SPARC (Phase1) main Scientific Goal is to drive a SASE-FEL to saturation @ 500 nm

But…

There are now several (conceived, untested) operating modes for SASE-FEL's

Chirped FEL pulses for selection of single spikes and/or smaller bandwith

Slice manipulation in the electron bunch for shorter pulses

What can we do with the anticipated hardware for Phase1 that may be relevant to future X-ray FEL's ?

What are the key issues for Phase2, before LCLS/TESLA-FEL come into operation (2008/?)

RF Deflector is the key to perform critical experiments

FEL2003 SEPTEMBER 8-12 JAPAN
25TH INTERNATIONAL FREE ELECTRON LASER CONFERENCE
&
10TH FEL USER WORKSHOP

Approaches for the generation of femtosecond x-ray pulses

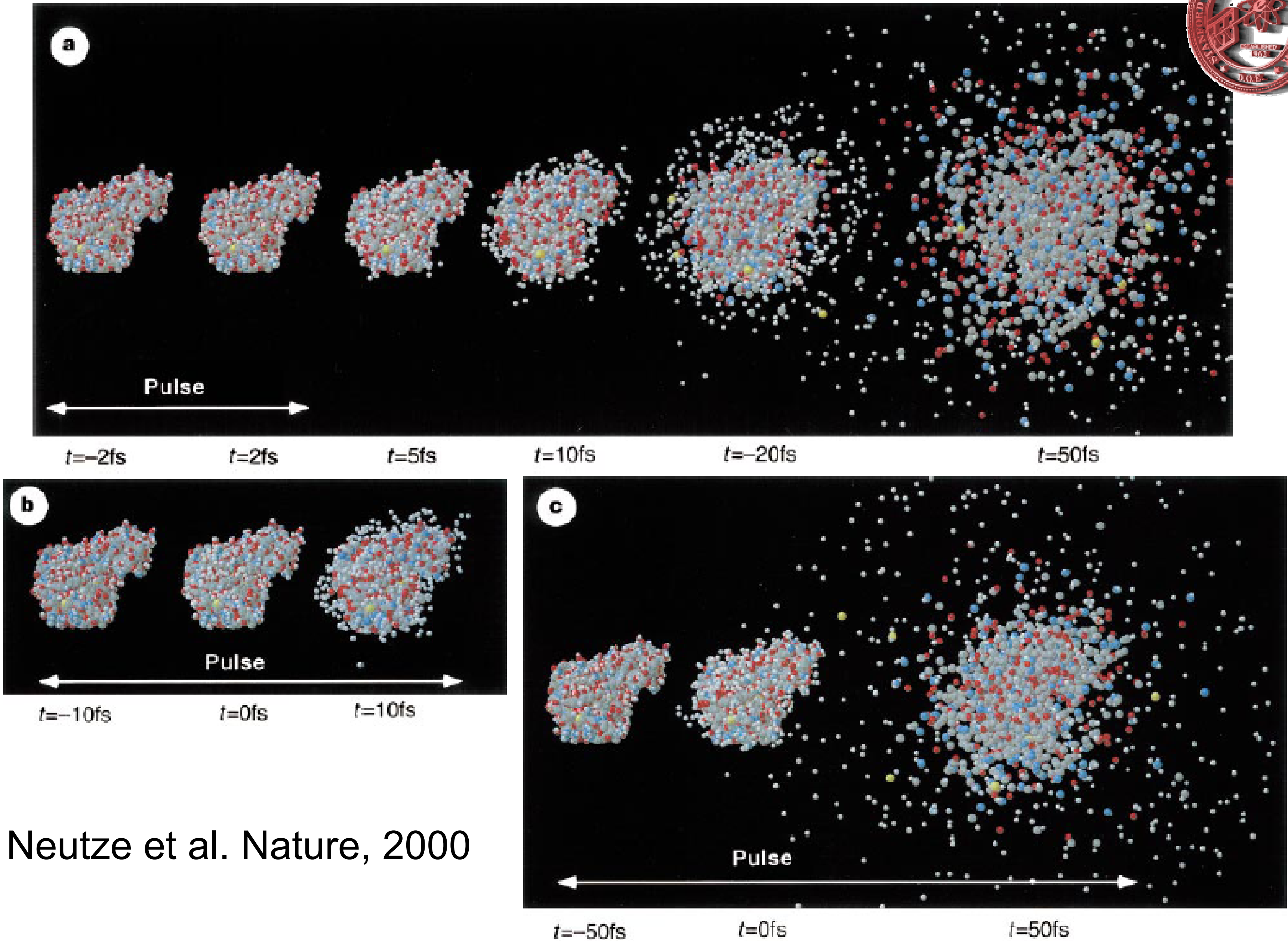
Zhirong Huang (SLAC-LCLS)

SPARC Review - Sept. 23rd 2003

INFN Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

SPARC

Single Molecule Imaging with Intense fs X-ray



R. Neutze et al. Nature, 2000

Introduction

- Femtosecond (fs) x-ray pulses are keys to exploring ultra-fast science at a future light source facility

- In typical XFEL designs based on SASE the photon pulse is similar in duration to the electron bunch, limited to 100~200 fs due to short-bunch collective effects

- Great interests to push SASE pulse length down to ~10 fs and even below 1 fs

- A recent LCLS task force studied upgrade possibilities, including short-pulse approaches

