

# Commissioning and First Results from the **P**hoto **I**njector **T**est Facility at DESY **Z**euthen (**PITZ**)

- introduction
- rf measurements
- dark current
- measurements with beam

F. Stephan (DESY Zeuthen) for the PITZ Collaboration,  
ICFA Workshop @ Sardinia, Italy, July 1<sup>st</sup> – 5<sup>th</sup>, 2002

# The Photo Injector Test Facility at DESY Zeuthen (PITZ)

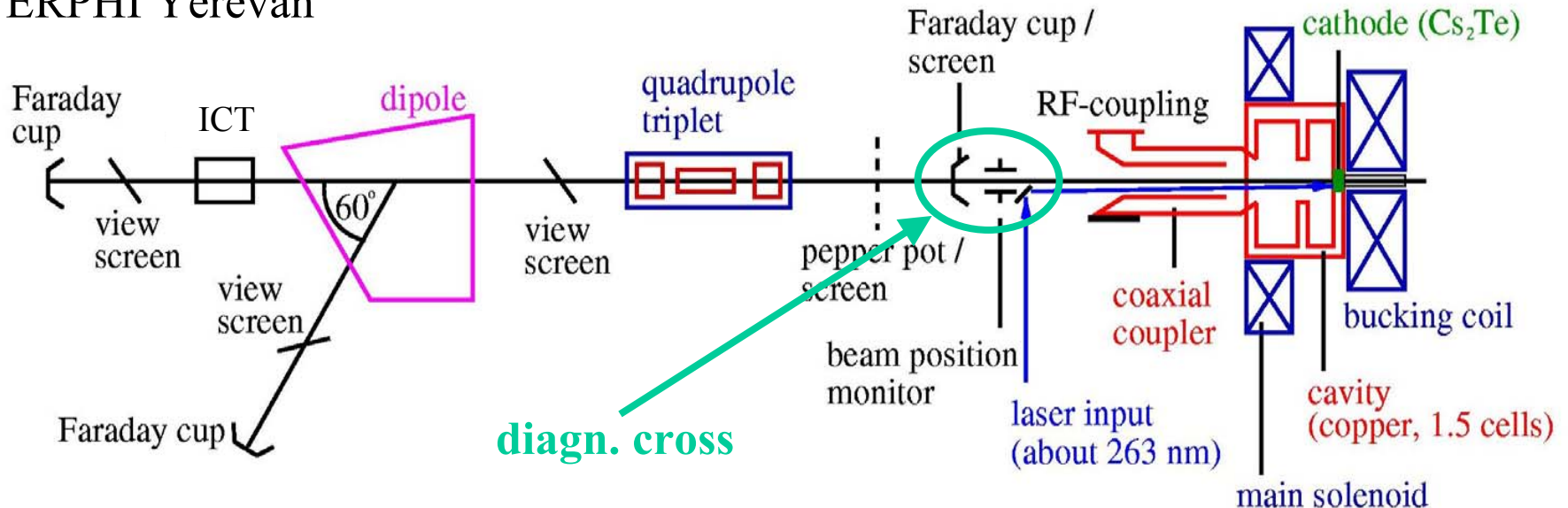
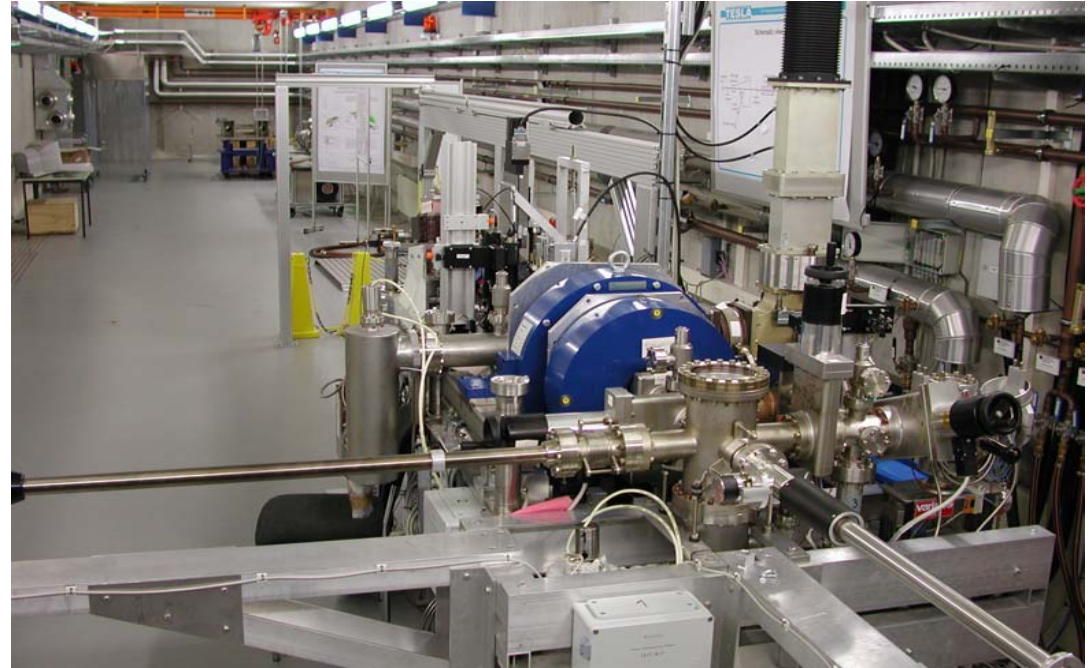
## Goals:

- test facility for FELs and future LCs:
  - ⇒ **very small transverse emittance (1 mm mrad @ 1 nC)**
  - ⇒ **stable** production of short bunches with small energy spread
- **extensive R&D** on photo injectors in parallel to TTF operation
- compare **detailed experimental results** with simulations:
  - ⇒ **benchmark theoretical understanding of photo injectors**
- test rf guns for subsequent operation at TTF-FEL
- test **new developments** (laser, cathodes, beam diagnostics)
- for **TESLA**: flat beams, polarized electrons

