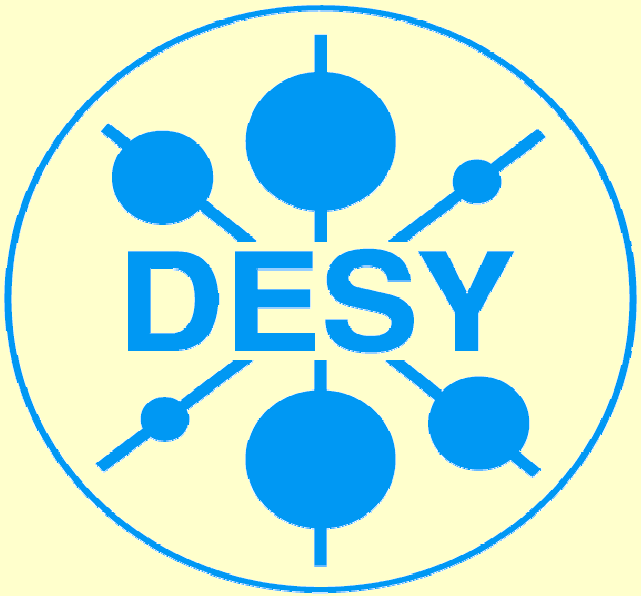
The Zeuthen Photo Injector Test Facility



Anne Oppelt
DESY

Outline

- Motivation and goals of a photo injector test facility
- Results of PITZ 1
- Facility upgrade: PITZ 2
- Summary and Outlook

Photo injector test facility

Main goal: develop and optimize high quality electron sources for Free Electron Lasers and Linear Colliders

high brightness:	high luminosity:
• small transverse emittance	• extremely small beam size at the IP
• high beam current	• high beam power

different beam characteristics for optimal performance
→ needed for VUV-FEL, XFEL, and TESLA LC

Motivation

"The photo injector determines to a large extend the performances and the potential for new science of the facility." (J.Schneider)

→ need to do specific R&D on photo injectors independent of serving concrete FEL / user requests

→ PITZ in parallel to TTF operation

PITZ in Zeuthen

→ significant contribution of Zeuthen to TTF and TESLA

→ get new technical + scientific capacities for TTF and TESLA

→ opens long term research field for Zeuthen

→ large project at Zeuthen

→ near to BESSY and MBI

Work program

- compare detailed experimental results with simulations to improve theoretical understanding of photo injectors
- test and optimize rf guns for subsequent use at TTF2-FEL and TESLA XFEL
- test new developments (laser, photo cathodes, beam diagnostics, gun geometries)
- studies for TESLA XFEL (BC, CSR) and TESLA LC (flat beams, polarized electrons)