Optical manipulations of a frequency-chirped SASE

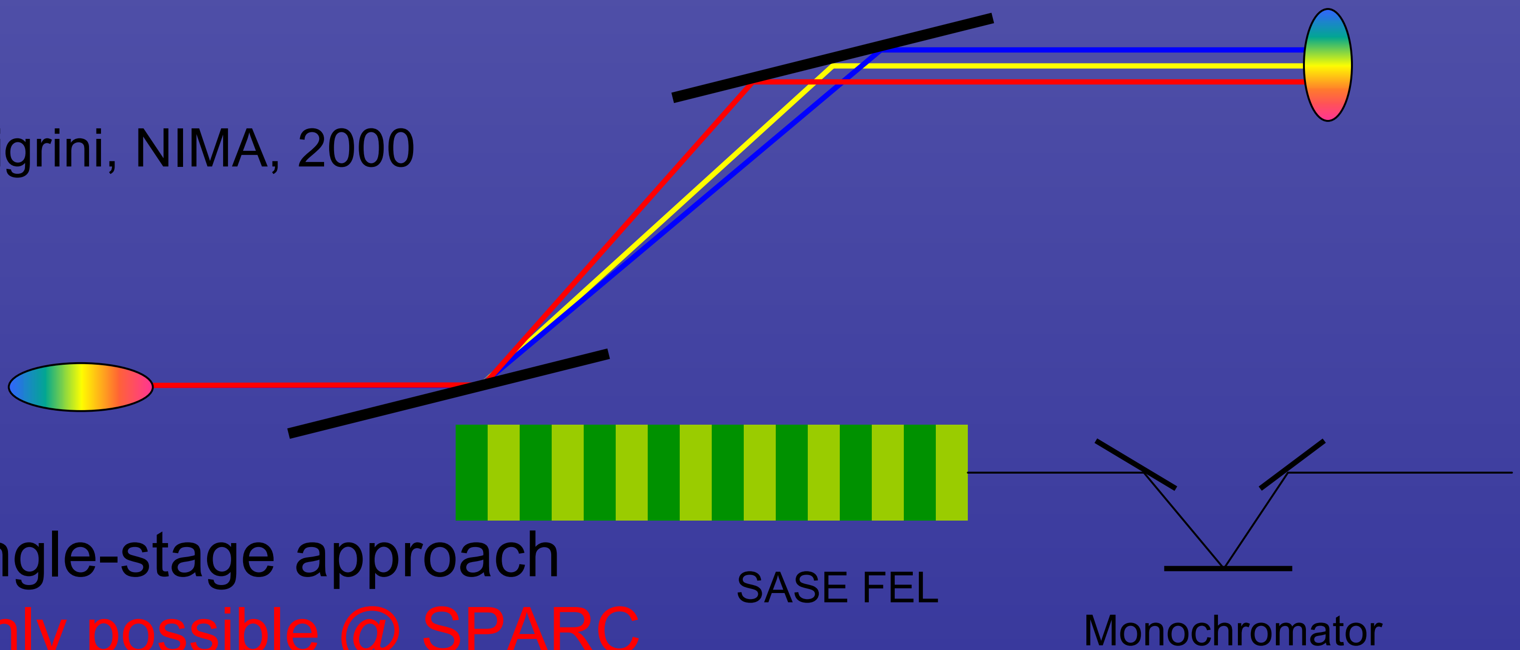
X-ray Pulse Compression

- Energy-chirped e-beam produces a frequency-chirped radiation

$$\omega = \frac{2\gamma^2\omega_u}{(1+K^2/2)}$$

- Pair of gratings to compress the radiation pulse

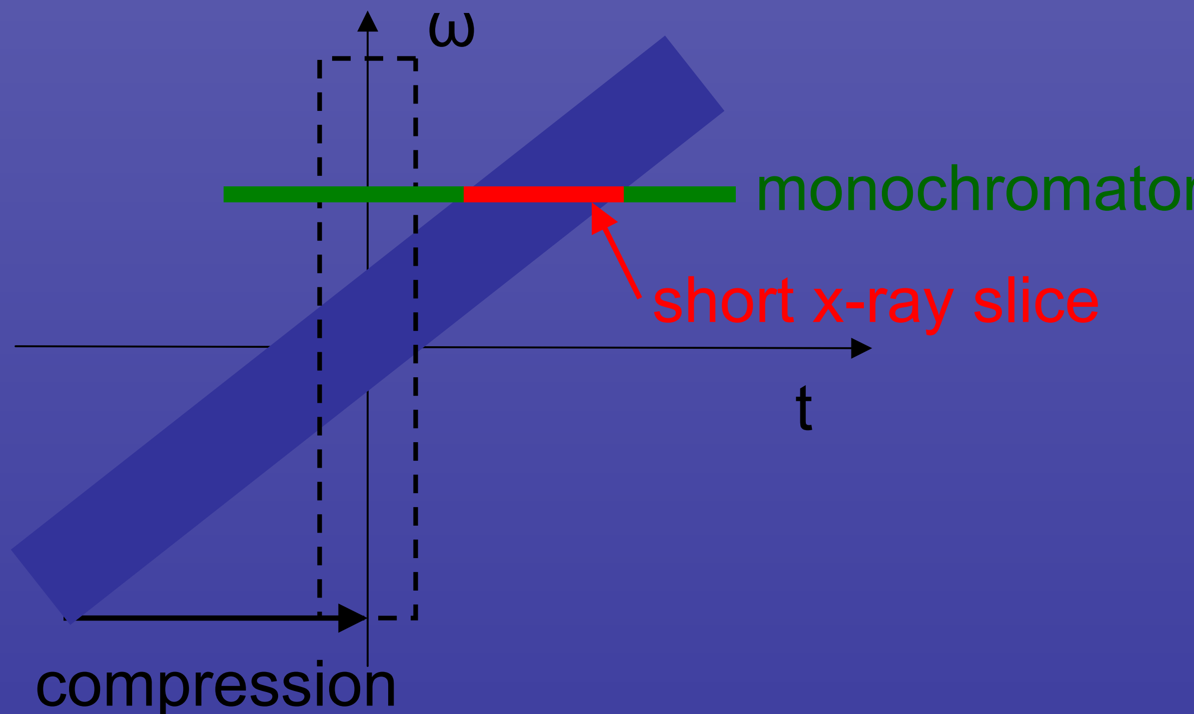
C. Pelligrini, NIMA, 2000



- Single-stage approach
- The only possible @ SPARC

X-ray Pulse Slicing

➢ Instead of compression, use a monochromator to select a slice of the chirped SASE



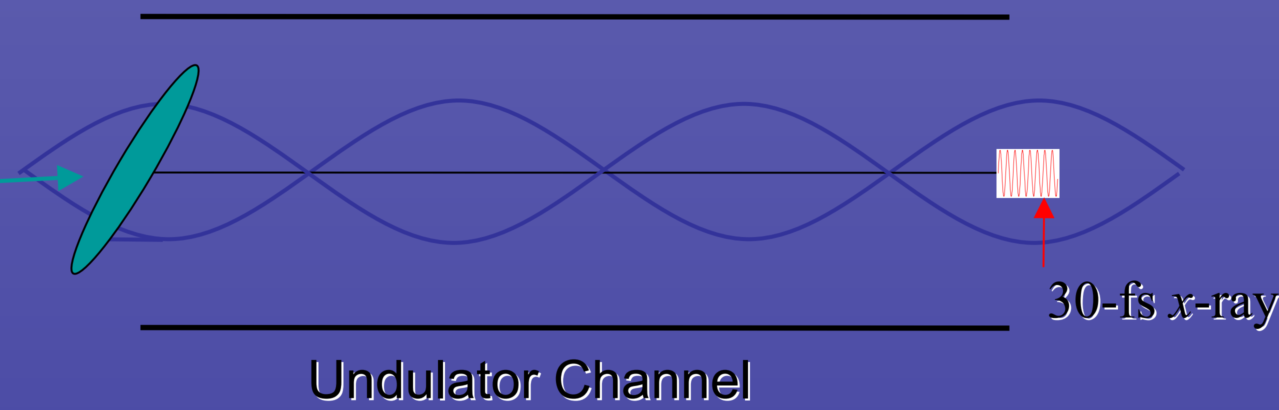
No Crucial role played by SPARC in this field

Most critical issue: monochromator (easy in the visible, tough in the XUV)