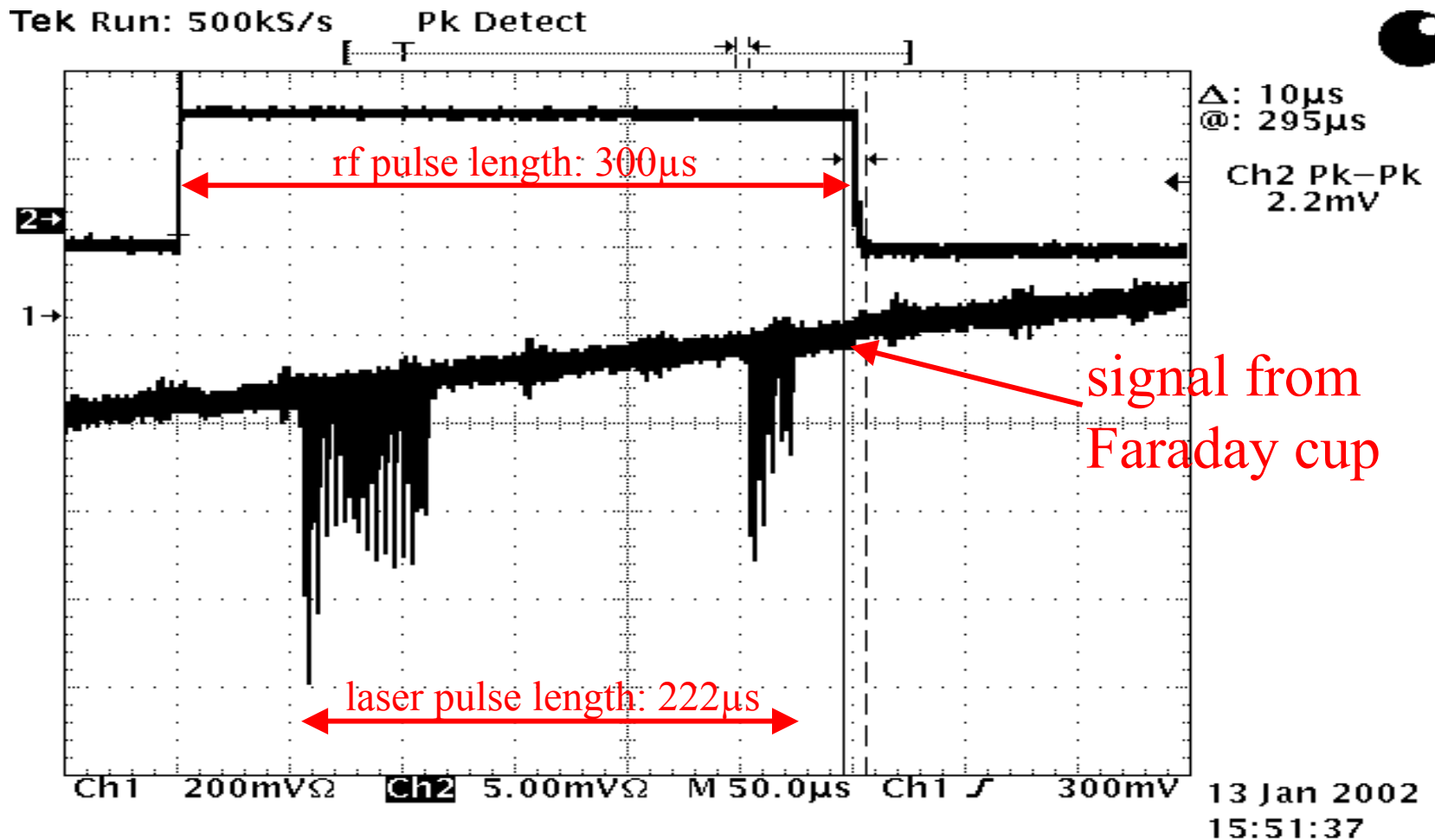
# Collaboration:

BESSY, Berlin  
CAEP Mian Yang  
DESY, Hamburg and Zeuthen  
HEPI Tbilisi  
INFN Milano  
INR Troitsk  
INRNE Sofia  
Max-Born-Institute, Berlin  
TU Darmstadt, department TEMF  
YERPHI Yerevan

# Current Layout



- January 13<sup>th</sup>, 2002: first photo electrons



$\Delta_{rf} (\text{laser- rf}) = 5 \text{ kHz} \Rightarrow \text{automatic phase scan}$

# RF Conditioning in March 2002

- **rf pulse length: stable operation up to 400  $\mu$ s**

(more needs adjustment of gun water cooling system, ongoing)

