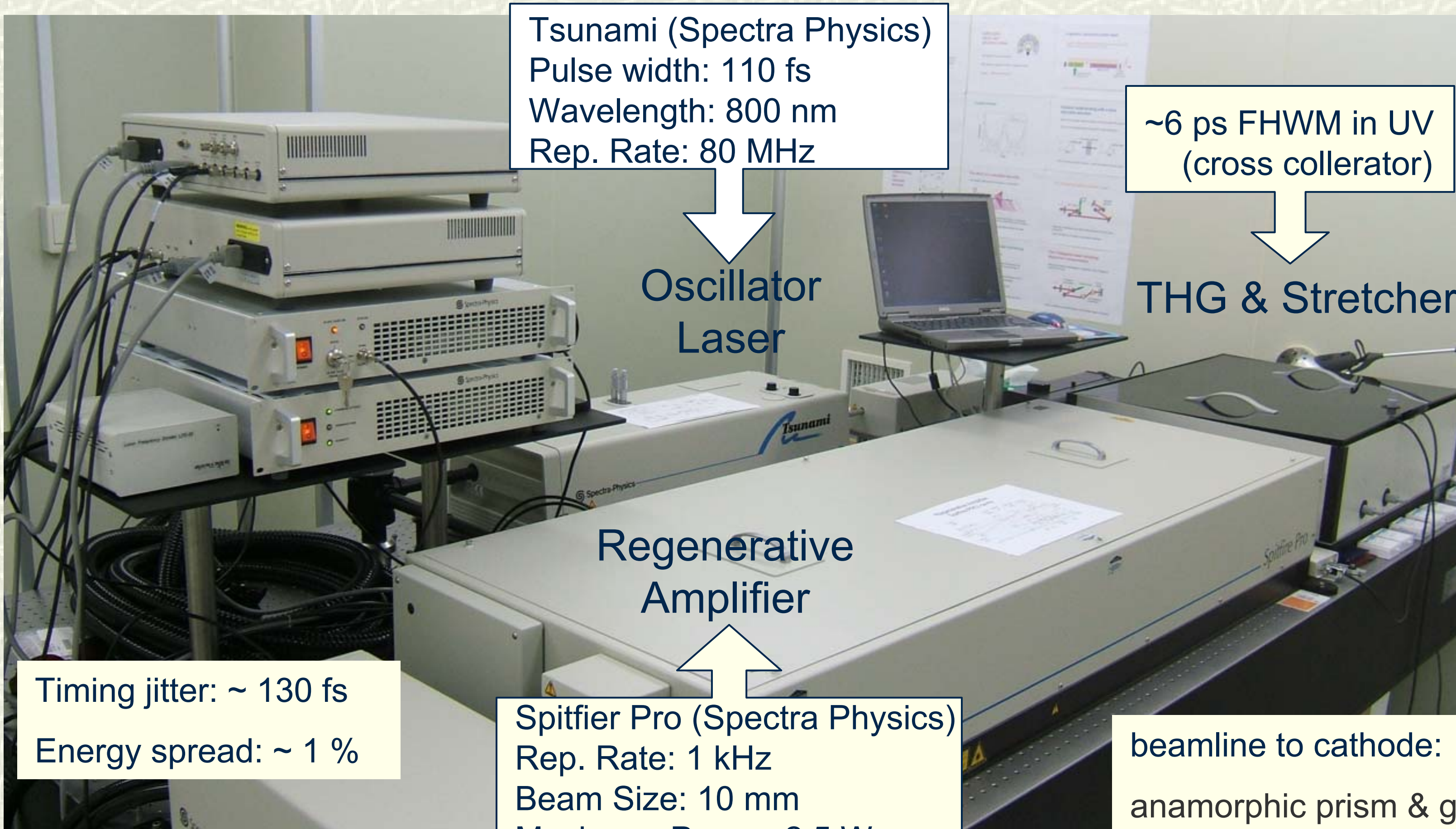


quick progress !

4. Things to be done
   - Energy measurement
   - Time slew compensation (need normal incidence ?)
   - Tests at higher energies (with a new cavity ?)