High quality beam production

short bunches, **medium charge**, **low emittance**

~ 20 ps **~ 1 nC** **~ 1-2 π mm mrad**

⇩

laser driven RF photo cathode gun

high power UV laser, required pulse structure

Cs_2Te cathode

normal conducting 1.5 cell standing wave cavity, π-mode

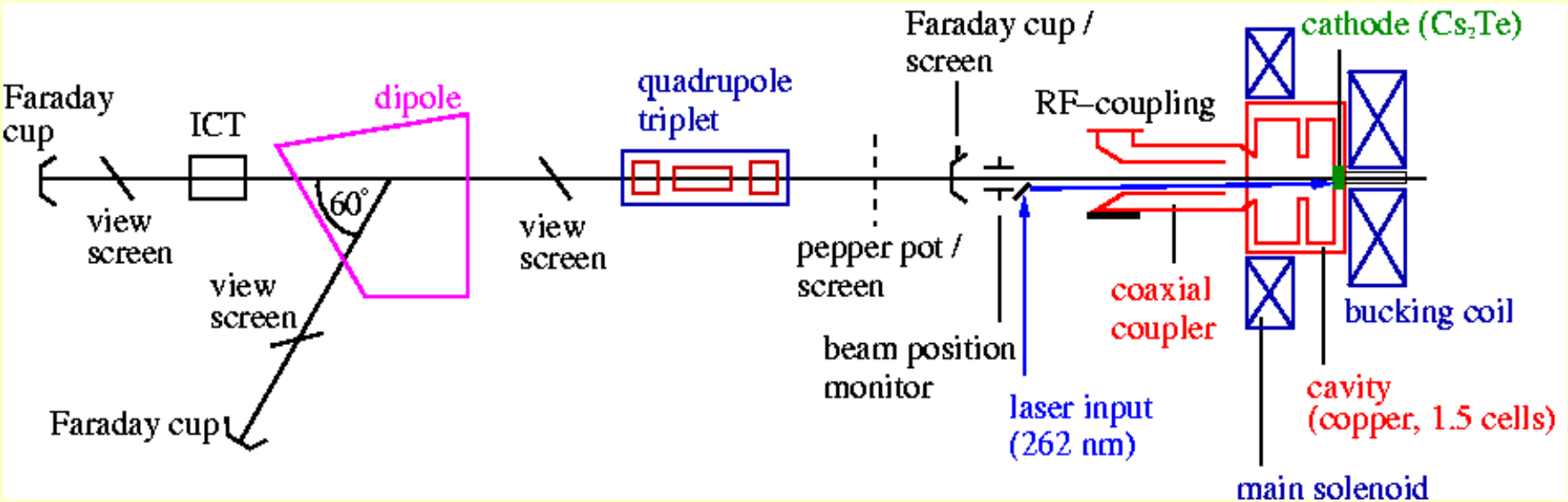
⇩

coaxial rf input coupler, high gradient at cathode, focussing solenoid field

The Photo Injector Test Facility at Zeuthen

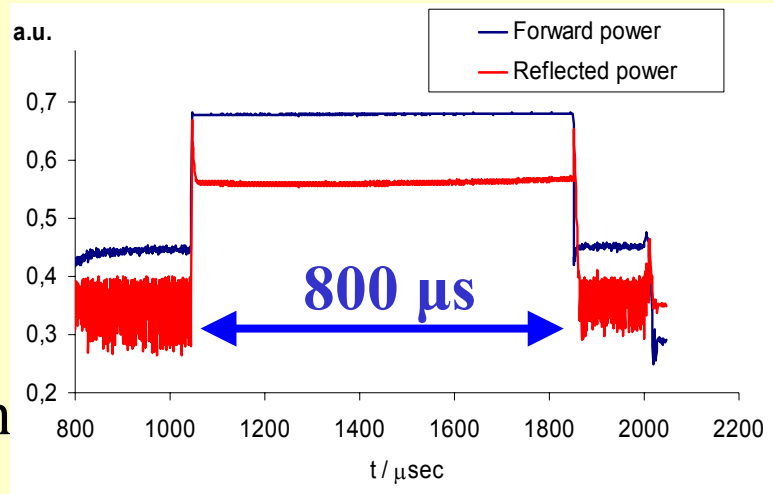
PITZ phase 1

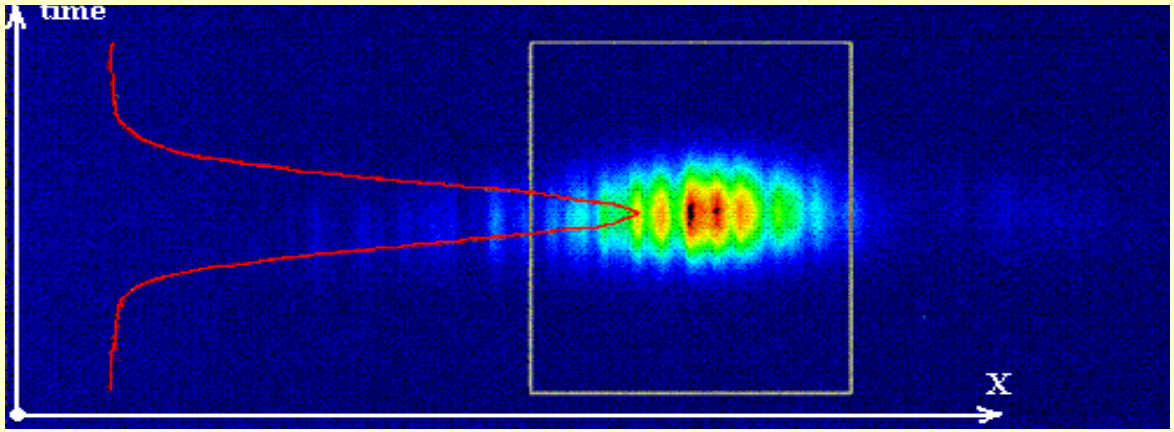
- commissioning of the facility is done
- gun preparation for TTF2 is ongoing
- first measurements were published

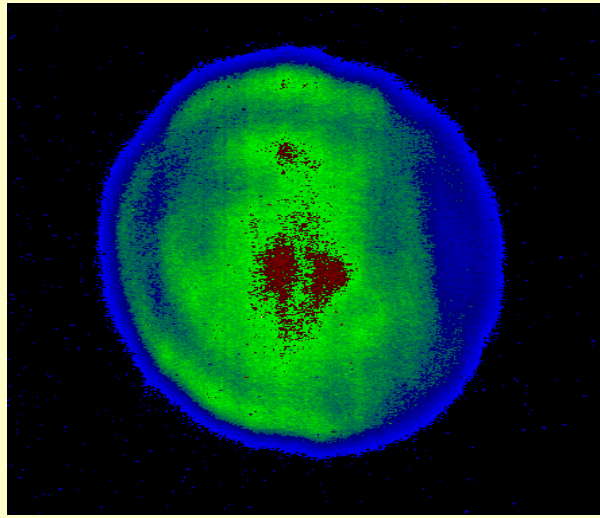


Current results of PITZ 1

- average power in the gun: up to 27 kW
- rf duty cycle: up to 0.9 %
- laser pulse length: (7 ± 1) ps FWHM
- rms laser spot size @ cathode: 0.3−1 mm
- QE of the photocathode: ~ 0.5 %