- **rf pulse repetition rate: 5 Hz operation**

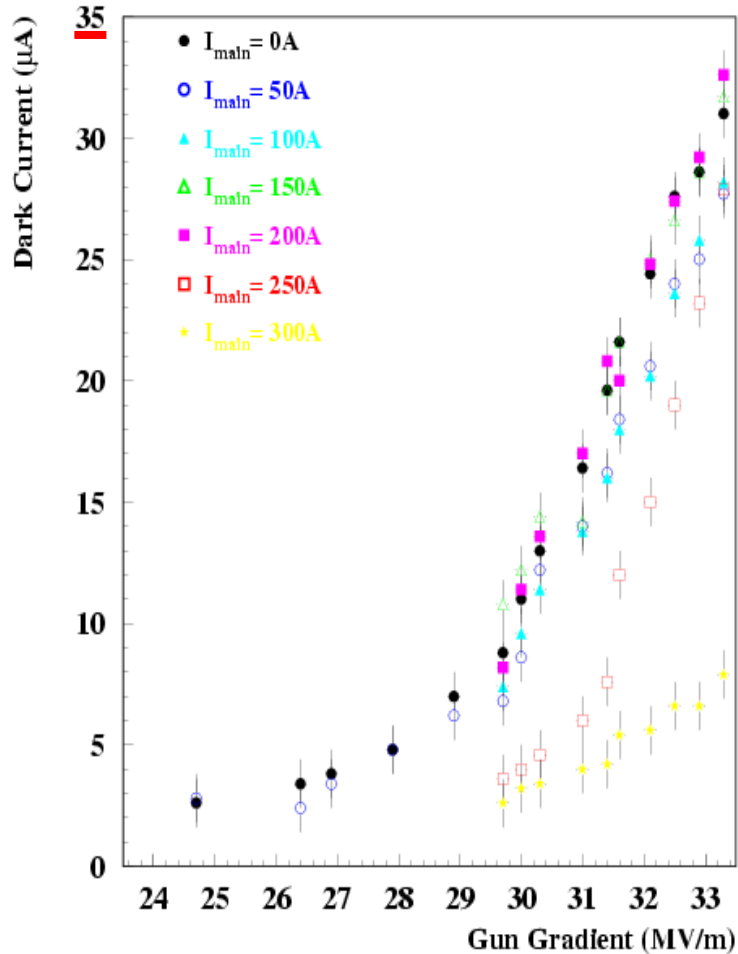
duty cycle:  
0.2%

- **gradient at cathode: up to 34 MV/m**, limit of old PS

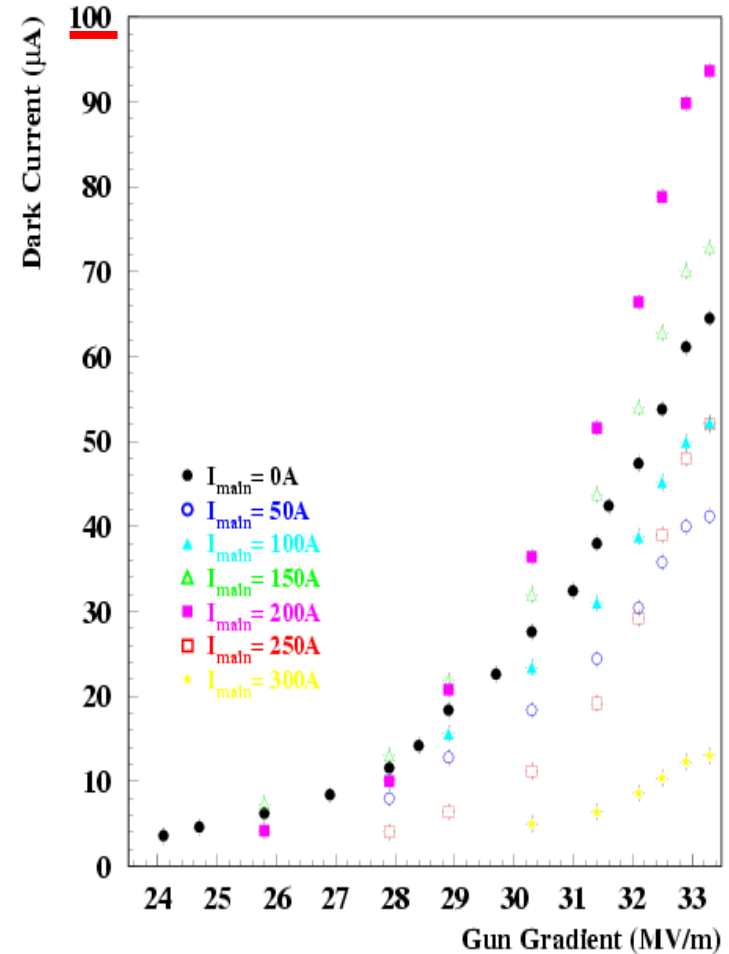
(new PS is installed, now under commissioning)