Changbum Kim: Photocathode Laser System for PAL XFEL



Tsunami (Spectra Physics)
Pulse width: 110 fs
Wavelength: 800 nm
Rep. Rate: 80 MHz

~6 ps FHWM in UV
(cross collerator)

Timing jitter: ~ 130 fs

Energy spread: ~ 1 %

Spitfier Pro (Spectra Physics)
Rep. Rate: 1 kHz
Beam Size: 10 mm
Maximum Power: 2.5 W
Pulse Energy: 2.5 mJ
Pulse Width: 110 fs

beamline to cathode:

anamorphic prism & grating to correct oblique incidence

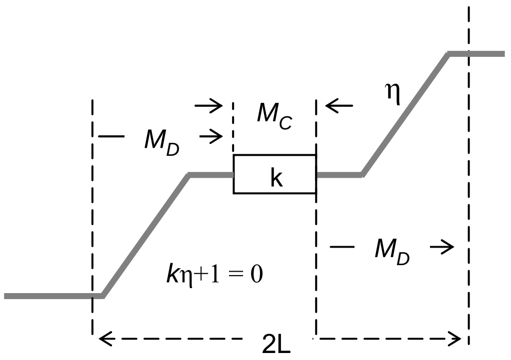
Transverse-Longitudinal Phase Space Manipulations

Kwang-Je Kim with P. Emma, Z. Huang, P. Piot

Reduce transverse emittance by exchanging it with longitudinal emittance

$$\left(\gamma\varepsilon_x, \gamma\varepsilon_y, \sigma_{\Delta E/E}\right) = \left(10^{-6} m, 10^{-6} m, 10^{-7}\right) \rightarrow \left(10^{-7} m, 10^{-7} m, 10^{-5}\right)$$

Double dogleg with RF



- Flat beam technique (units in m-rad)

$$\gamma\varepsilon_x \otimes \gamma\varepsilon_y : \quad \left(10^{-6}\right)^2 \rightarrow 10^{-5} \otimes 10^{-7}$$

- Exchange ($x \leftrightarrow z$)

$$\gamma\varepsilon_x \otimes \gamma\varepsilon_y \otimes \gamma\varepsilon_z : \left(10^{-6}, 10^{-6}, 10^{-7}\right) \rightarrow \left(10^{-5}, 10^{-7}, 10^{-7}\right) \rightarrow \left(10^{-7}, 10^{-7}, 10^{-5}\right)$$

After flat-beam injector

$$\gamma\varepsilon_z = 0.080\ \mu m$$
$$\gamma\varepsilon_x = 0.0054\ \mu m$$
$$\gamma\varepsilon_y = 9.92\ \mu m$$

After double dogleg

$$\gamma\varepsilon_z = 9.92\ \mu m$$
$$\gamma\varepsilon_x = 0.0054\ \mu m$$
$$\gamma\varepsilon_y = 0.084\ \mu m$$

Operating Parameter	**Value**	**Units**
Bunch charge	20	pC
B-field on photocathode	0.191	T
Cavity off-crest phase	4	deg
Beam Parameter	**Value**	**Units**
Before flat beam transformation		
Transverse emittances	4.96	μm
	0.23	μm
Longitudinal emittance	0.071	μm
Kinetic energy	215.4	MeV
After round-to-flat-beam transformer		
Emittance $\gamma\varepsilon_x$	9.923	μm
Emittance $\gamma\varepsilon_y$	0.005	μm
Longitudinal emittance	0.080	μm
	0.23	μm

COMMISSIONING OF THE SPARC PHOTO-INJECTOR
Daniele Filippetto

- ***Best achieved results***
  - ***2.1 mm-mrad @ 700 pC , 10 ps***
  - ***0.7 mm-mrad @ 160 pC, 10 ps***

Work in Progress

- Understanding dipole and quadrupole components in solenoid (mask, different fields in each coil and different configurations,…)
- high charge (up to 1.1 nC) emittance measurements
- Comparison with simulation ongoing (next step real transverse and longitudinal profile)
- Main linac installation scheduled to start in the summer

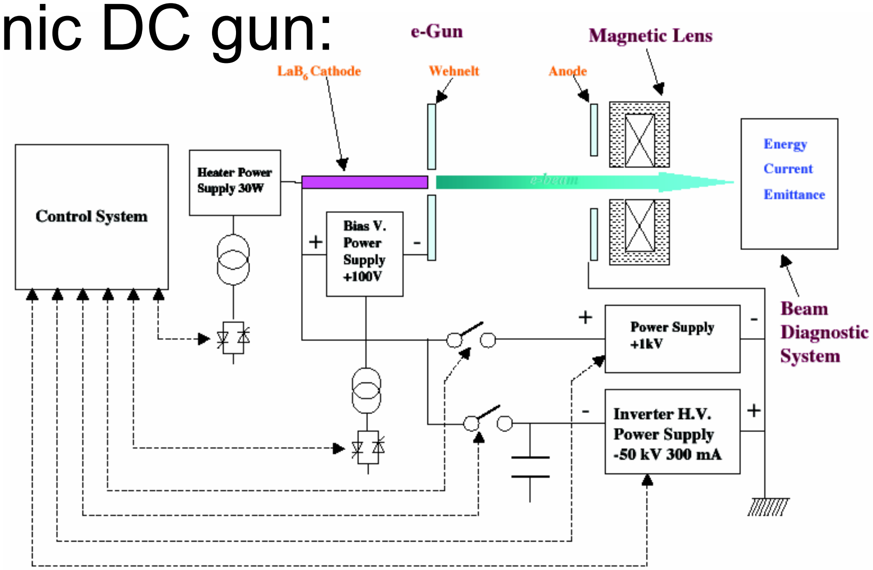
Dark current at the Euro-XFEL
Jang-Hui Han