Electron Bunch Manipulations

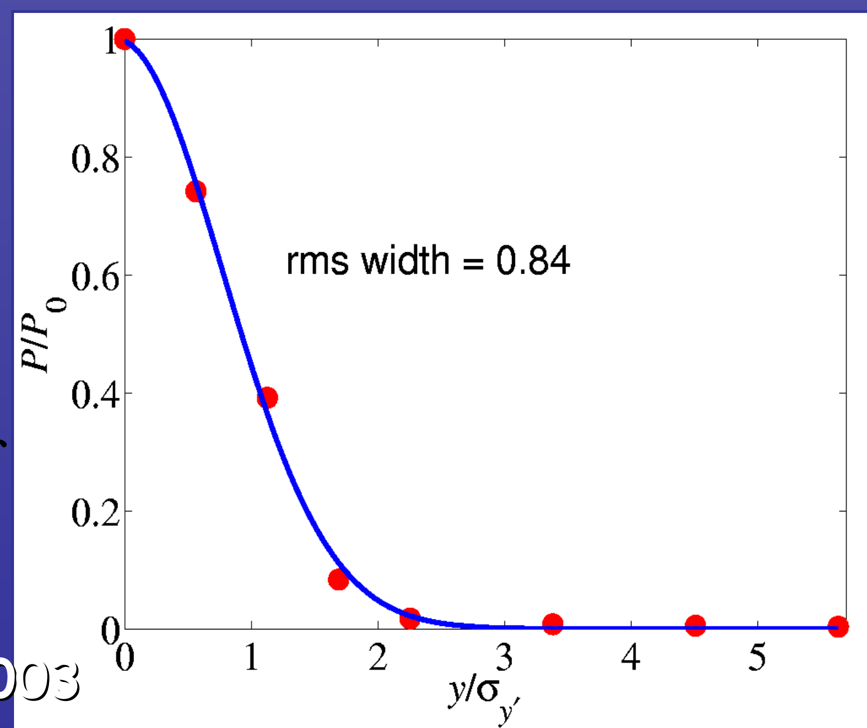
Spatially Chirped Bunch

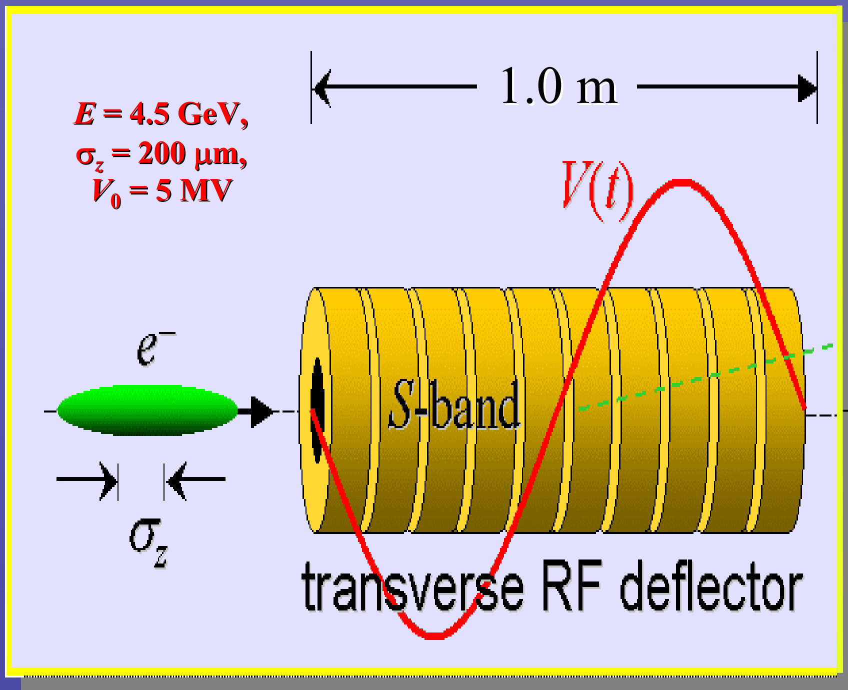
P. Emma & Z. Huang, 2003 (Mo-P-52)

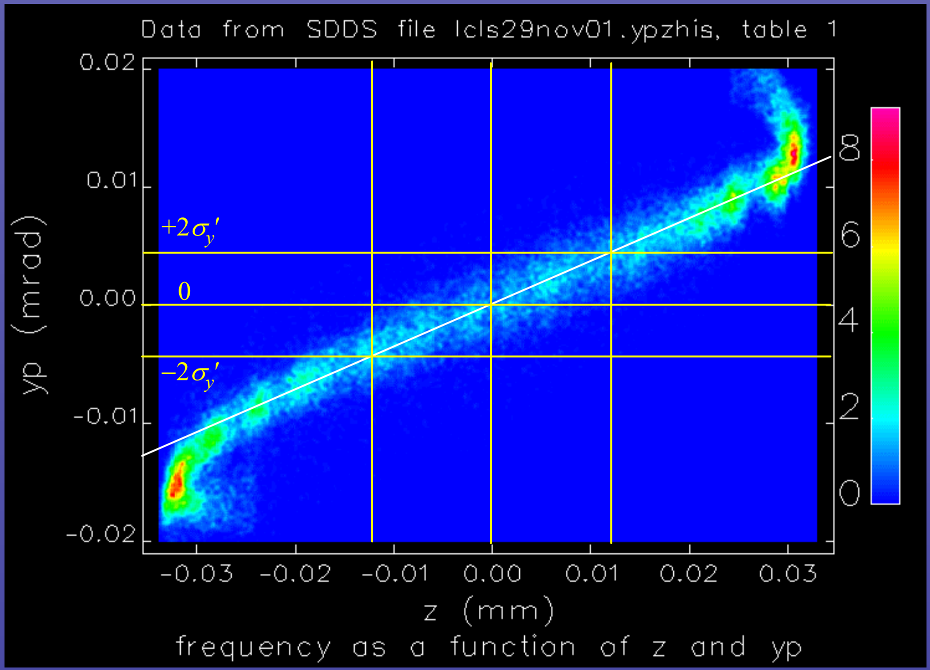


- FEL power vs. y' offset for LCLS

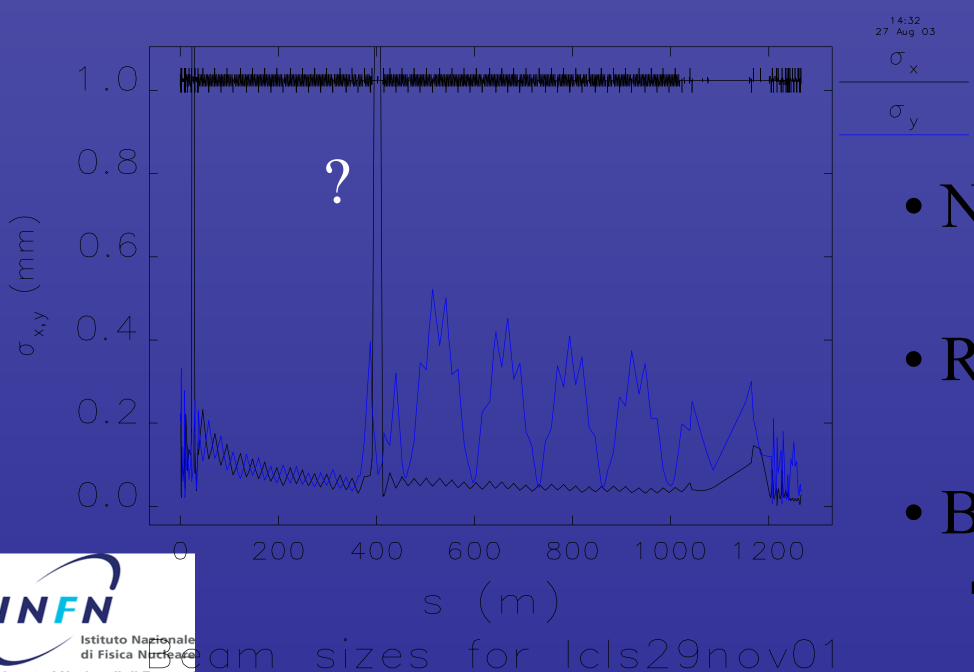
- Gain is suppressed for most parts of the bunch except the on-axis portion







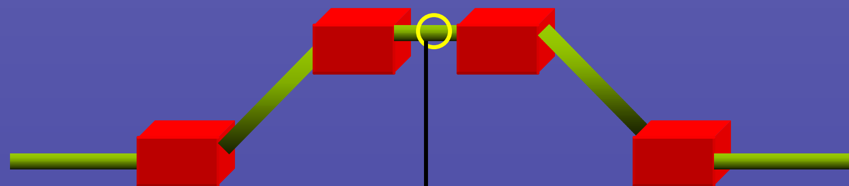
y' vs. z at start of undulator



- No additional hardware for LCLS
- RF deflector before BC2 less jitter
- Beam size < 0.5 mm in linac
  - ➔ FWHM x-ray pulse ~ 30 fs