# DC measurements (preliminary results)

20/03/02 Dark current for 400  $\mu\text{s}$  pulse length, Mo-cathode

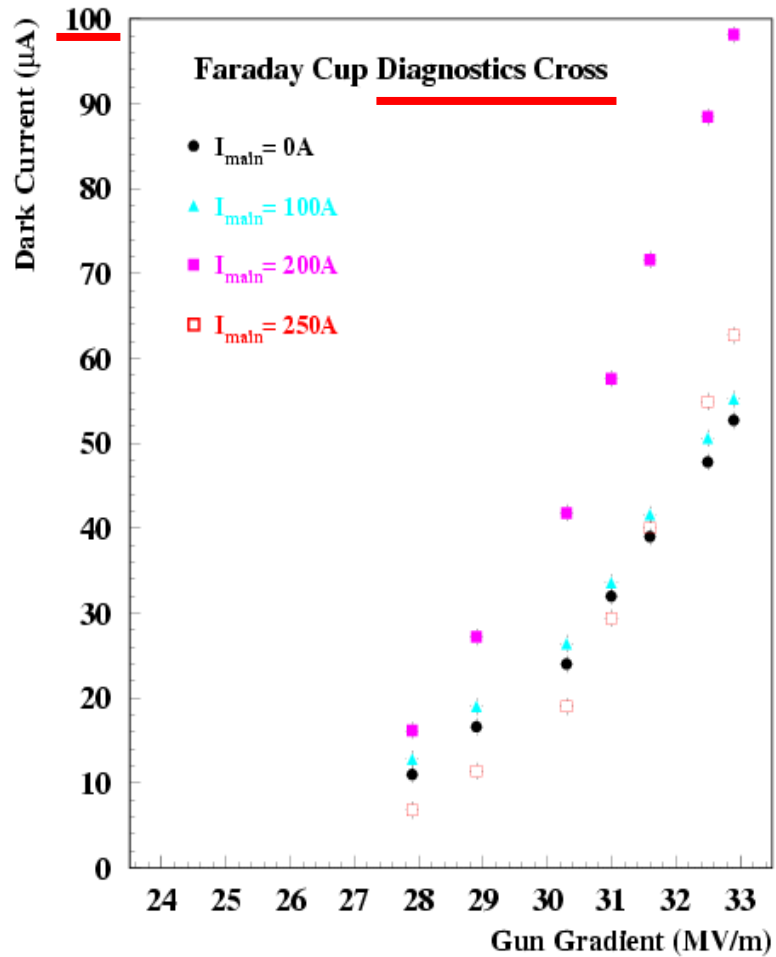


22/05/02 Dark current for 100  $\mu\text{s}$  pulse length, Cs-cathode



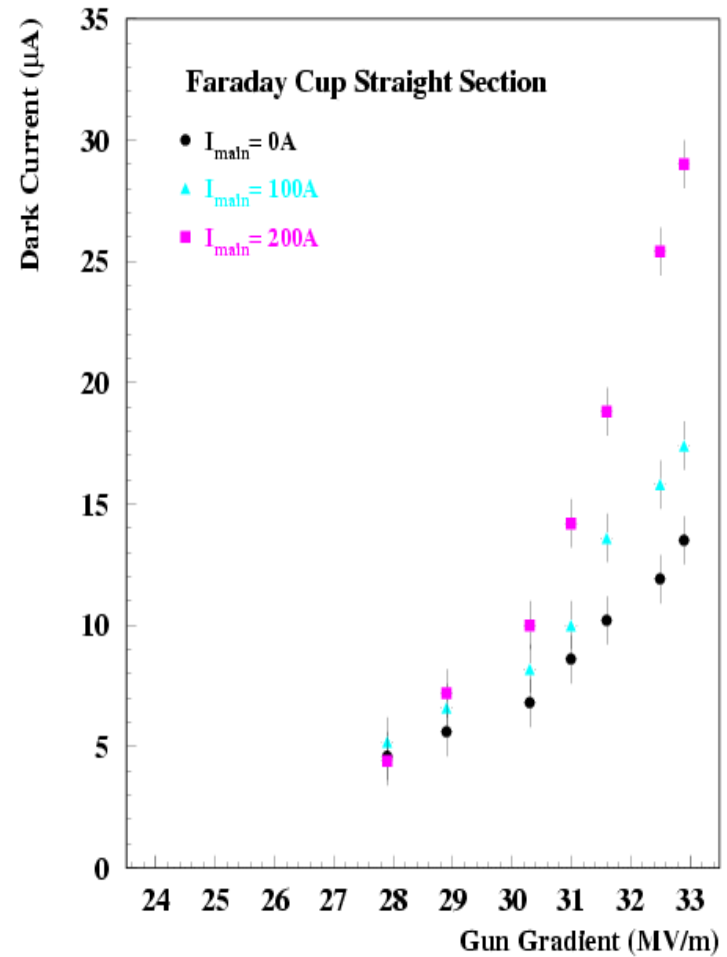
31/05/02

Dark current for 100  $\mu$ s pulse length, Cs-cathode



31/05/02

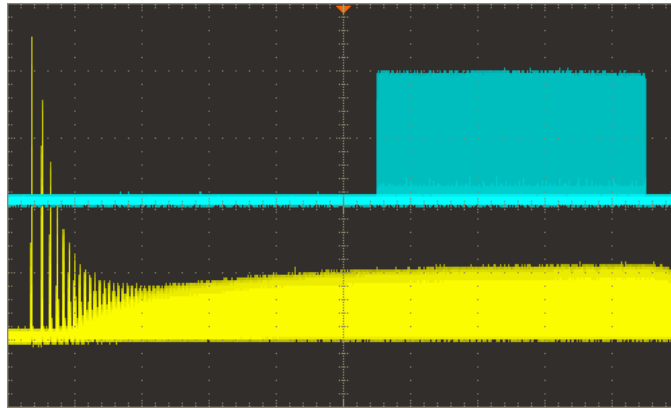
Dark current for 100  $\mu$ s pulse length, Cs-cathode



# Laser Parameters and Bunch Charge

## Laser:

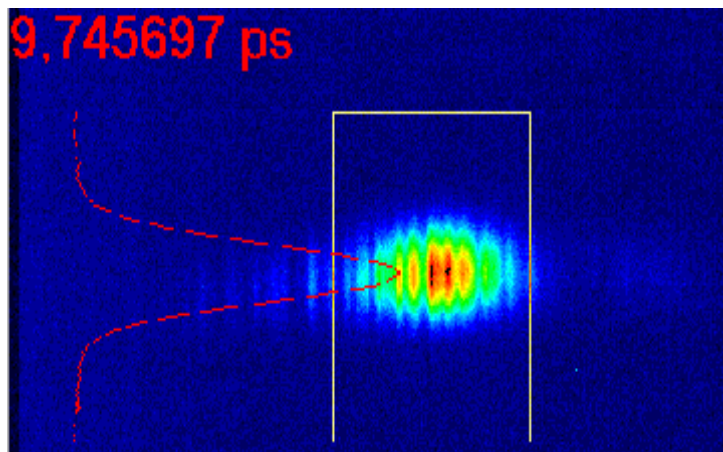
(MBI,  
Berlin)



long. profile  
by streak camera:

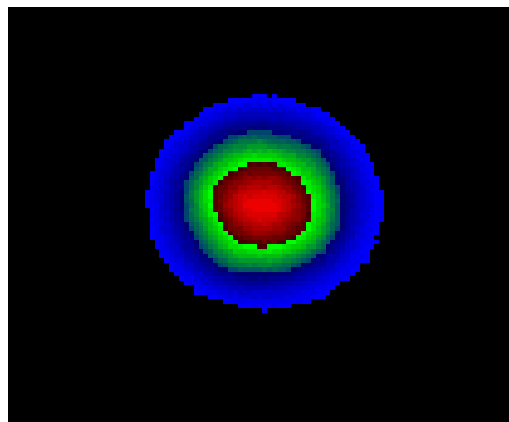
$$FWHM_z \approx 10 \text{ ps}$$

(still gaussian shape)



UV light at  
virtual cathode:

$$RMS_{x,y} = 0.65 \text{ mm}$$



## Bunch Charges:

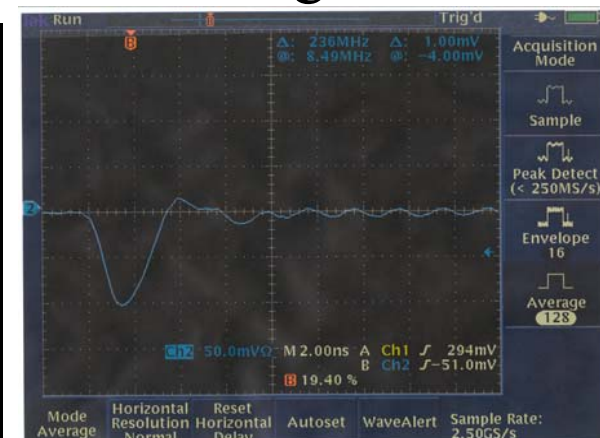
- during first run:

$$Q_{bunch} \approx (5 - 30) \text{ pC}$$

- after cathode exchange:

up to 0.8 nC

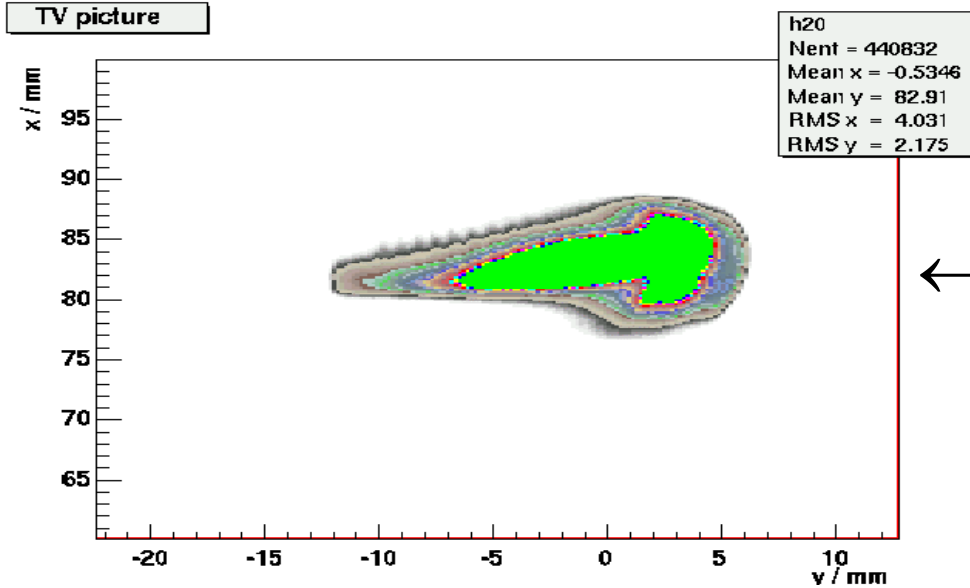
- several nC with  
better cathode  
handling