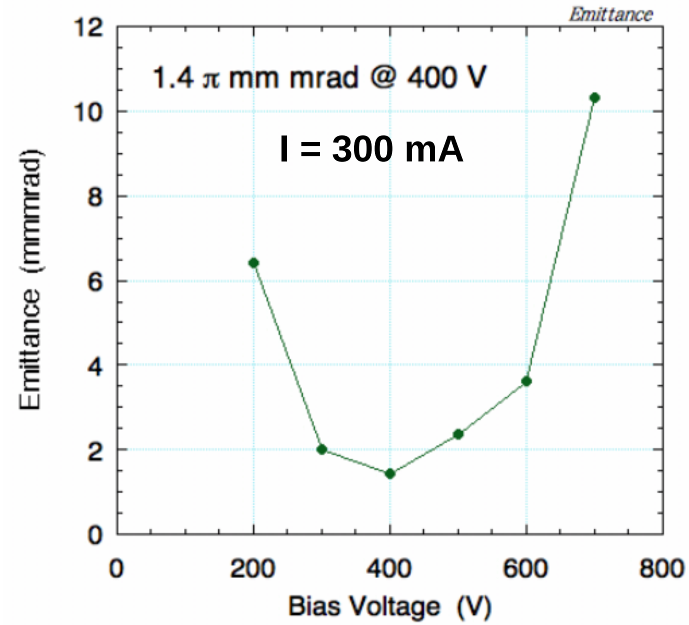
• Dark current might be more serious problem at the Euro-XFEL
• Most of dark current at the gun is originated from the cathode area
• For XFEL case, higher solenoid field makes dark current over-focused quickly
• With enlarging the half cell length, the momentum distribution of beams and dark current can be separated.

• Further optimization of the cell length ratio and machine parameters are necessary.
• Find optimum position and size of collimators

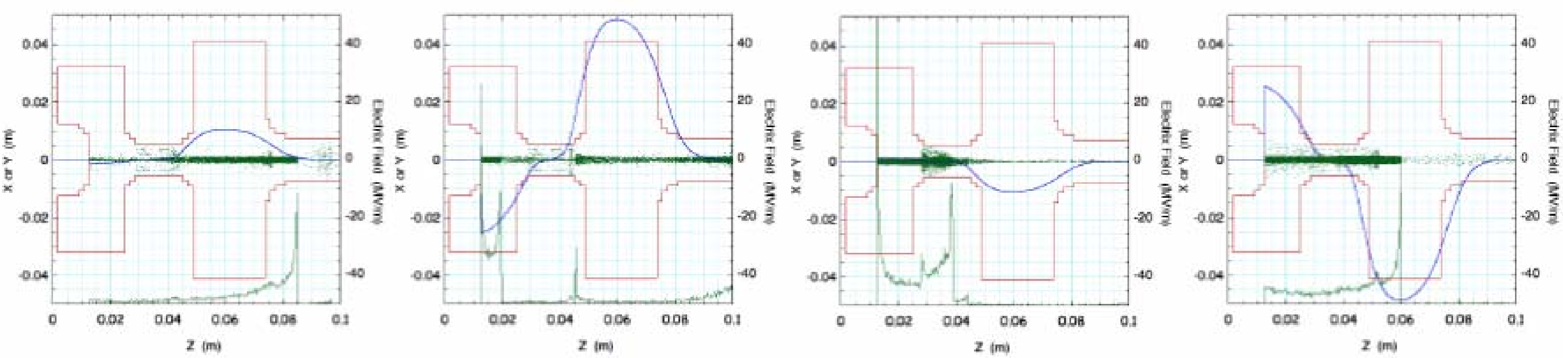
Hiroyuki Hama: Low Emittance Electron Guns Employing the LaB6 Single Crystal Cathode

Thermionic DC gun:





Thermionic RF gun:



E1 = 25 MV/m
E2 = 50 MV/m
$\Delta\theta$ (cav_1-cav_2) = 18°

n + 0 cycles **n + 0.25 cycles** **n + 0.5 cycles** **n + 0.75 cycles**

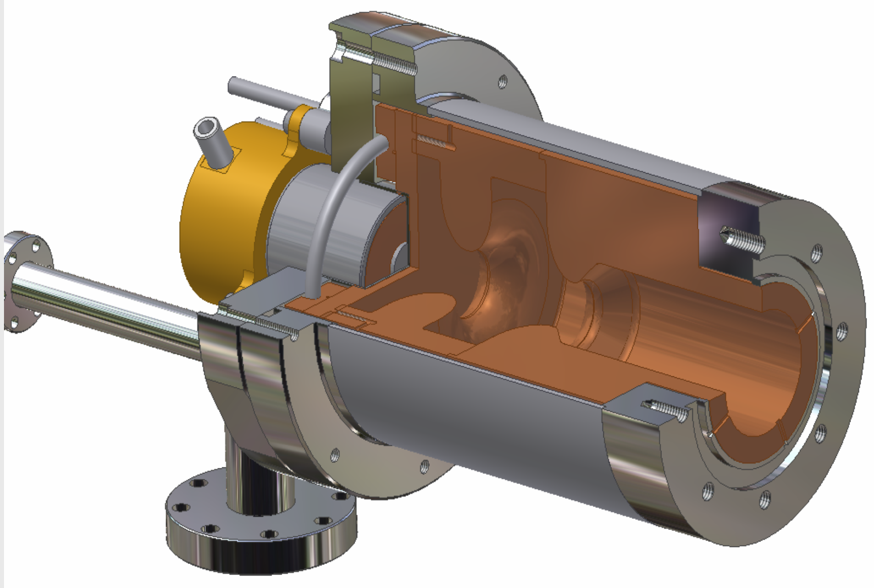
working ongoing for 100fs, ~ 50pC, ~ 1 mm mrad

Bas van der Geer

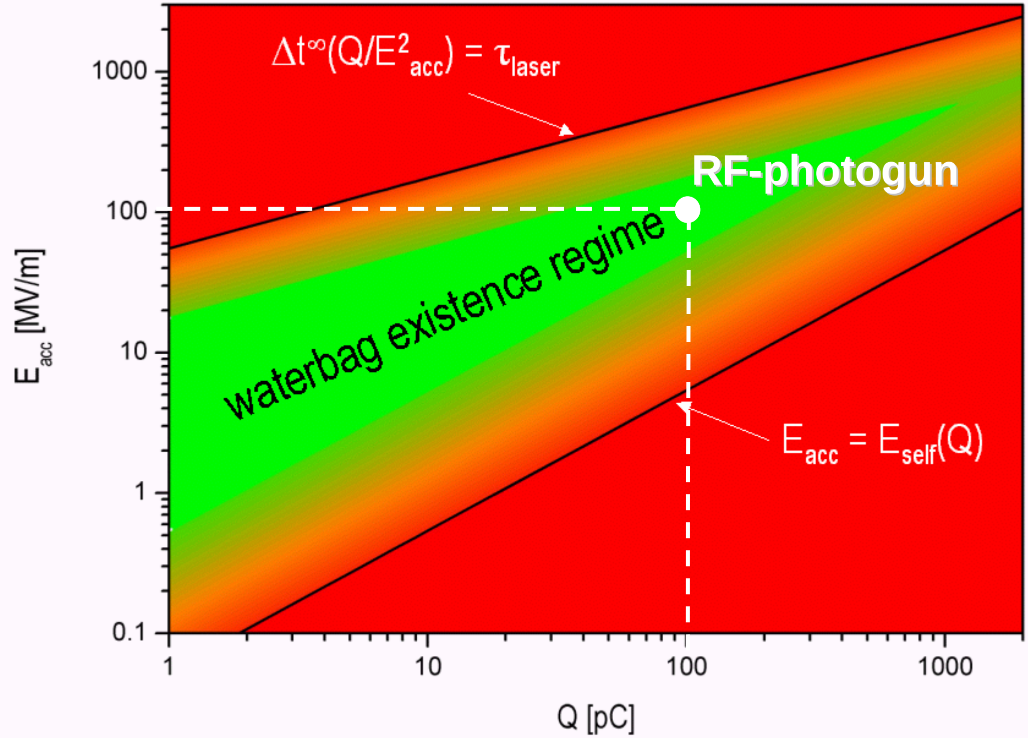
Cavity development @ Eindhoven

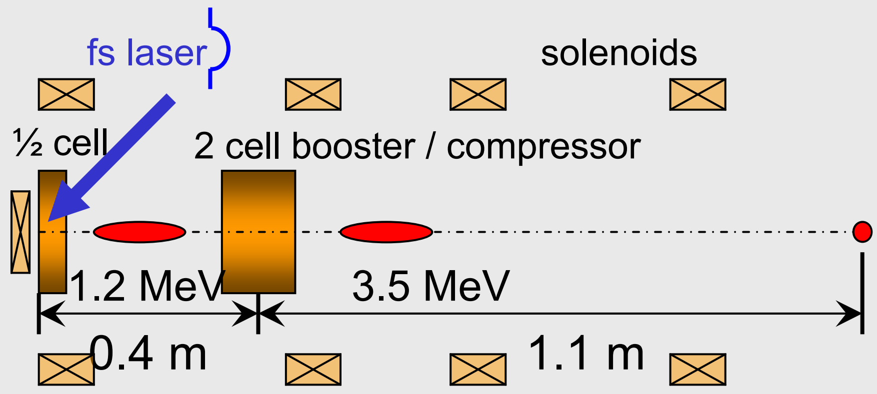
1.5 cell → THz
2.6 cell → Laser wakefield
1.6 cell → Pulsed radiolysis