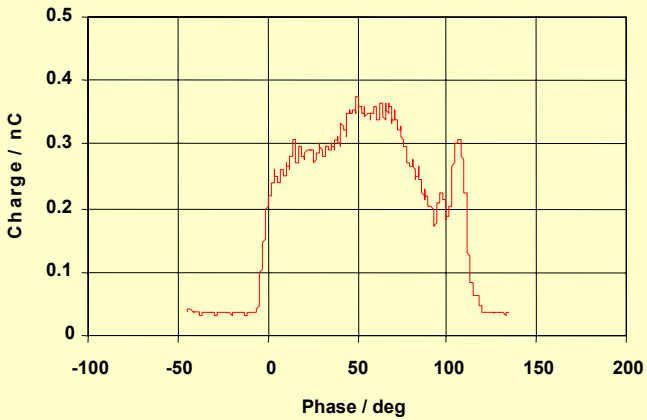




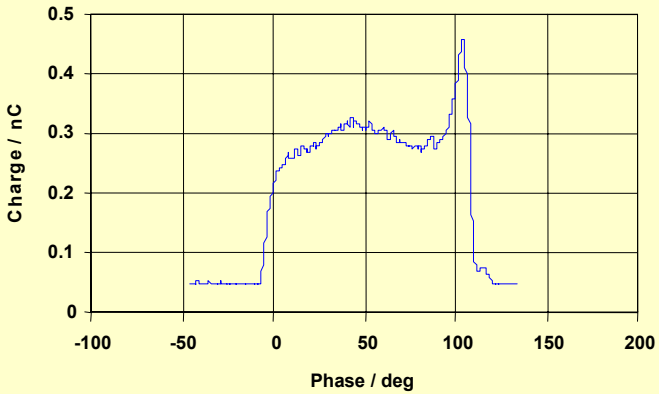


Charge measurement

max. charge: ~7 nC



320 A



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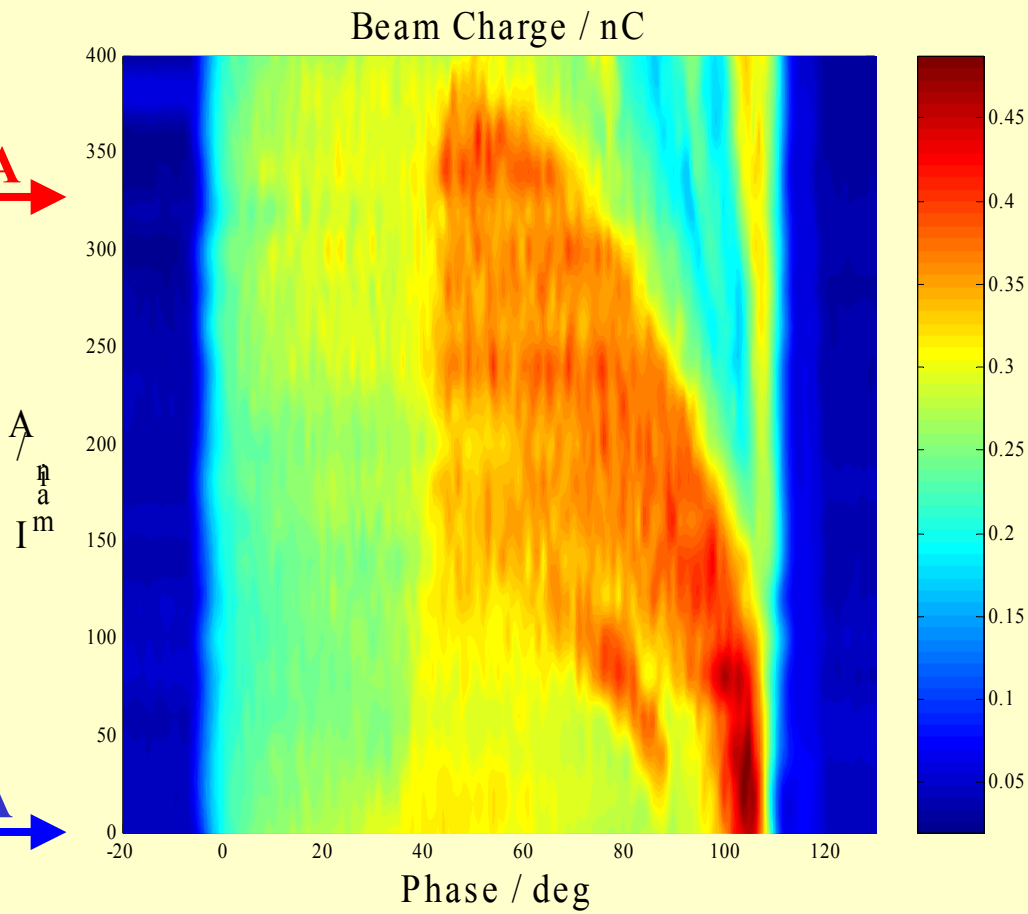


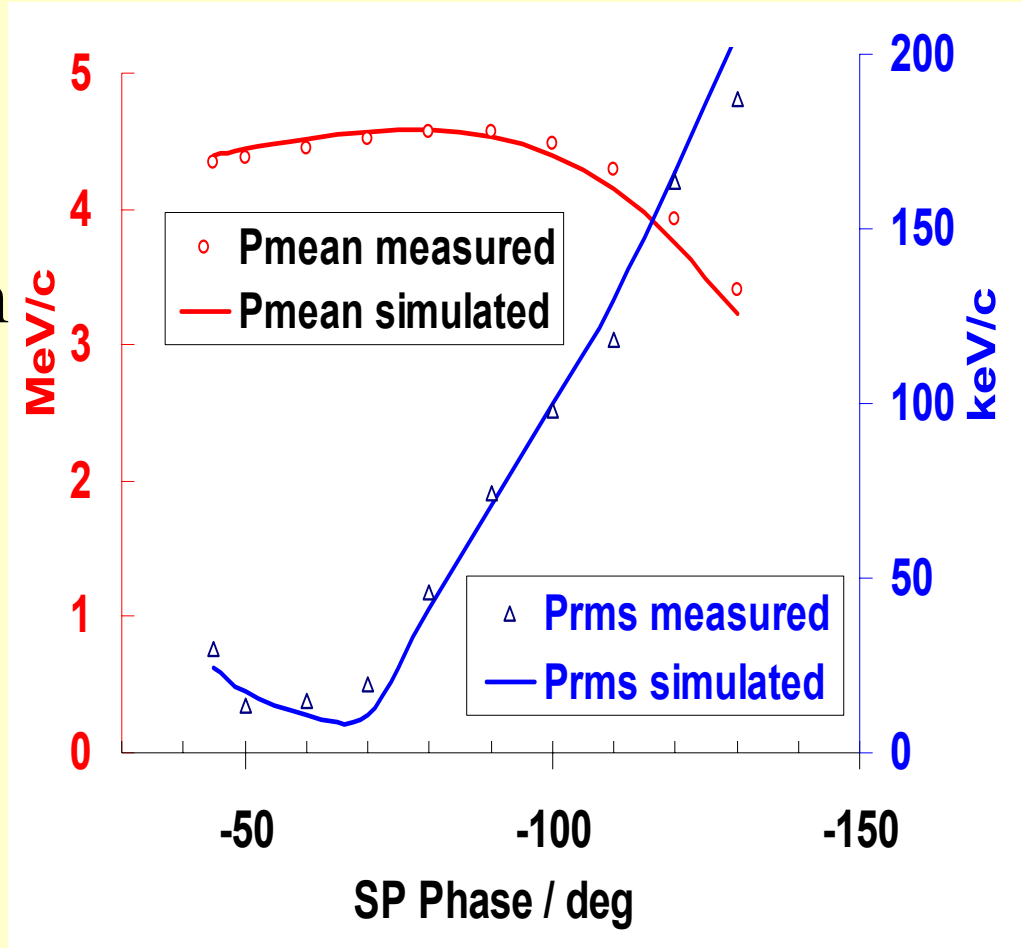
Momentum measurement

max. momentum:

4.7 MeV/c @ 41.5 MV/m

momentum spread:

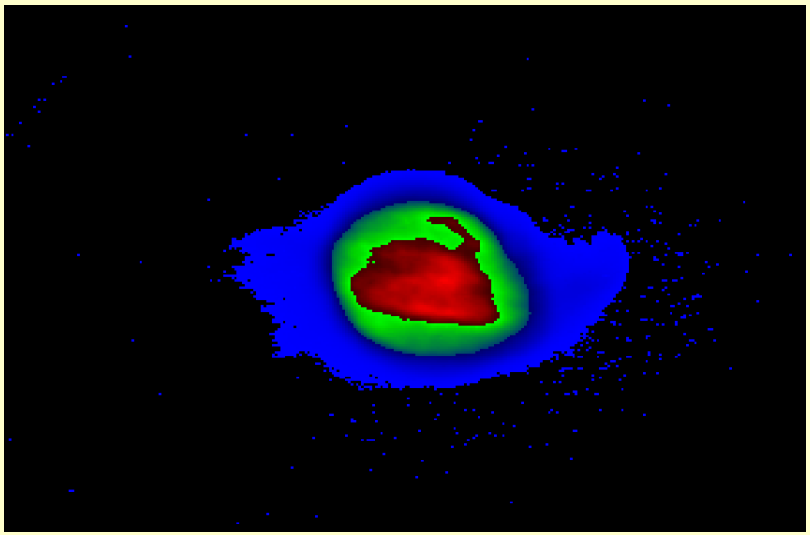
~ 15 keV/c @ 1 nC

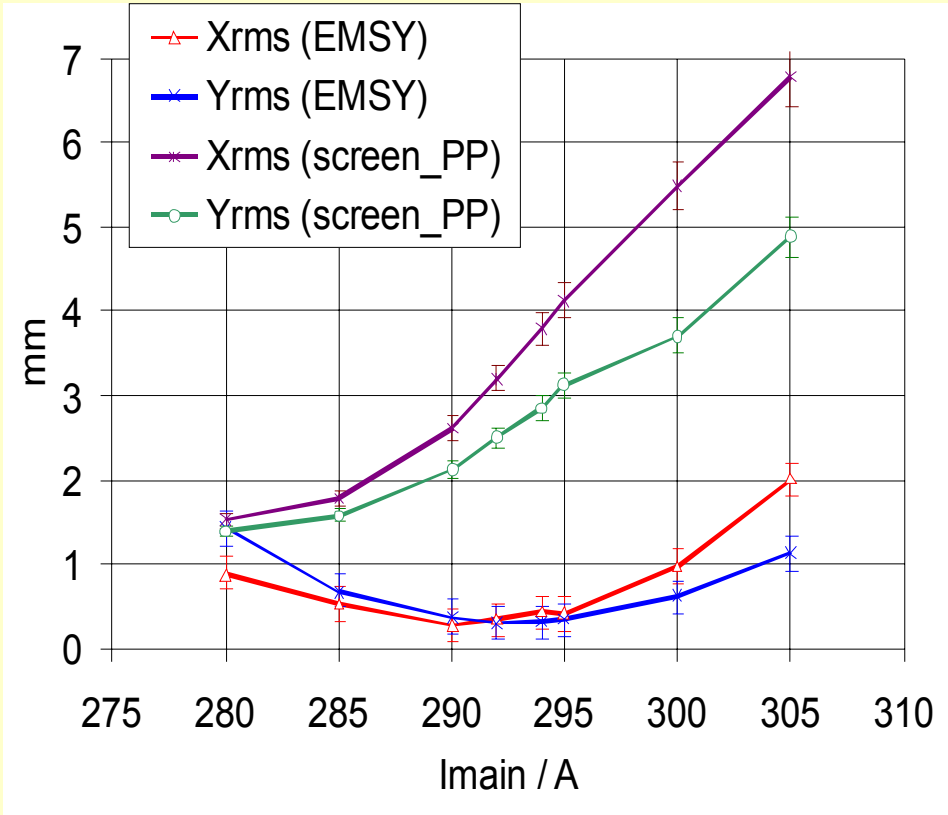


Beam size measurement

typical rms beam spot size:

0.2 - 2 mm (focussed)