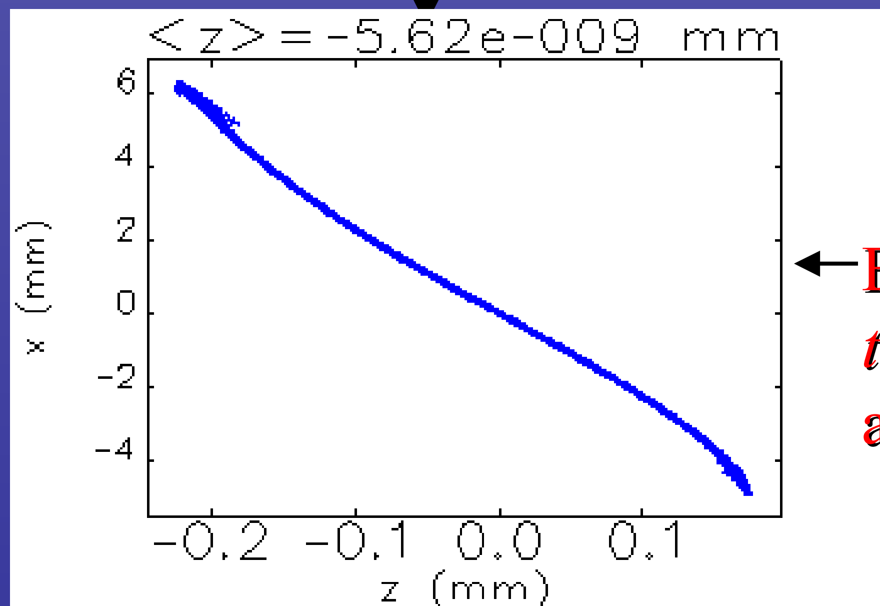
Where else can we access fs time?

Large x-z correlation inside a bunch compressor chicane



LCLS BC2

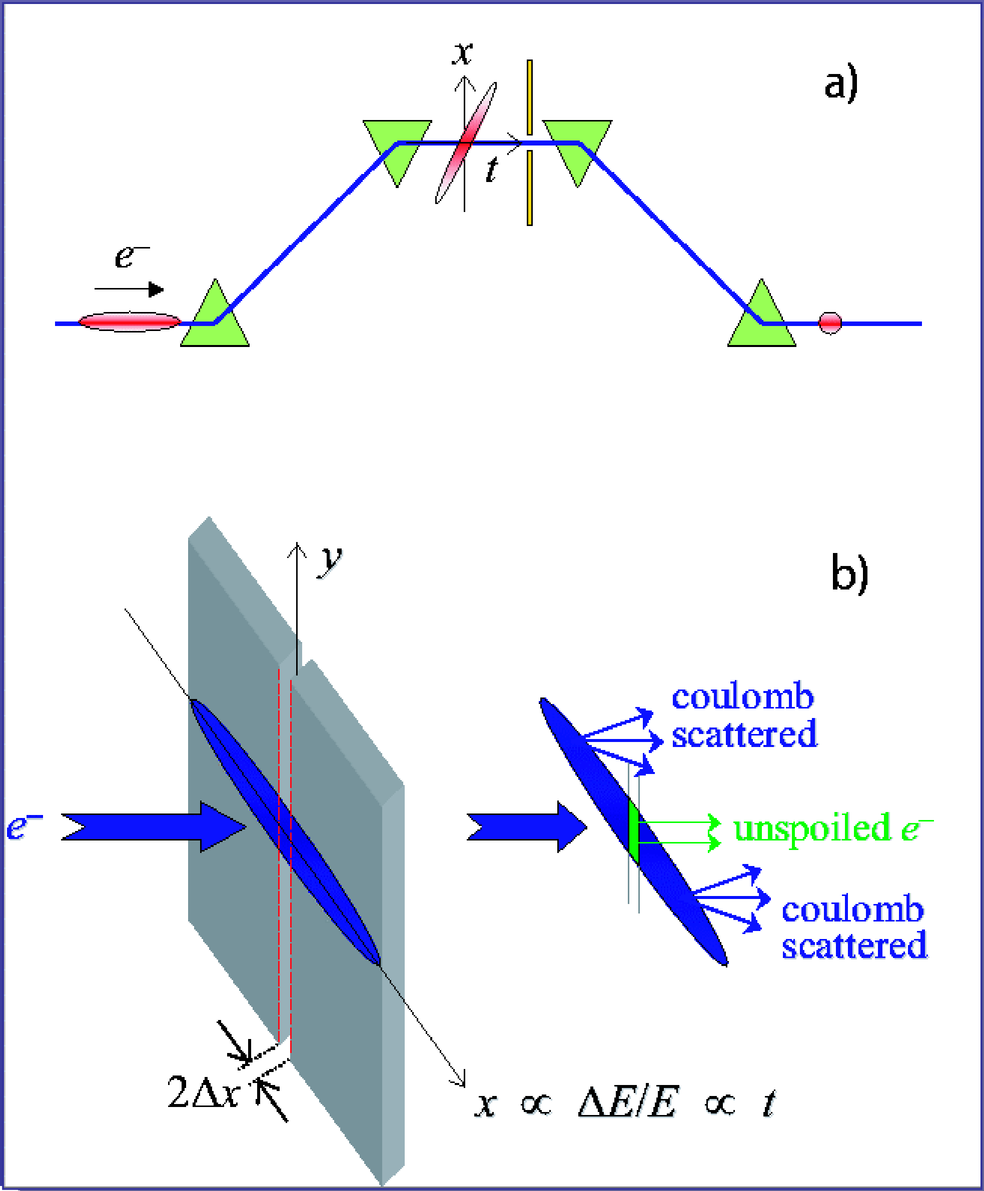
2.6 mm rms

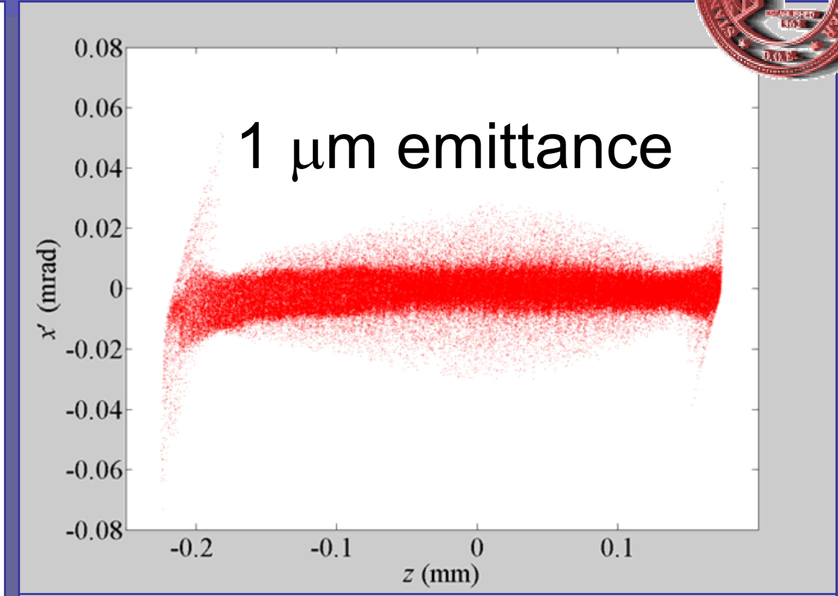


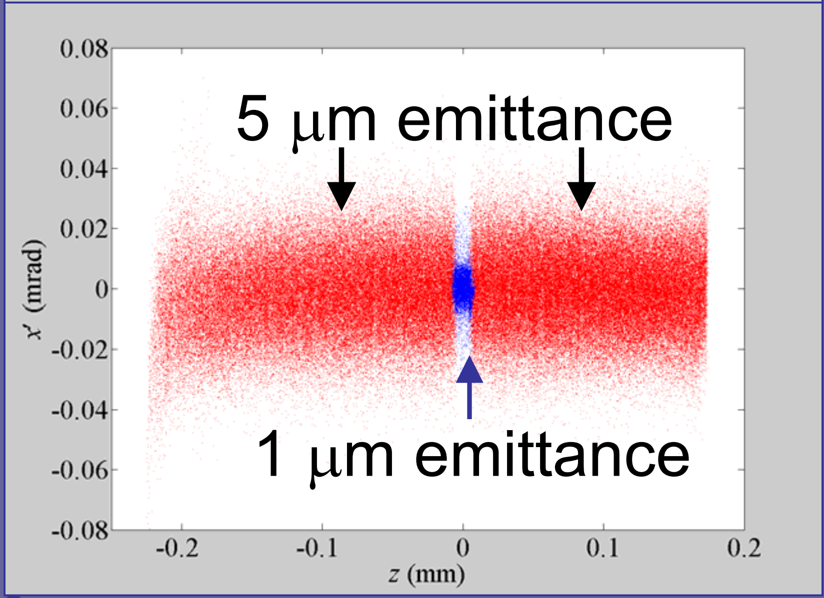
Easy access to *time* coordinate along bunch