- separated cells: **clamped, not brazed**
- inside stainless steel vacuum vessel
- **μm precise design and manufacture**
- axial incoupling
- elliptical irises



Production and application of waterbag bunches





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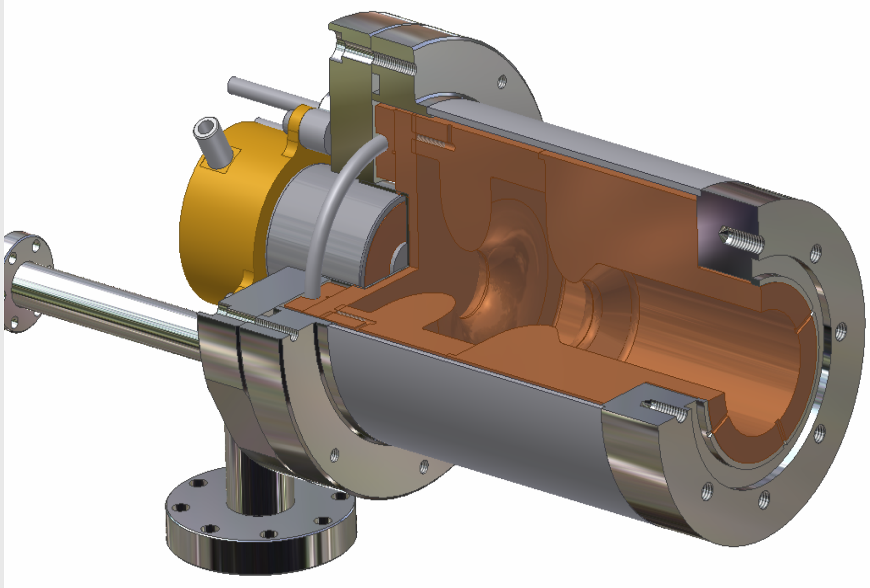
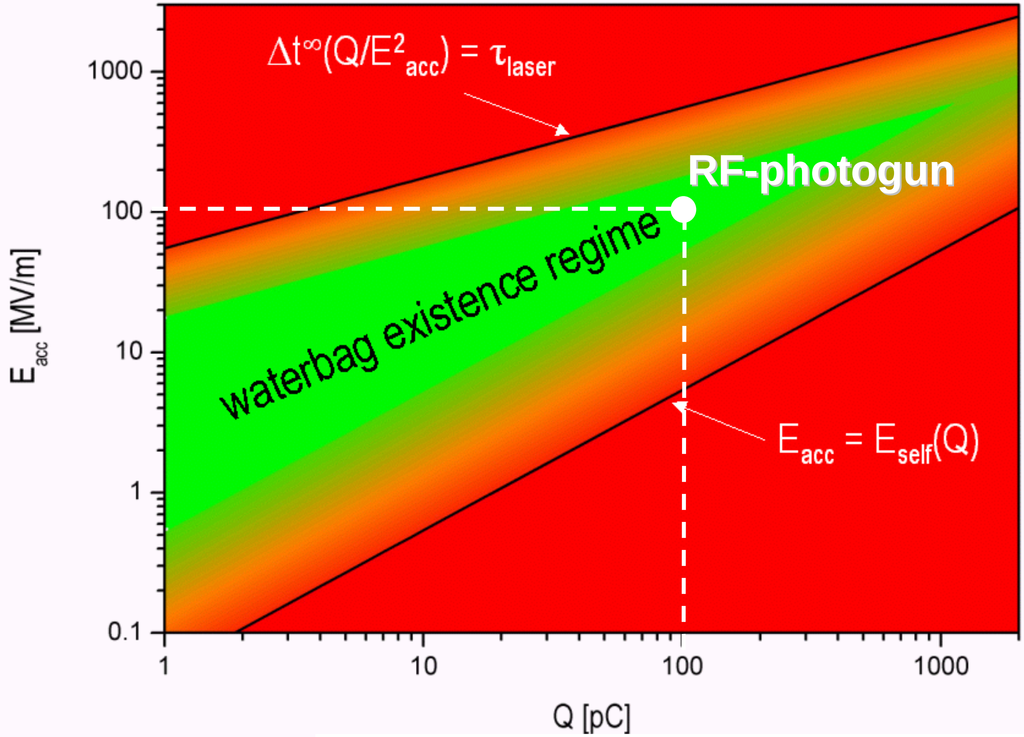
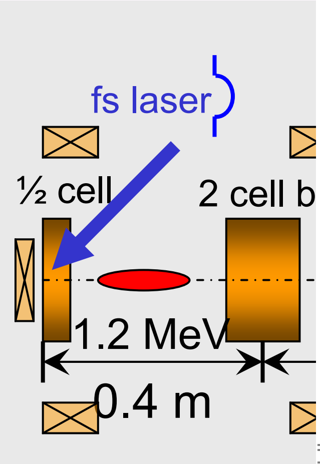
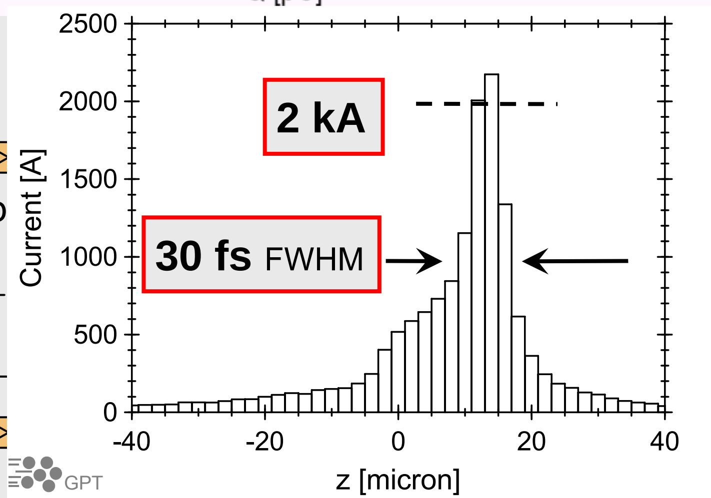