# Momentum Measurements

(preliminary results)



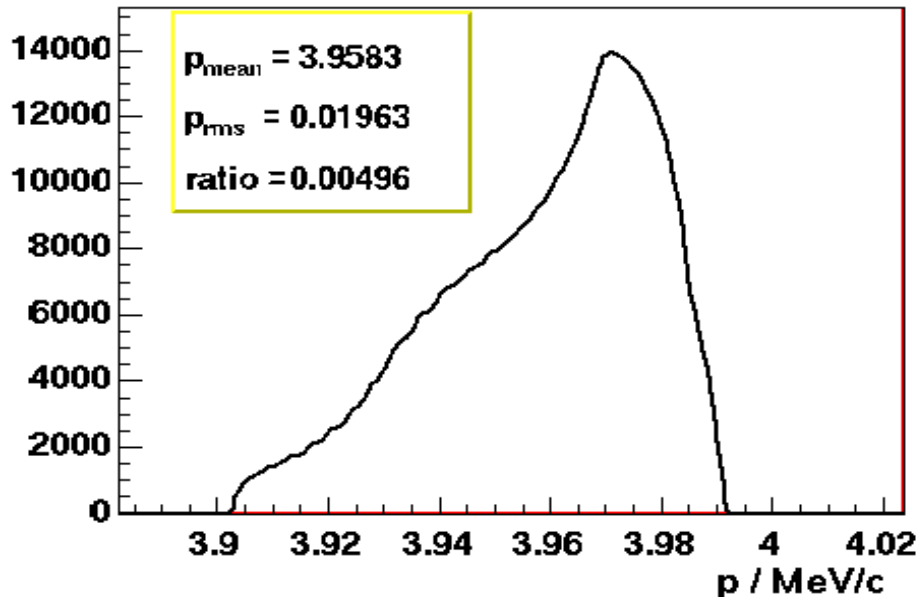
parameters:

$$I_{main} = 180 A$$

$$SP_{Voltage} = 35 MV / m$$

$$SP_{Phase} = -70^\circ$$

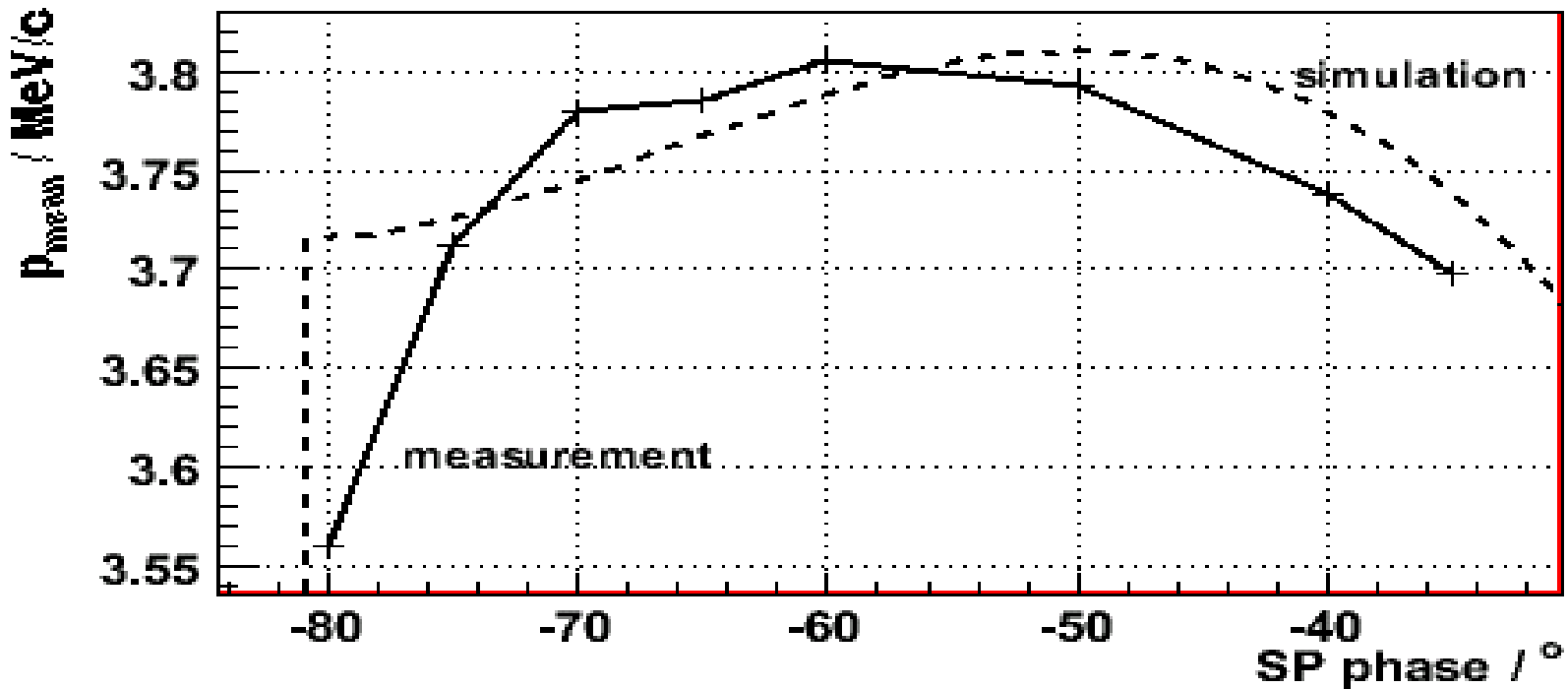
$$Number\ of\ laser\ pulses = 80$$



⇒ up to 4.0 MeV/c

# Mean Momentum vs. RF Phase

(preliminary)



parameters:

$$I_{\text{main}} = 200 A$$

$$SP_{\text{Voltage}} = 27 MV / m$$

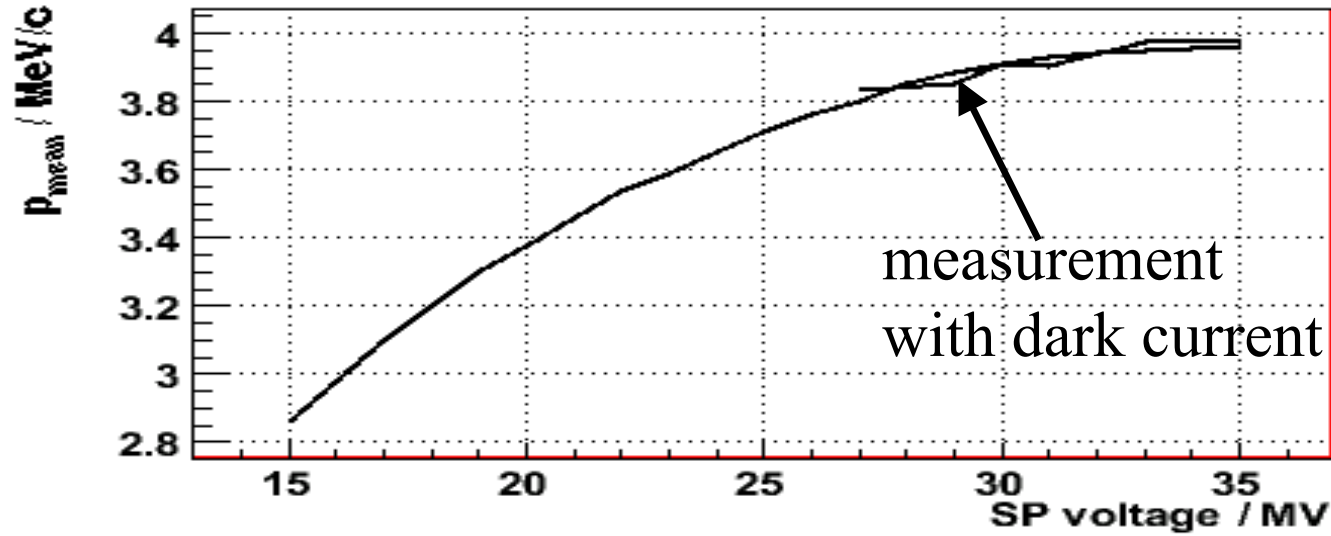
$$Charge = 70 pC$$

$$Number\ of\ laser\ pulses = 1$$

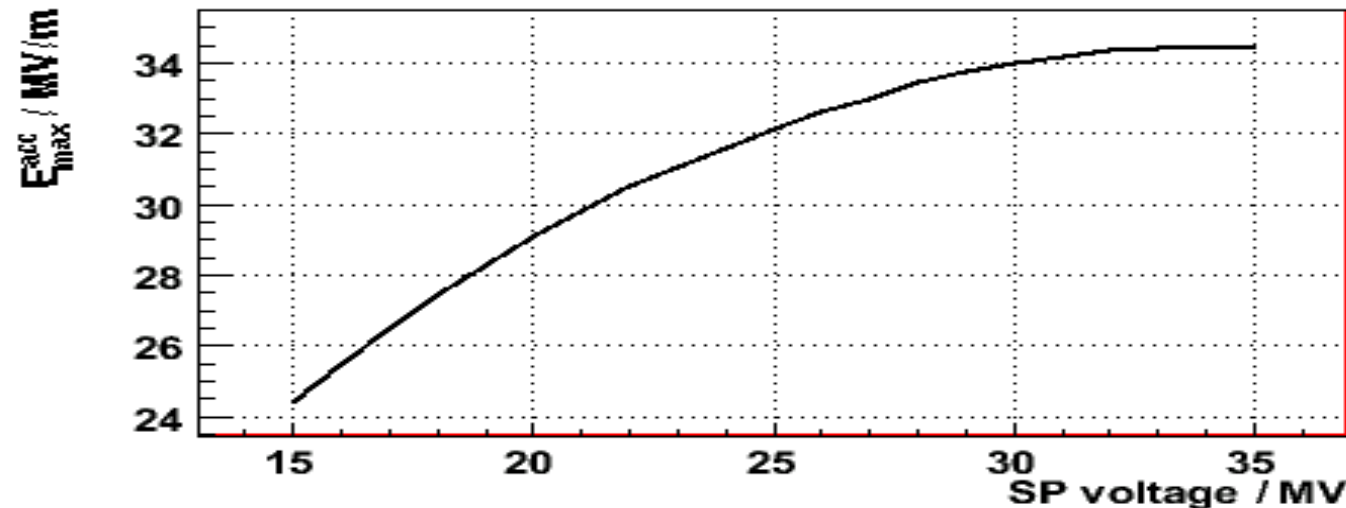
**good agreement**

# Calibration of Set Point voltage

maximum electron momentum vs. SP voltage:



maximum electric field vs. SP voltage:



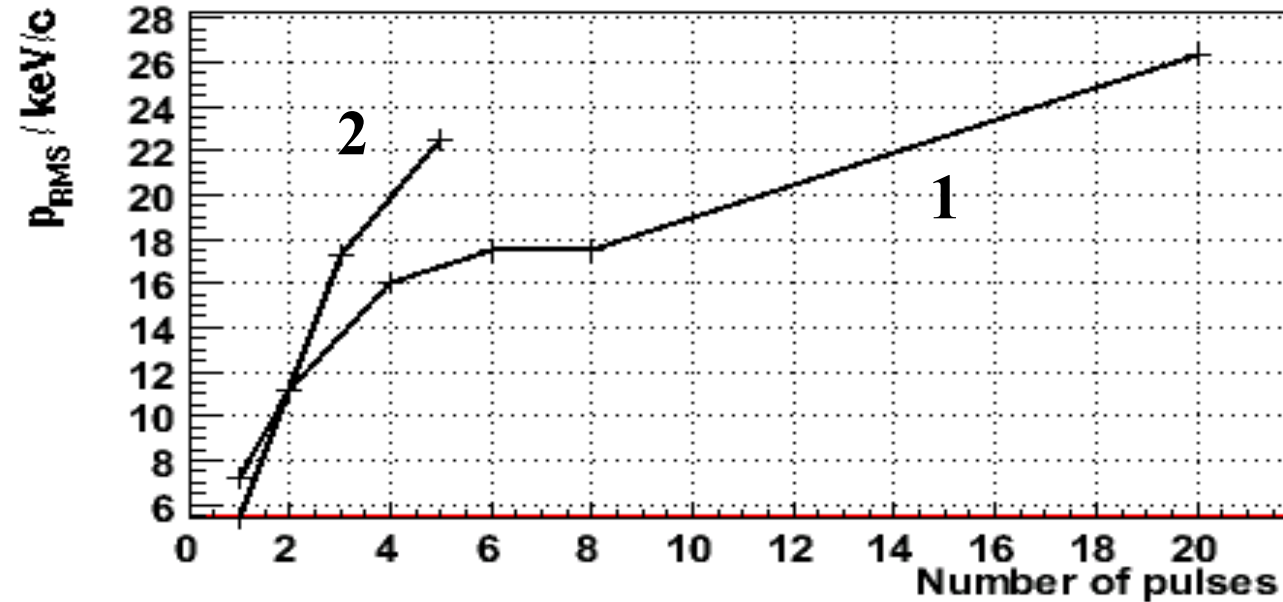
**conclusions:**

$$E_{\text{max}}^{\text{acc}} \approx 34 \text{ MV/m}$$

klystron is operated  
close to saturation

# Momentum spread vs. # of bunches

(preliminary results)



parameters:

for 1:

$$I_{main} = 200 A$$

$$SP_{Voltage} = 30 MV / m$$

$$Charge = 100 pC$$

$$SP_{Phase} = -42^\circ$$

possible explanation:

RF amplitude changes during rf pulse

## conclusions:

need to run with RF feedback (in preparation),  
measure momentum spread with low # of bunches

for 2:

$$I_{main} = 190 A$$

$$SP_{Voltage} = 27 MV / m$$

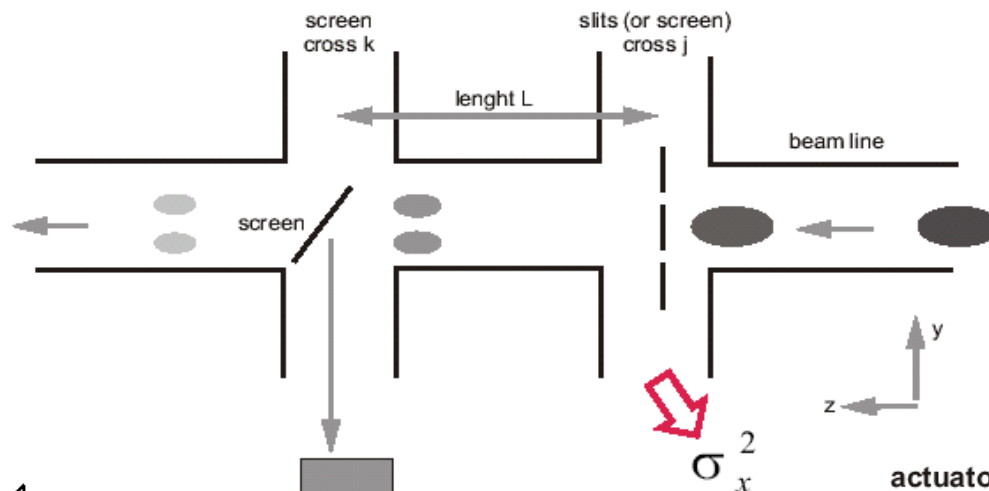
$$Charge = 180 pC$$

$$SP_{Phase} = -50^\circ$$

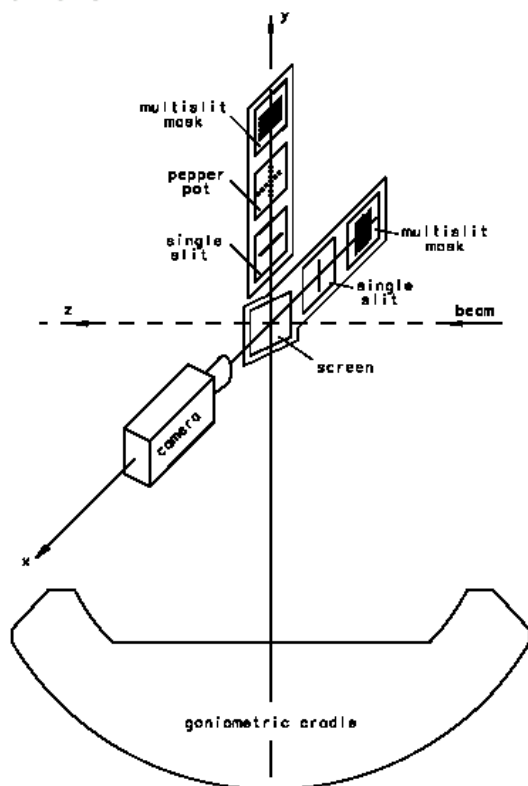
# The new emittance measurement system at PITZ

- normalized transverse emittance:  $\epsilon_x^n = \beta\gamma\sqrt{\sigma_x^2\sigma_{x'}^2 - \text{cov}^2(x, x')}$
- emittance range:  $\sim 1-10 \pi$  mm mrad

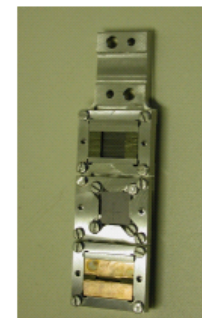
principle:



hardware:

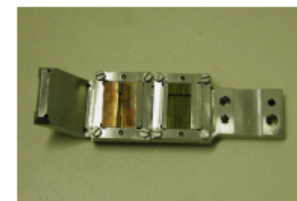
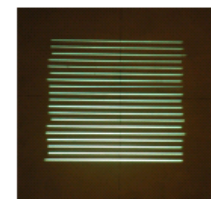
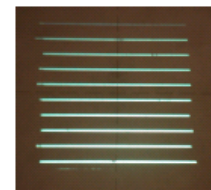


actuators:



vertical

multislit masks:



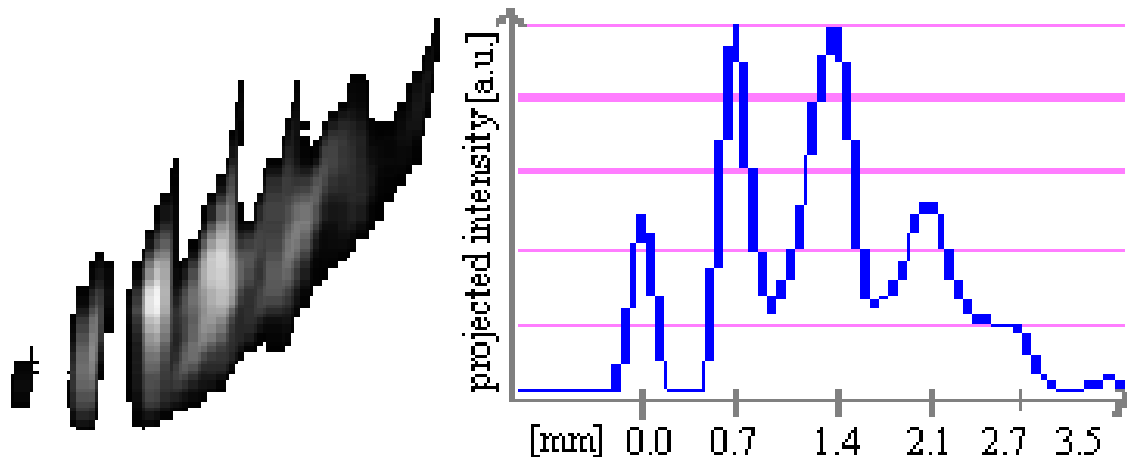
horizontal

$\sigma_{x'}^2$

$\text{cov}(x, x')$

# Commissioning the emittance measurement system

(very preliminary results)