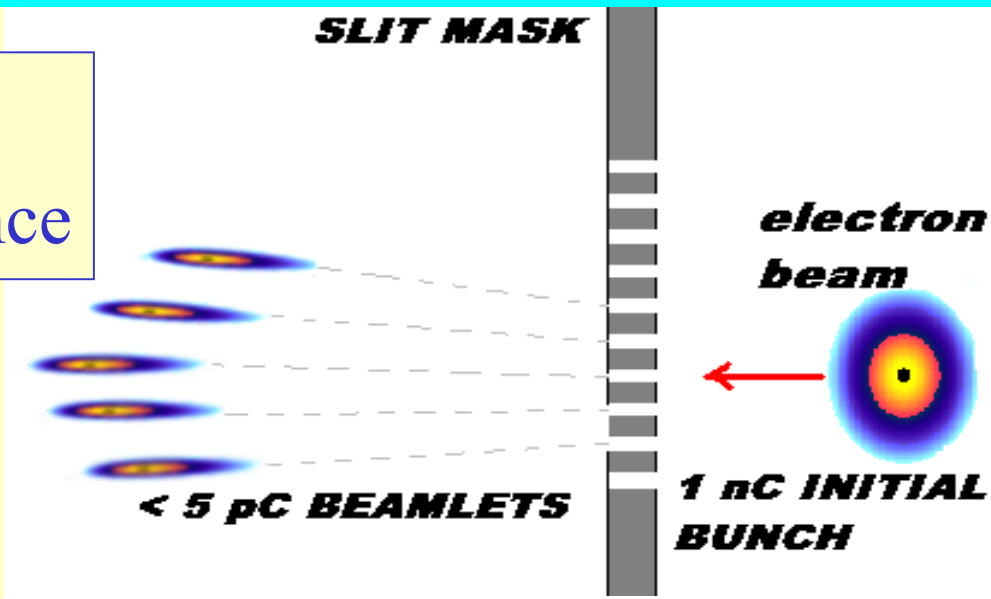
Emittance measurement principle

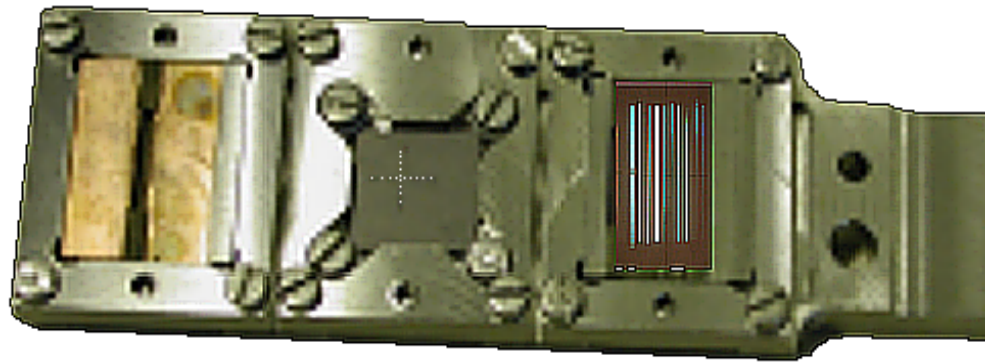
emittance $\propto$

beam size · angular divergence

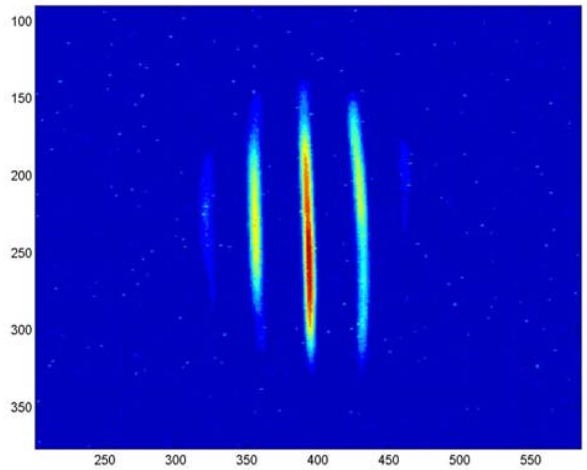
Measurements with EMSY:

1. screen
   → beam size
2. pepperpot / slit masks followed by a screen
   → angular divergence