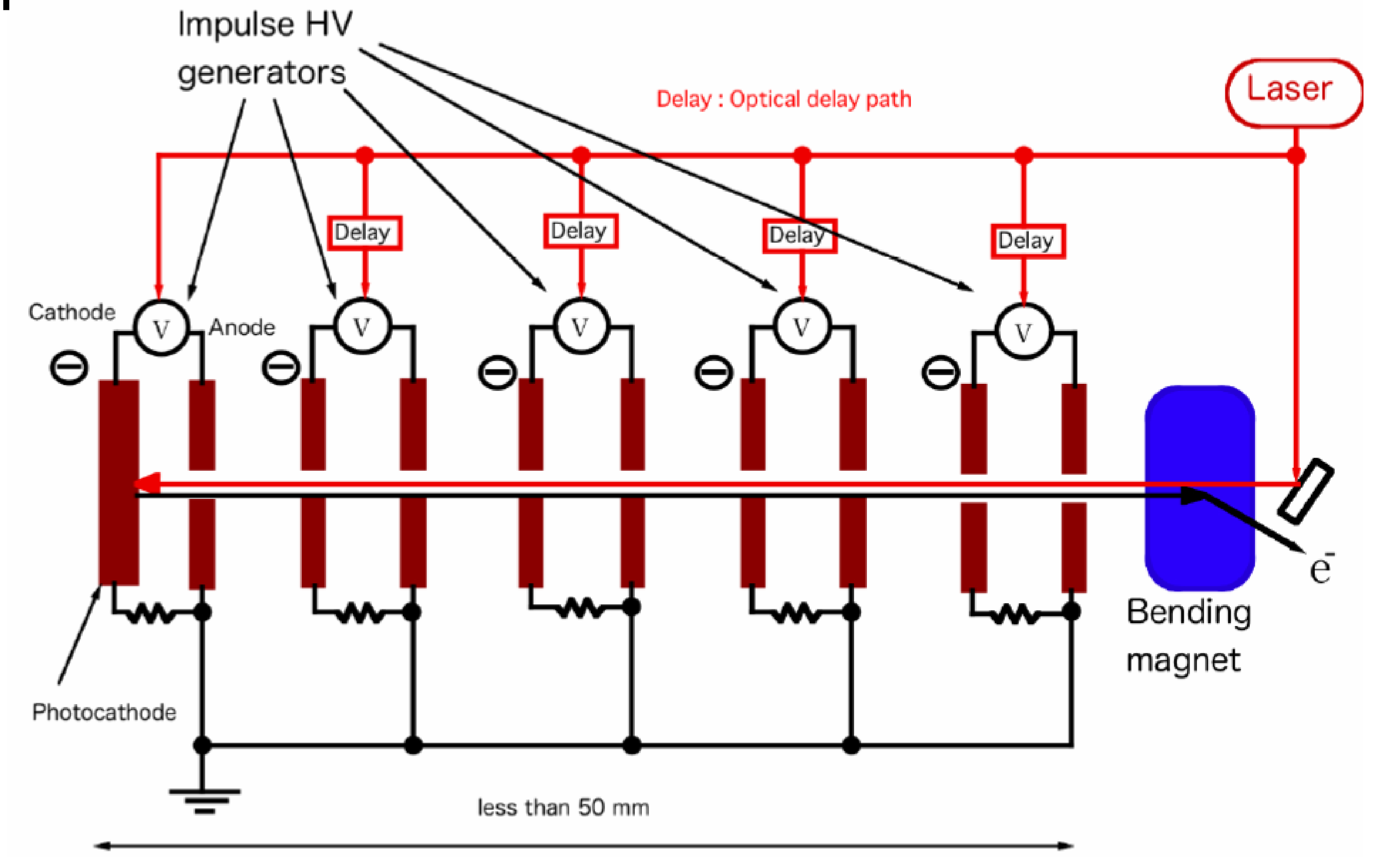
Production and application of waterbag bunches