0.1 mm rms

Slotted-spoiler Scheme

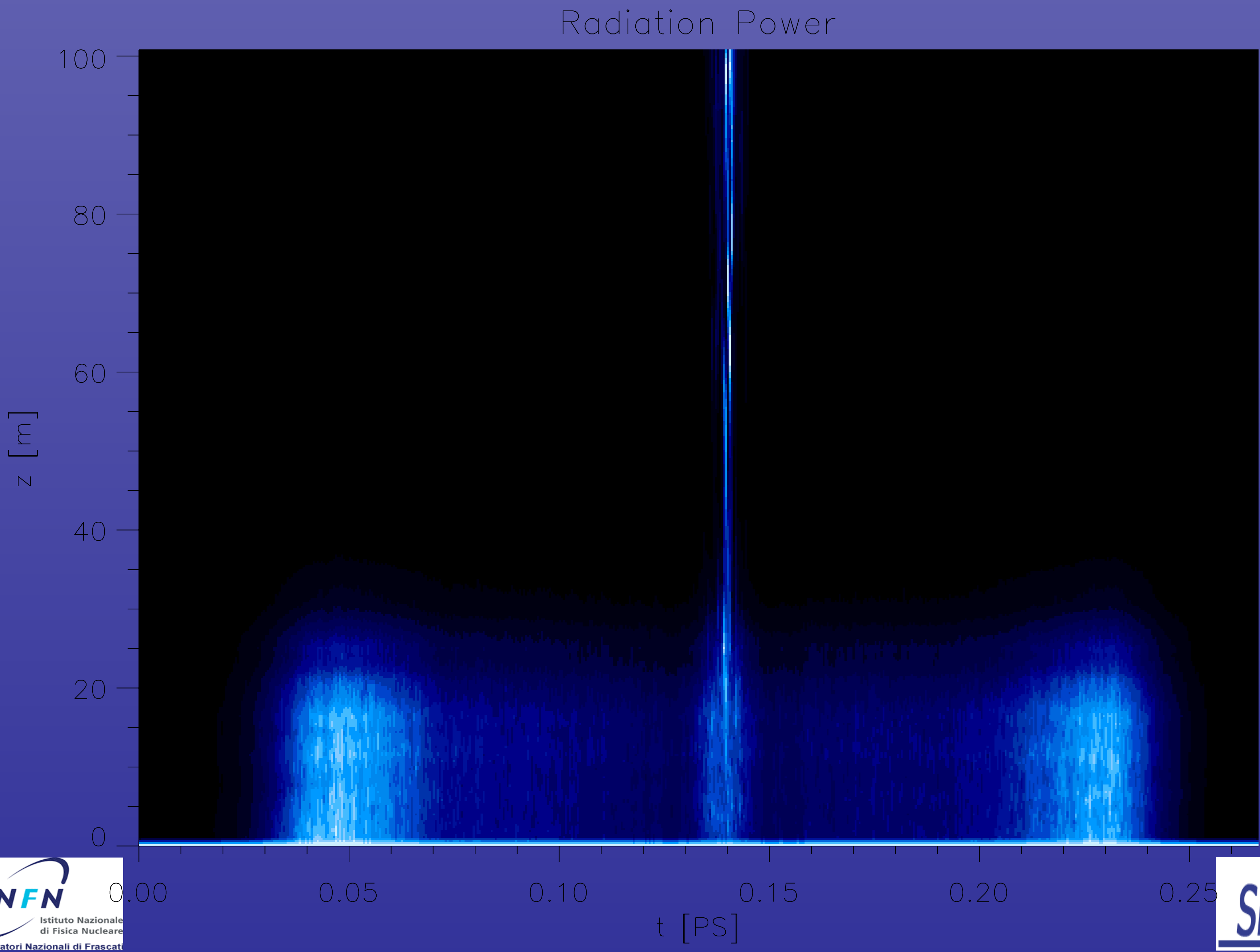






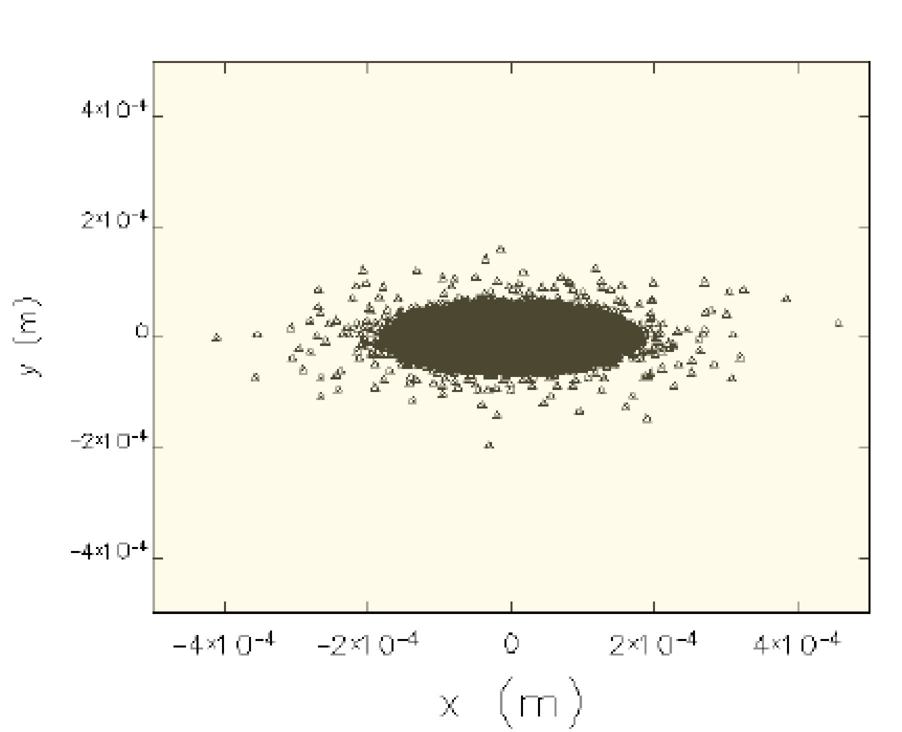
P. Emma et al. submitted to PRL, 2003 (Mo-P-51)

Parmela → *Elegant* → *Genesis* Simulation, including foil-wake, scattering and CSR