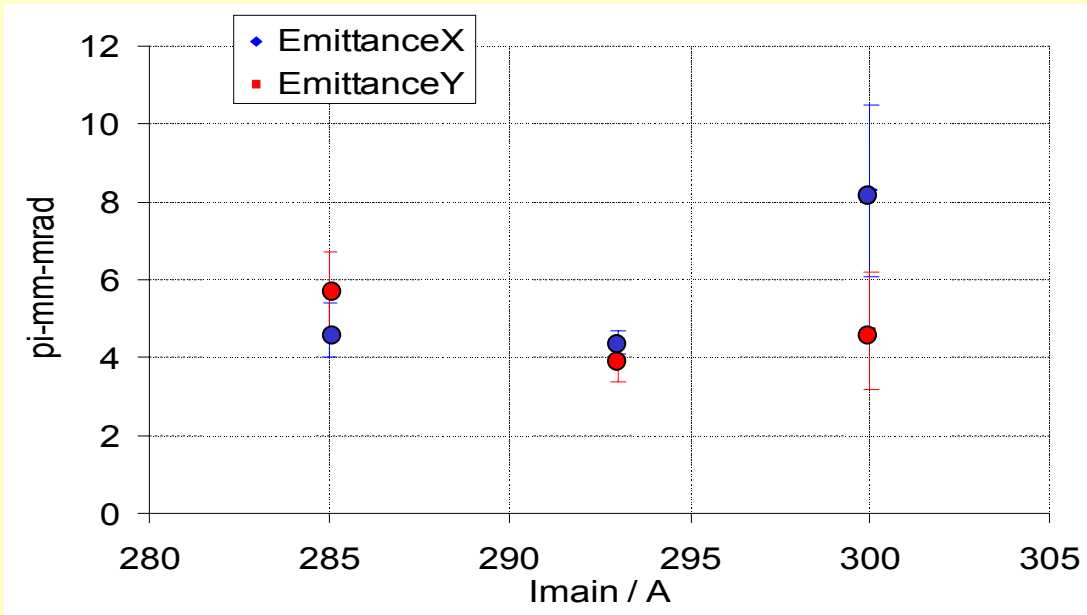




Emittance measurement results



normalized transverse emittance:
3-4 π mm mrad @ 0.5 nC

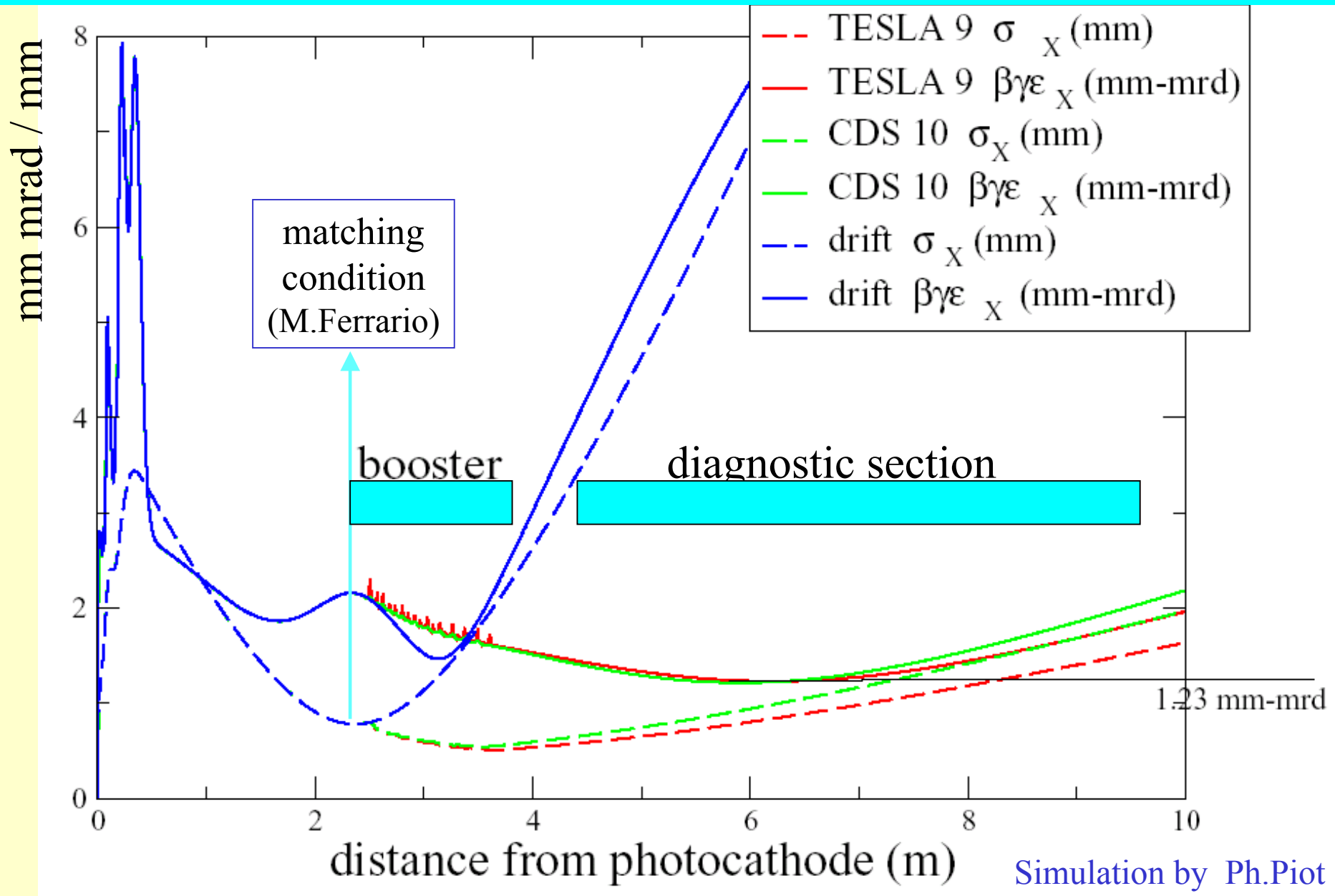


PITZ 2

large extension of the facility and its research program with two main goals:

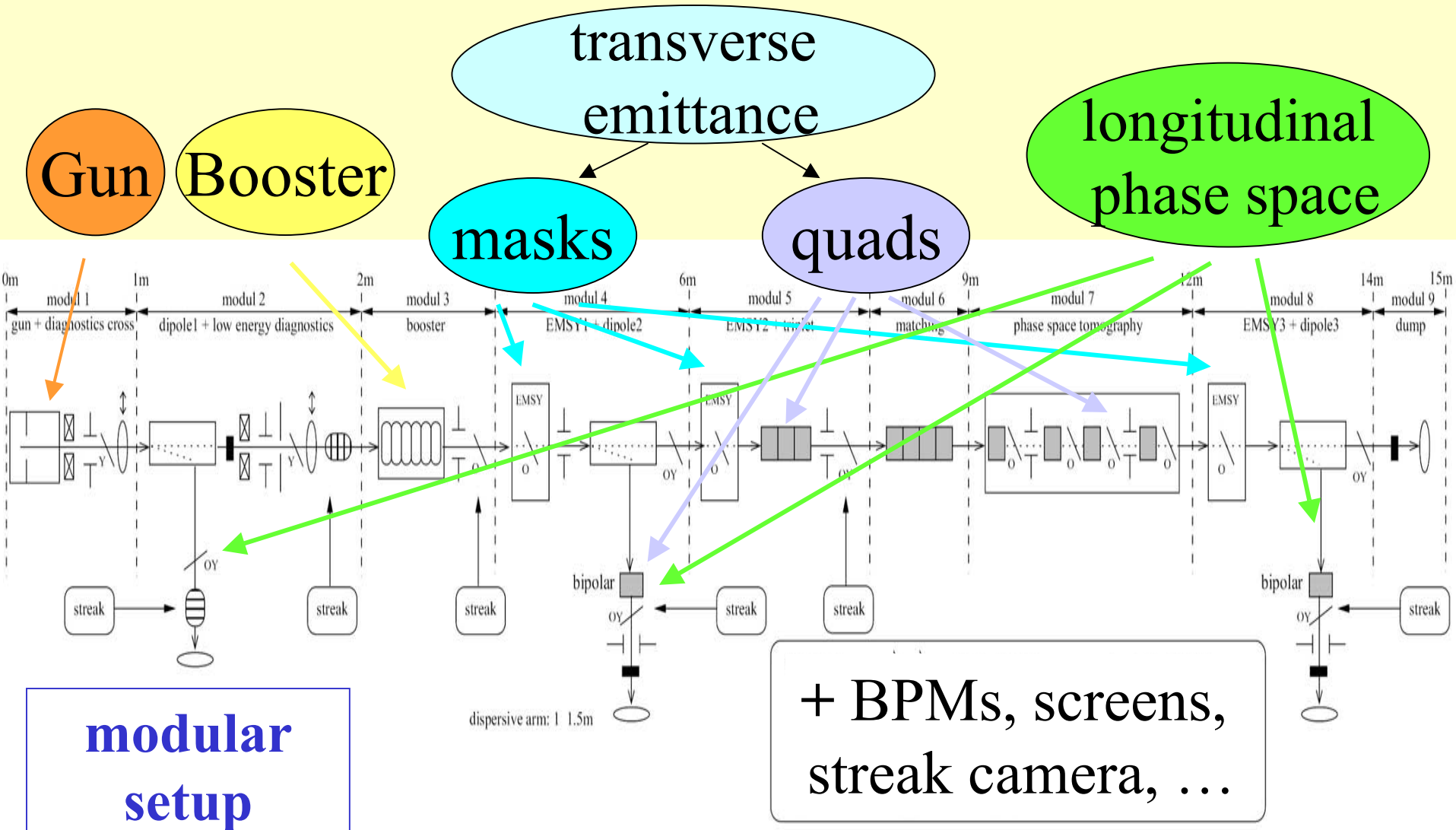
study the emittance conservation principle	extensive R&D on photo injectors
produce and conserve low emittance beams using a booster cavity	improve and optimize all sub-systems including laser, cathode, gun, …