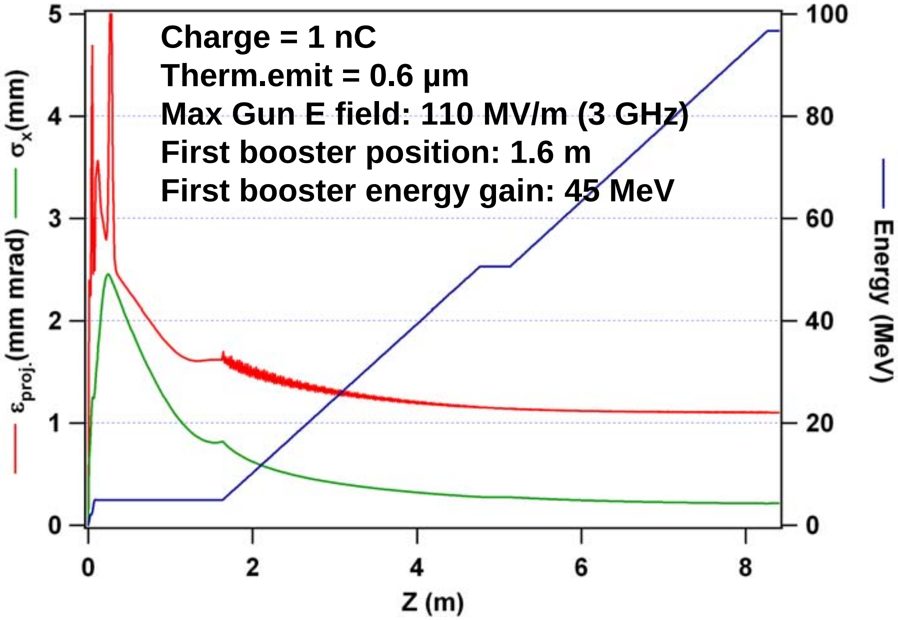


Yoshitaka Kawashima: **Proposal of a Photocathode Impulse-Gun Followed by Impulse Accelerating Structures to Produce a Low Emittance Electron Beam**