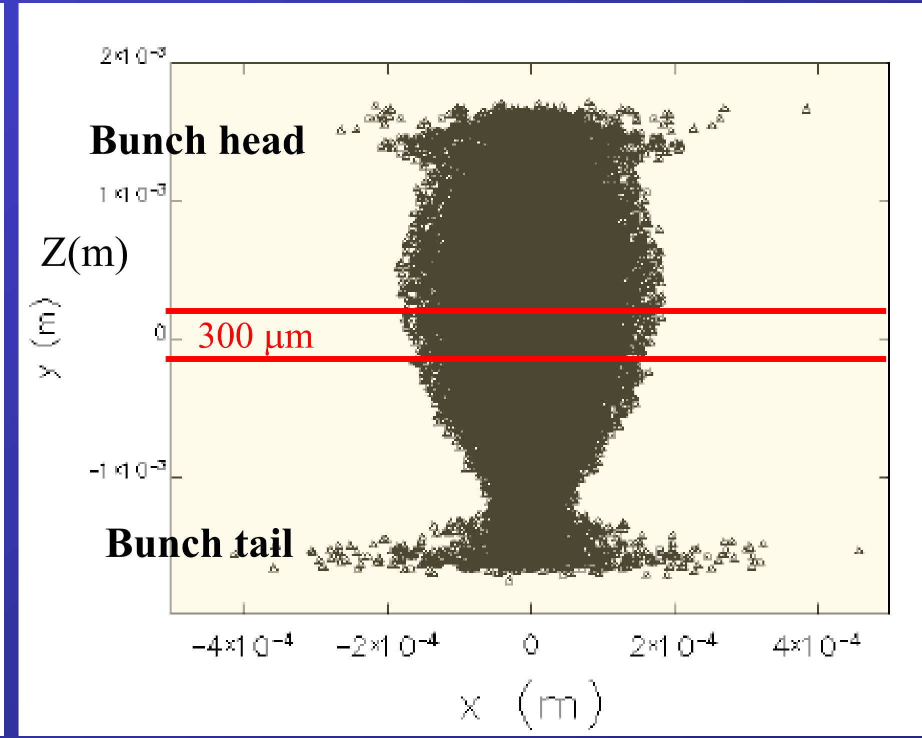


Slice selection @ SPARC using a slit and RF Deflector, with and without clipping

Bunch transverse distribution* at the screen location F0

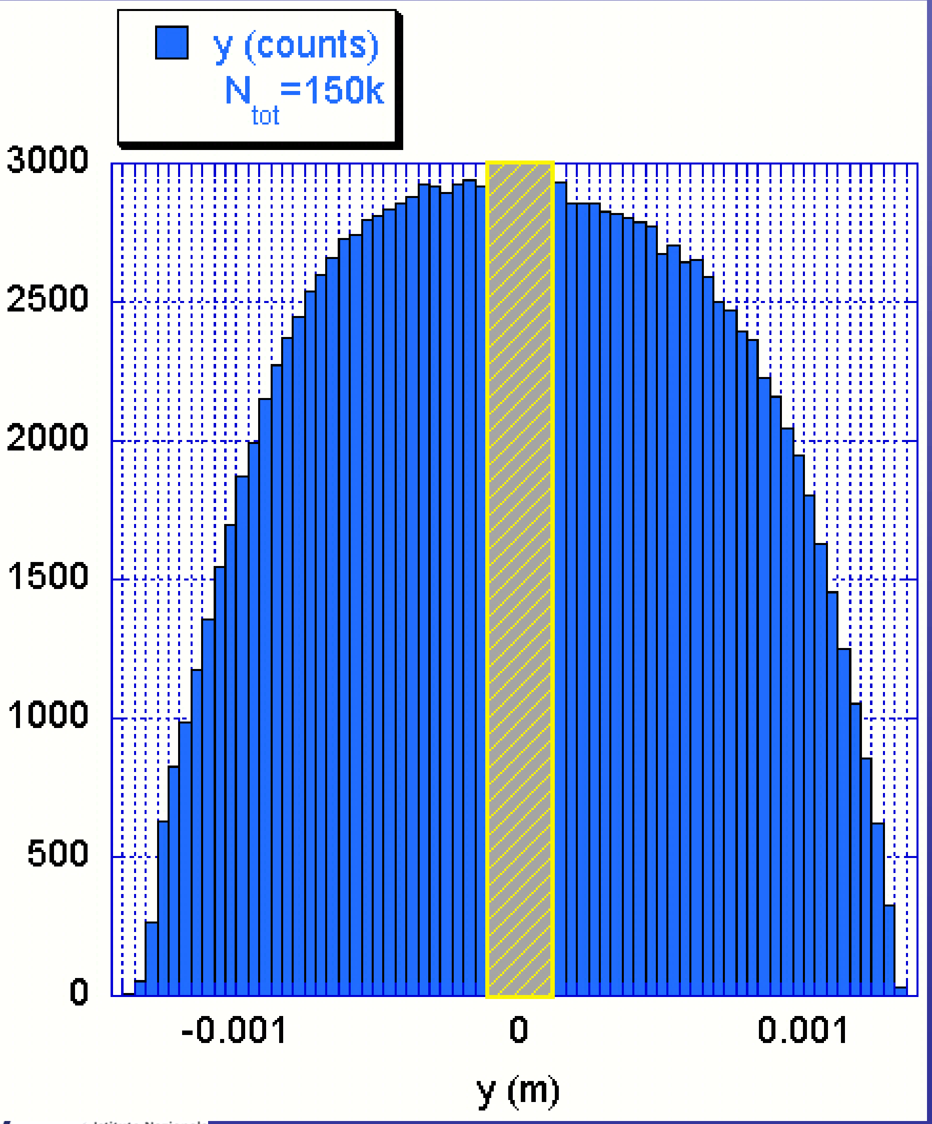


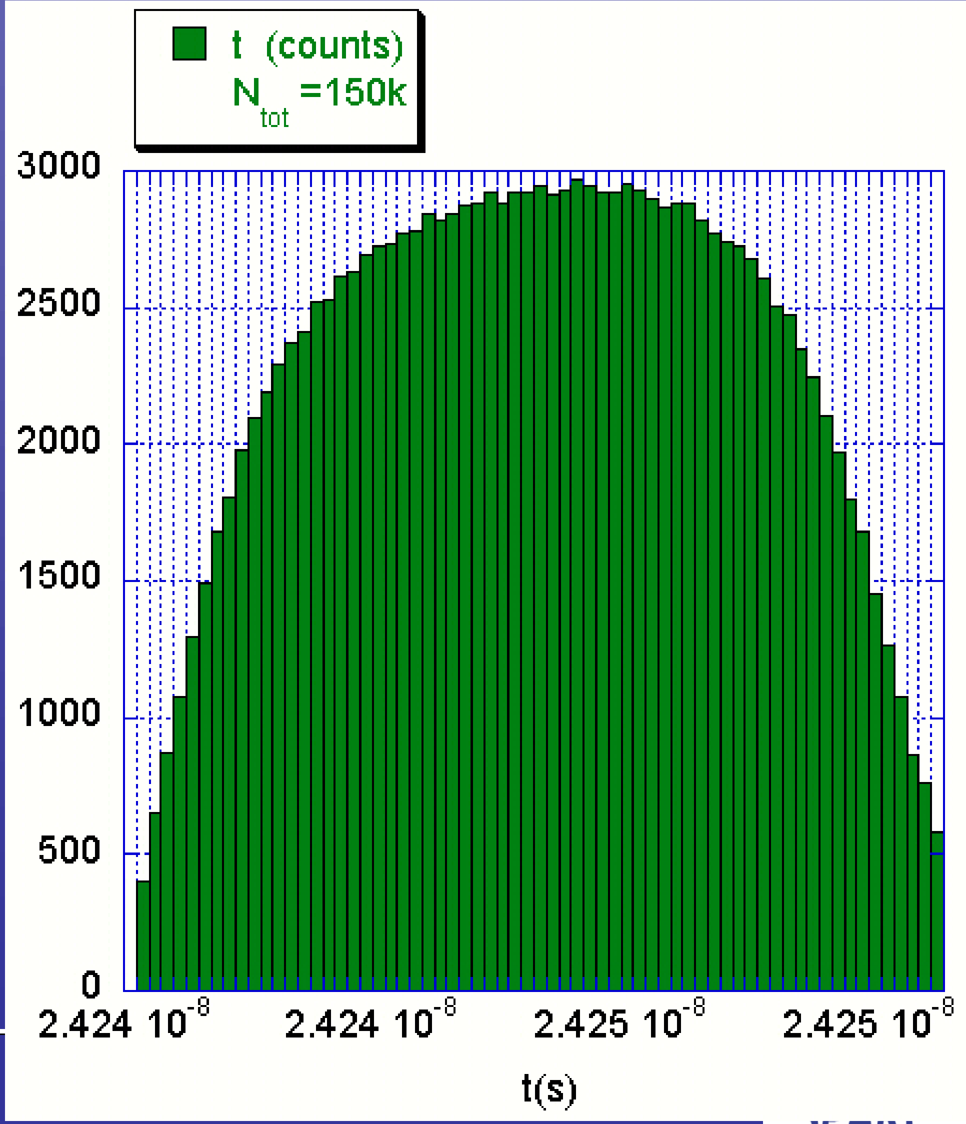
RFD OFF



RFD ON ($V_\perp$ = 1 MV)