Simulation with booster cavity



Simulation by Ph.Piot

Preliminary layout of PITZ 2



Laser system development by MBI

very small transverse emittances

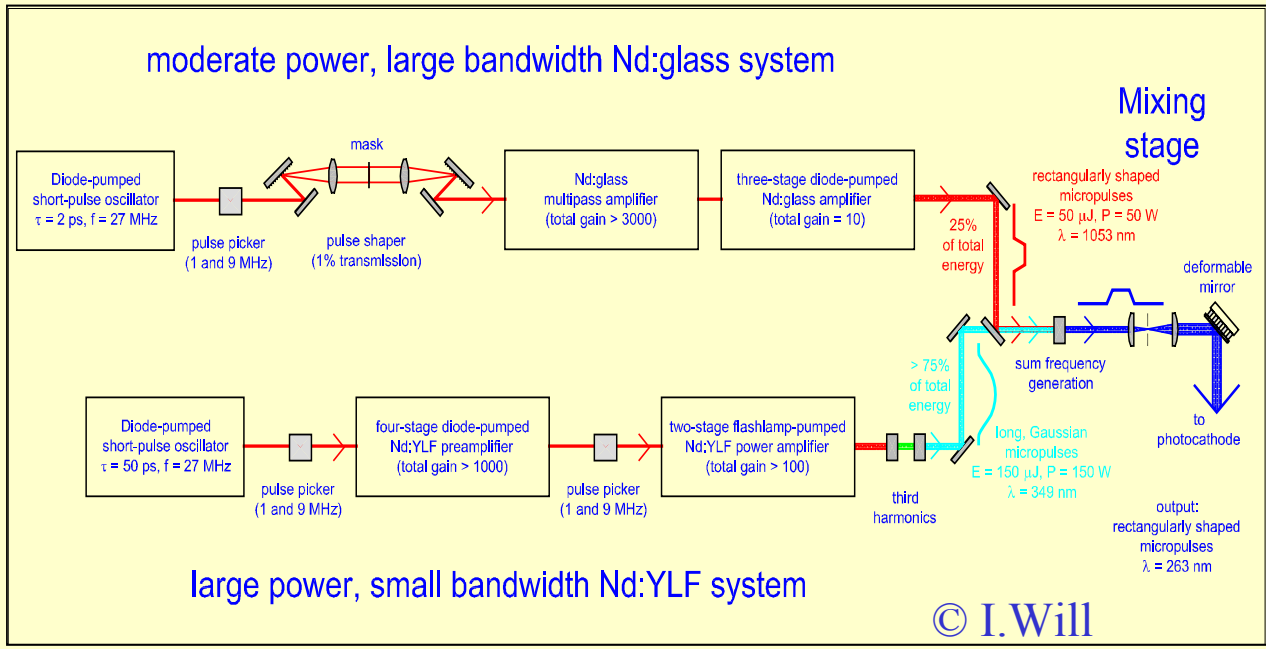
TESLA pulse structure (trains of ps pulses)

Requirements on the driving laser:

- powerful UV laser providing ps pulses
- rectangularly shaped pulses (20 ps FWHM)
- rise / fall times $\leq$ 2 ps
- homogenous transverse intensity profile
- laser parameters widely variable

realized by

- development of Nd:YLF laser
- mixing two-channel system:



Extensive R&D on optimized electron sources for FEL operation

- development, optimization, and characterization of new gun cavities, e.g. high duty cycle gun for high repetition rate FELs and ERLs, or rf-gun with improved gun geometry
- studies of photo cathodes (life time, quantum efficiency, nano structuring)
- comparison of detailed experimental results with simulations and development of simulation tools

Operation of PITZ

PITZ group, including guests & PhD students

+ colleagues from TTF
+ collaboration partners, e.g. BESSY
+ substantial support from technical groups @ Zeuthen:
    - electronics group
    - mechanical group
    - computing group
    - mechanical and electronics workshop
    - technical infrastructure

… even more ressources needed for PITZ 2

Collaborating institutes

Extension of the existing collaboration
for PITZ 2:

BESSY Berlin, Daresbury Laboratory, DESY,
HU Berlin, INFN Frascati, INFN Milano,
INRNE Sofia, INR Troitsk, LAL Orsay,
MBI Berlin, TU Darmstadt, TU Eindhoven,
U Hamburg, YERPHI Yerevan, …