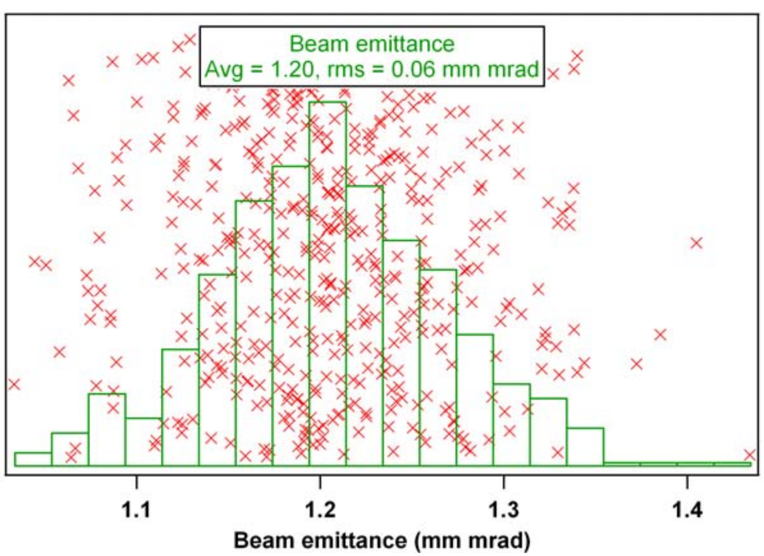


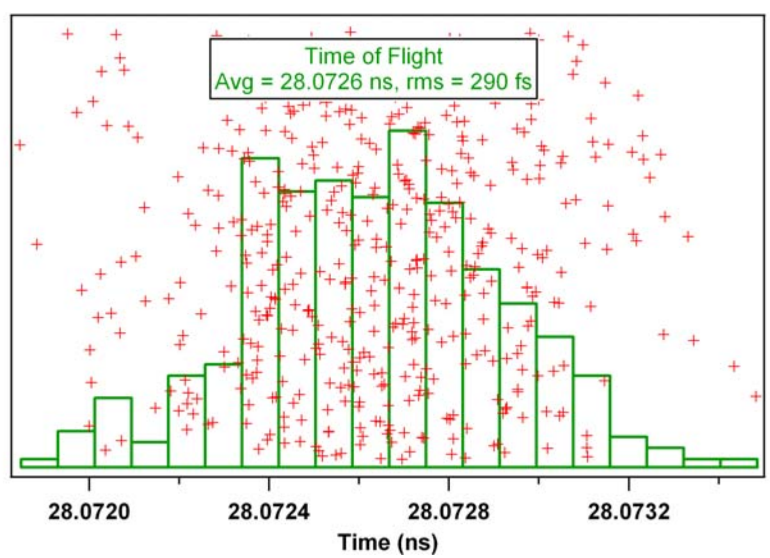
We should concentrate on the development of the impulse HV generator.

Gun Jitter Study for the FERMI@Elettra photoinjector
by M. Trovò

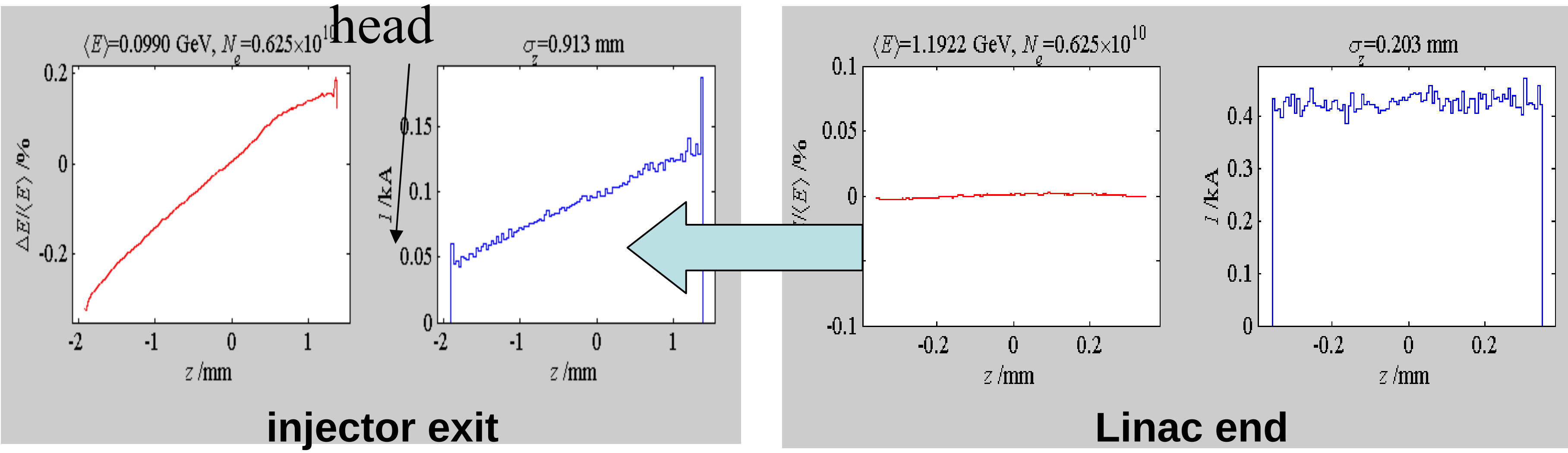


Parameters (variation)	ΔI (+ 1%)	ΔT (+ 100fs)	σ_E (10keV)	ΔE/E (+ 0.1%)	ε_{proj} (5%)	$<\varepsilon_{slice}>_{80\%}$ (5%)
Gun Solenoid (±3%)	2.3 %	5 %	n/s	n/s	0.7 %	0.3 %
Gun Eacc (±1%)	0.6 %	0.15 %	0.2 %	2.7 %	0.4 %	0.7 %
Gun RF phase (±0.3°)	1.4°	1°	0.3°	1.8°	3° *	2.7°
Bunch Charge (±12%)	1.5 %	20 %	40 %	n/s	6 %	7 %
Laser pulse length (FWHM) (±10%)	4 %	2.5 %	5 %	n/s	6 %	9 %
Laser time jitter (±0.9ps)	1 ps	150 fs	230 fs	1.5 ps	2 ps	2.5 ps *
SOA Eacc (±7%)	40 %	1.8 %	1.4 %	0.25 %	14 %	n/s
SOA RF phase (±0.3°)	6°	0.12°	0.27°	0.8°	27° *	n/s





Ramping current distribution option for the FERMI@ELETTRA photoinjector
by G. Penco



Which current distribution at the cathode?