Slice selection @ SPARC using a slit and RF Deflector, with and without clipping

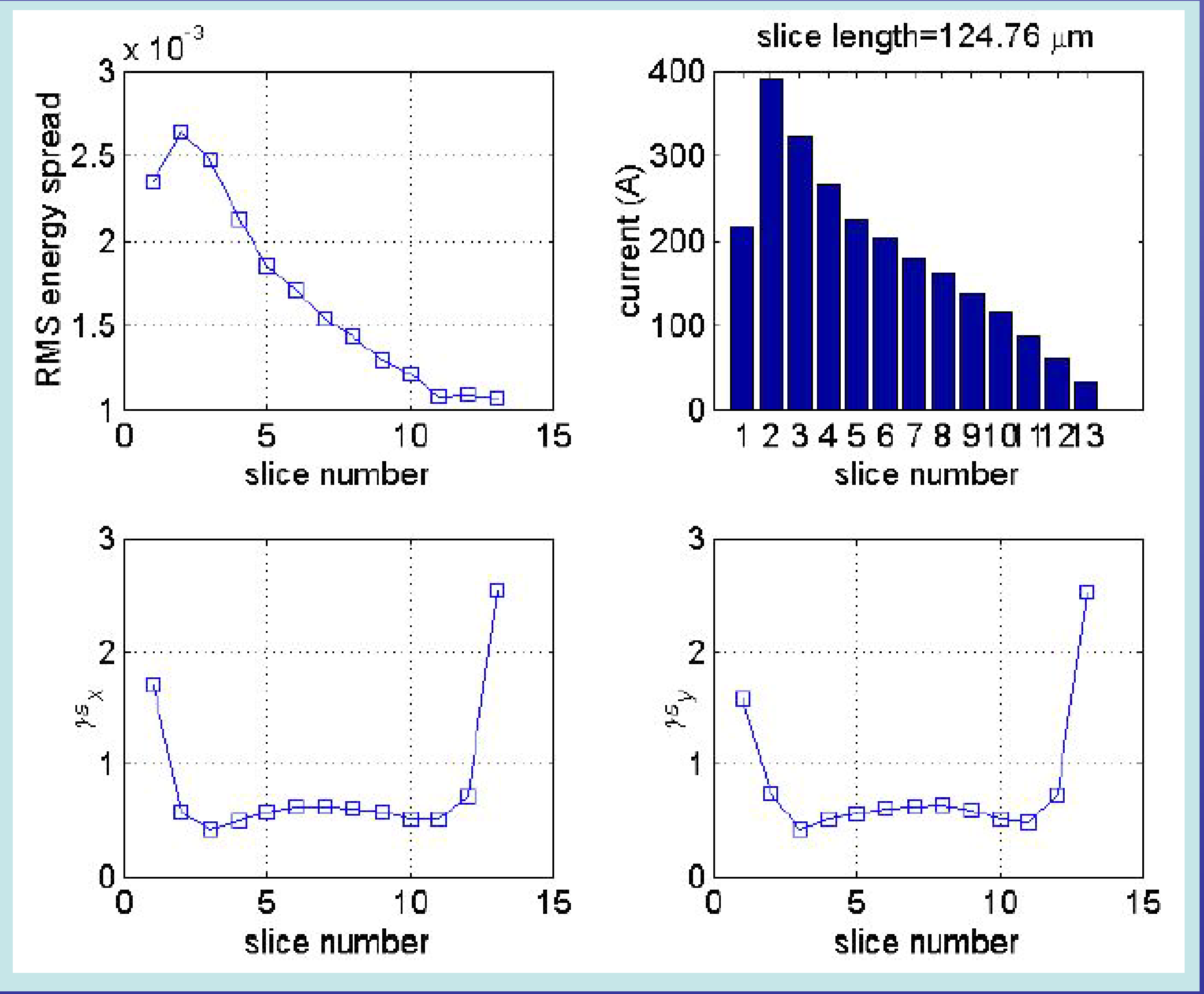




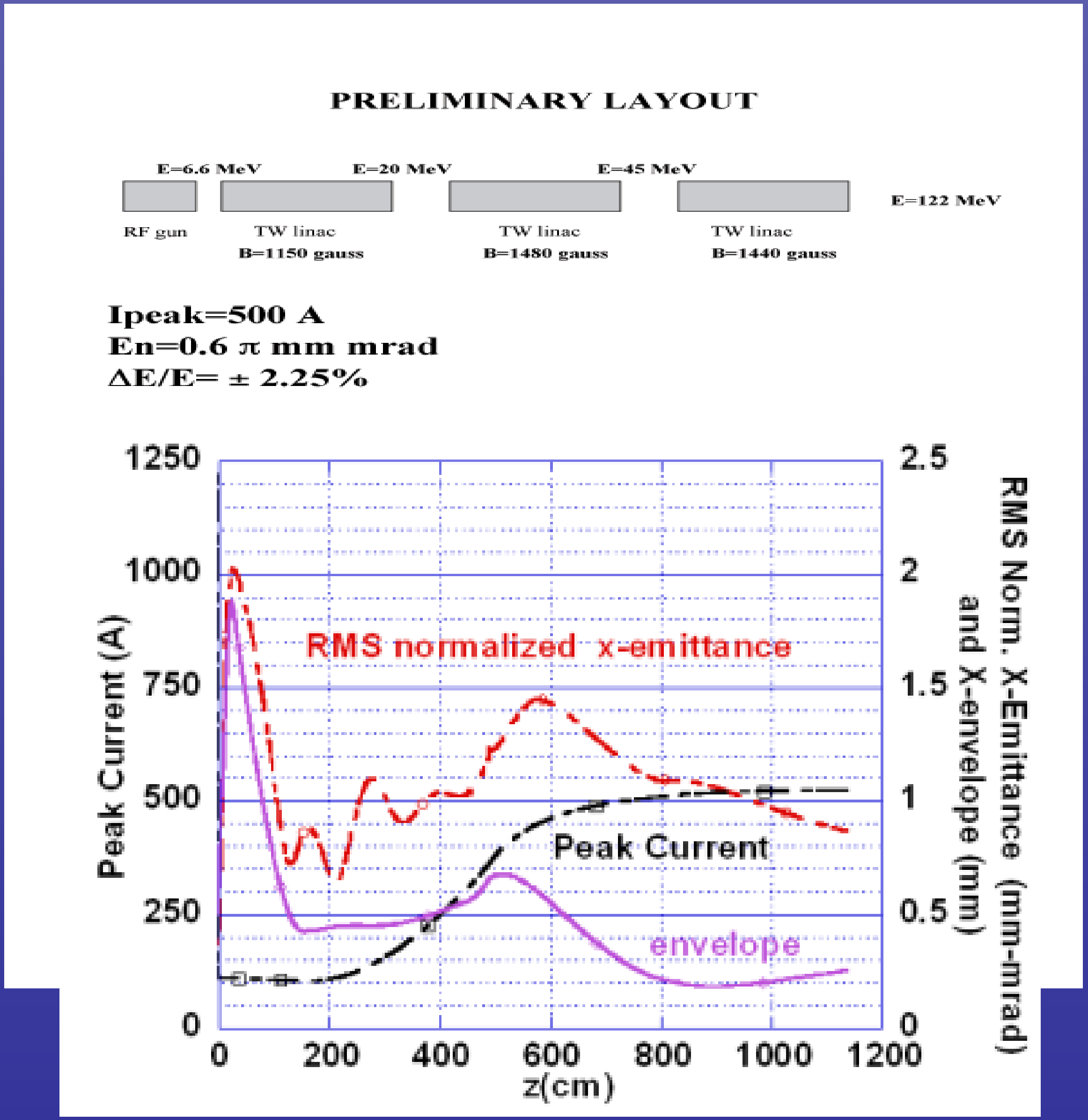
Slice selection using velocity bunching

The longitudinal phase space rotation applied by velocity bunching typically produces a current spike when the process approches full compression

Weak velocity bunching



Strong velocity bunching



In Perspective…

SPARC is well suited to make first (innovative) experiments to test, in a scaled down system, newly conceived modes of operation of X-ray FEL's

Competitors: BNL-DUV (higher beam emittances), TTF-FEL (?)

SPARC-MI 2003 Activity

1) DAZZLER Acquired and ready for tests

2) Software for Laser Pulse Shaping Developped and Tested @ UCLA and Elettra (p.o. for LCM ready)

3) 3 Cell Model for RF Compressor built and characterized (design for 9 Cell ready)

4) RETAR code tested

FUNDIN G REQUESTS for SPARC-Milano 2004 Activities

F.Alessandria, A. Ba cci, I. Boscolo, F.Broggi, S.Cialdi, C.DeMartinis, D.Giove, C. Maroli, V. Petrillo, M.Rome', L. Serafini
INFN-Milano and LASA (4.15 FTE)