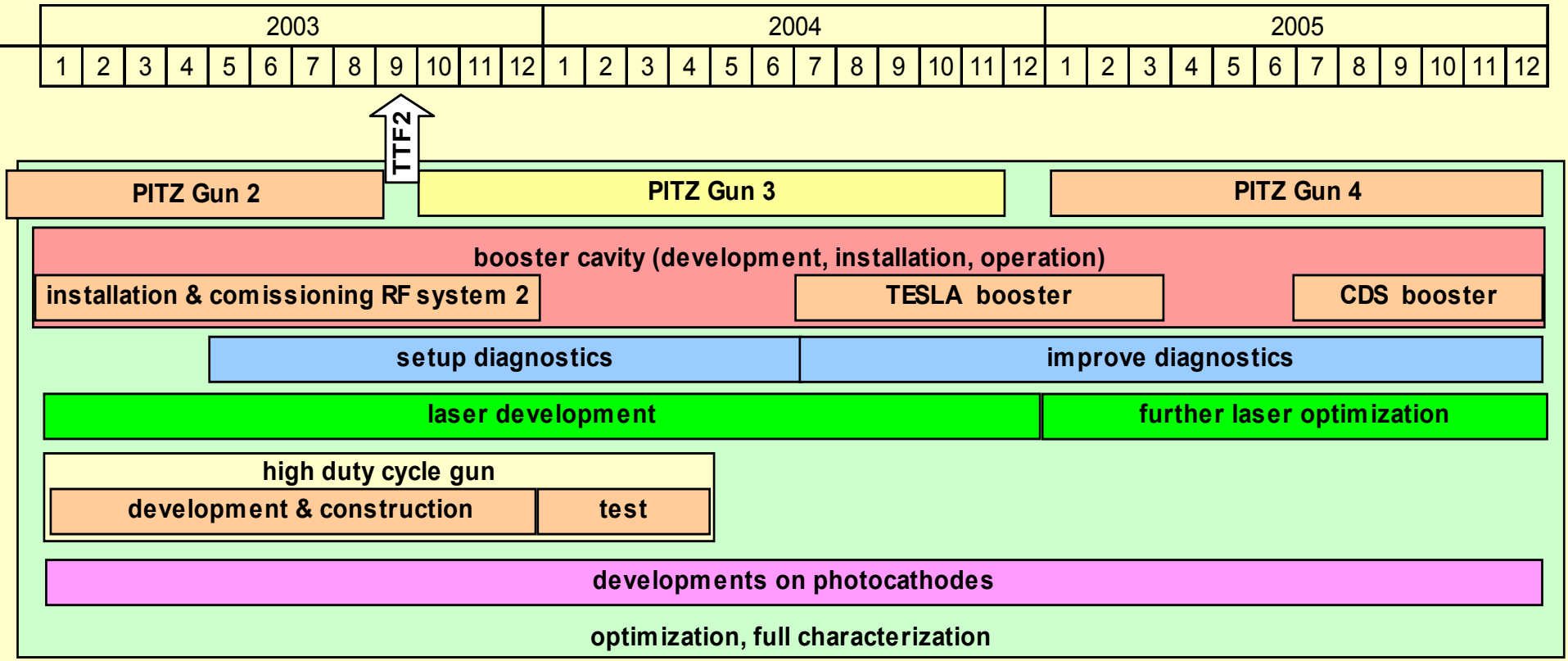
Summary – PITZ 1

- high duty cycle and high power operation have been demonstrated
- beam characterization is ongoing
- gun will be installed at TTF2 in September 2003
- preparations for facility upgrade have been started

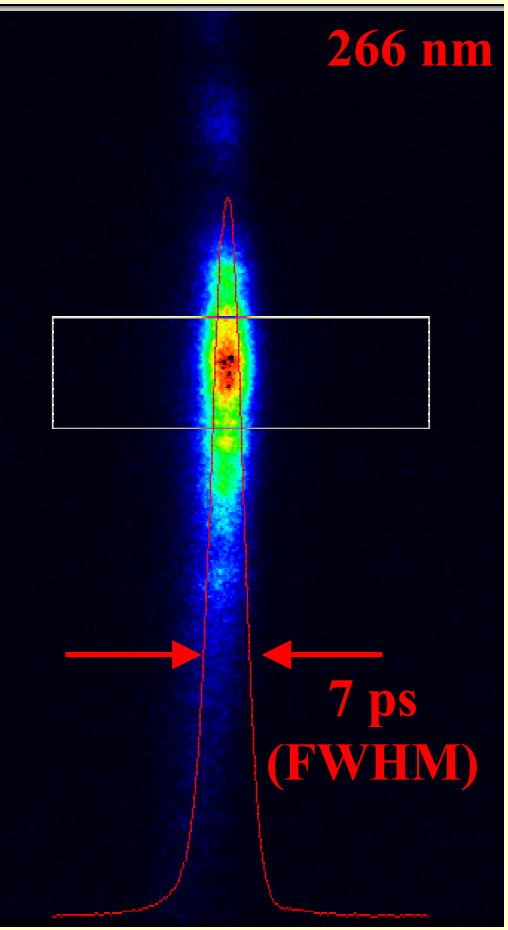
Outlook – PITZ 2

- study emittance conservation with booster and new beamline
- develop stable and reliable laser system with flat top temporal and transverse radial laser beam profile
- improve simulation tools for extensive beam dynamics studies
- develop and test a high duty cycle gun cavity and improve guns for VUV-FEL and XFEL
- do further studies on photocathodes
- other topics: GAN, BC, CSR
- study subjects like flat and polarized electron beams, important for TESLA LC

Milestones for PITZ 2



First results on laser development



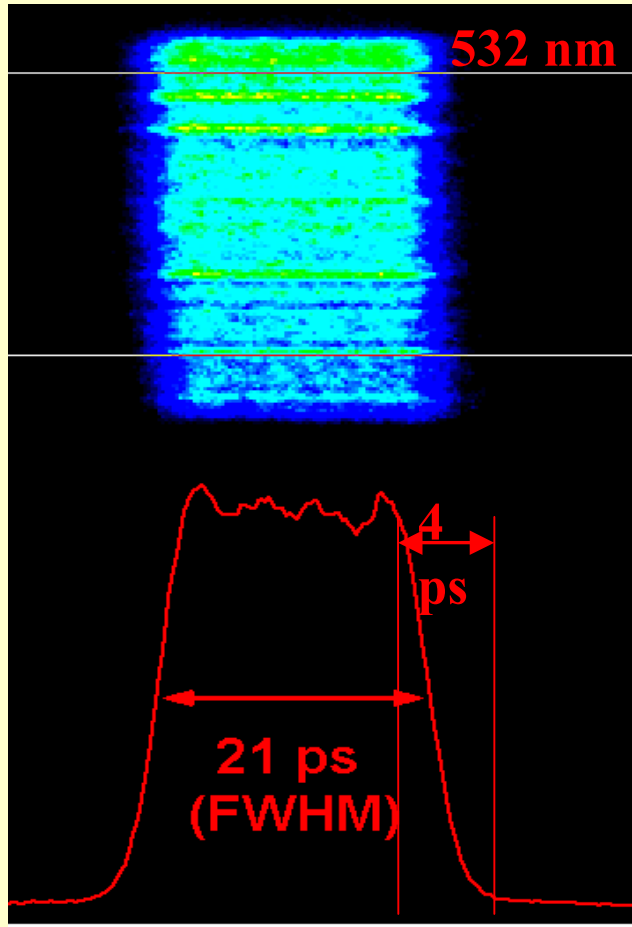
actual measurement

first promising results

but:

- rise time
- flat top
- laser stability
- …

have to be improved !



presented by I.Will (MBI)

PITZ 2 project costs

Institute	DESY	MBI	BESSY	TUD	Sum
Investment costs (kEUR)	3061	1847	1062	78	6048
Personnel costs (kEUR)	6966	1407	1883	337	10598
Total costs (kEUR)	**10027**	**3254**	**2945**	**415**	**16641**
Needed man power (man-years)	58	21	27	3	109