parameters:  
SP = 32 MV/m  
I(main) = 166 A  
charge = 20 pC  
phase at optimum

- method 1: measure all parameters with beamlets
- method 2: measure beam size separately at position of slit mask
- method 3: beam size from M2, divergence as weighted av. from beamlets, correlation set zero

rms values	method 1	method 2	method 3
beam size [mm]	1.05	1.73	1.73
divergence [mrad]	0.3676	0.3676	0.14
covariance [mm.mrad]	-0.343	-0.343	---
norm. emittance [mm.mrad]	1.5	4.3	1.9

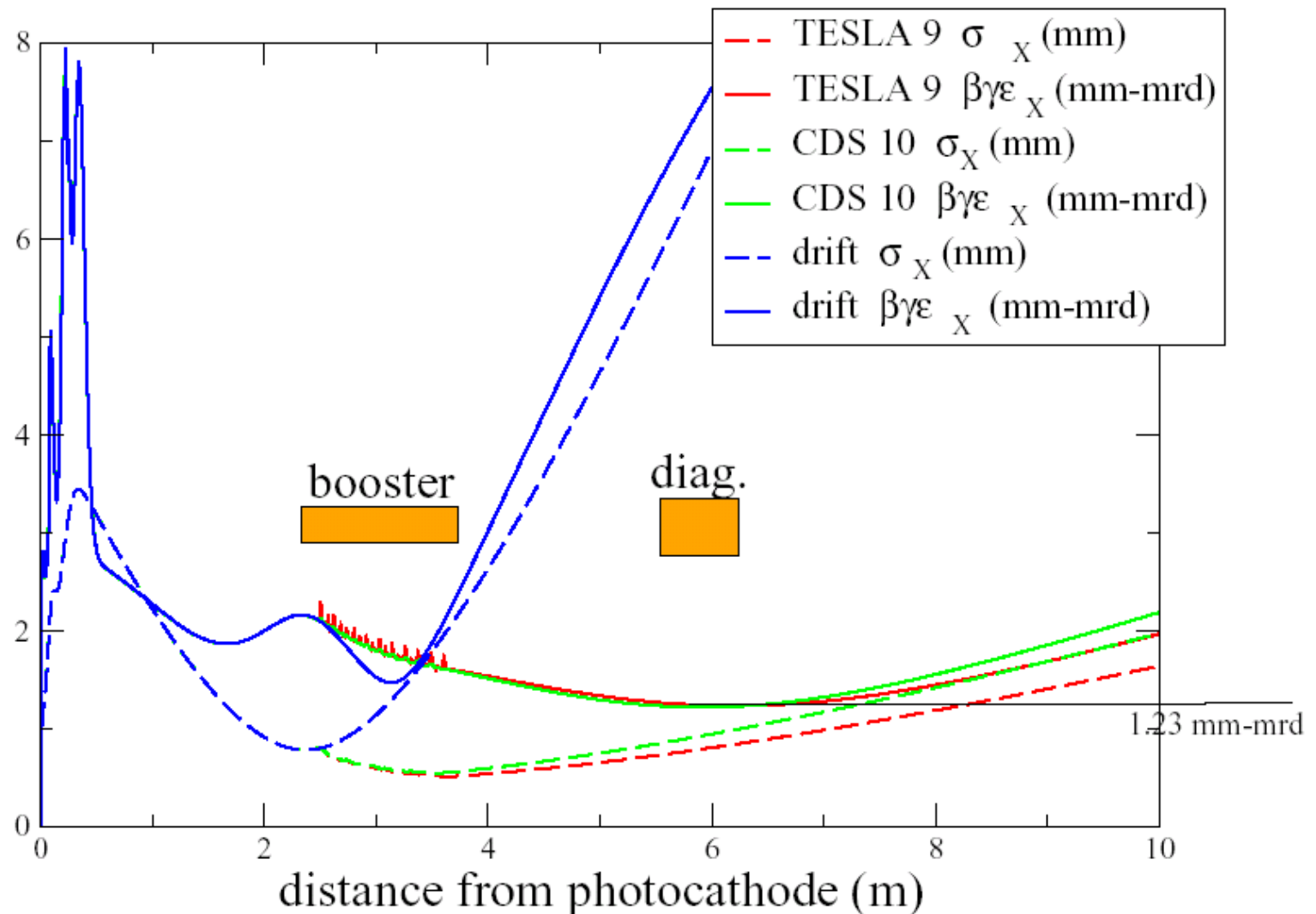
**simulation result:  $0.76 \pi$  mm mrad**

# Future plans @ PITZ

- **upgrade rf system**: better stability + higher output power (in autumn: 10 MW klystron)
- **commission diagnostics** (p& $\Delta$ p, Q, BPM, EMSY, bunch length, long. phase space)
- until end of **April 2003**: gun should be fully characterized  $\rightarrow$  use at TTF-FEL 2
- then: **upgrade PITZ with a booster cavity**
- 2004: measurements with higher beam energy ( $\sim 40$  MeV)

# Simulations with booster cavity (Ph. Piot)

TTF2 gun+sol. set-up with a booster





# Acknowledgements

for the current status of PITZ:

- **strong support** from **technical** groups, **physics** groups and **administration** at DESY (Hamburg and Zeuthen)
- people from cooperation partners: BESSY, CAEP Mian Yang, HEPI Tbilisi, INFN Milano, INR Troitsk, INRNE Sofia, Max-Born-Institute, TEMF@TUD, YERPHI Yerevan
- colleagues from DESY Hamburg: J.P. Carneiro, K. Flöttmann, Ph. Piot, J. Roßbach, S. Schreiber
- members of the Zeuthen PITZ group: J. Bähr, I. Bohnet, D. Lipka, A. Oppelt, T. Thon

# Summary

- photo injector test facility at DESY Zeuthen (PITZ) has taken **first measurements** with and without beam
- commissioning and upgrade is ongoing
- **characterization** of FEL gun is foreseen **until spring 2003**
- then upgrade facility with booster cavity