1) LASER-CAT

Tets on DA ZZLER and LCM Phase Mask

2) COMPR-RF (Phase2)

Construction of a 9 cell prototype for RF compressor

3) THEORY

Upgrade of RETAR for modeling CTR effects, Study of Ve locity Bunching (full optimization for SPARC) and comparison to ongoing experiments @ LLNL, NERL and BNL

2003 FUND INGS

	INT	EST	CONS	INV	TECHN. (my)
LASER-CAT			**14***	**72**	0.25 [1)]
COMPR-RF			**3**		0.25 [a)]
THEORY			**1**	**3**	0
Total	25(**19**)	25(**21**)	18 (**18**)	110 (**75**)	0.5

TOTAL 178 + 31 k€ research contract (2 yea rs) *Spent as of today

2004 REQUESTS

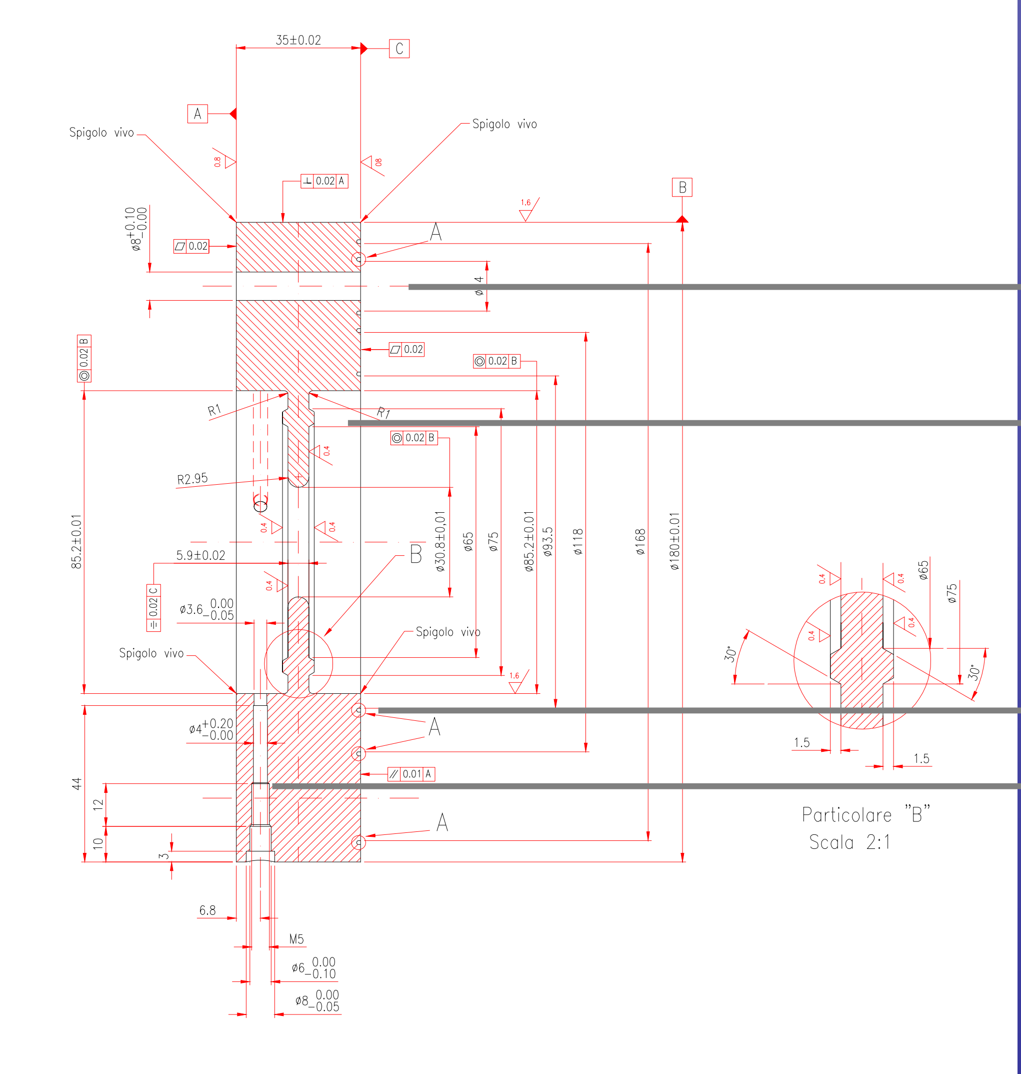
	INT	EST	CONS	INV	TECHN. (my)
LASER-CAT			10	10	1.25 [2)]
COMPR-RF			15	46	1.5 [b)]
THEORY			2	5	0
Total	30+8 (TS +LNF)	25	27	61	2.75

TOTAL 151

Laser-cat : autocorrelator (10 k€), 2 months TS+LNF

Compr-rf : coup ler 10 k€ , spectrum analyzer 11 k€ , 9 cell coppe r model 20 k€

Mechanical Design of the slow-wave high group velocity RF cell for RF Compressor



Cooling water hose

Tuning-ring

Brazing cave

tuning-rod hole

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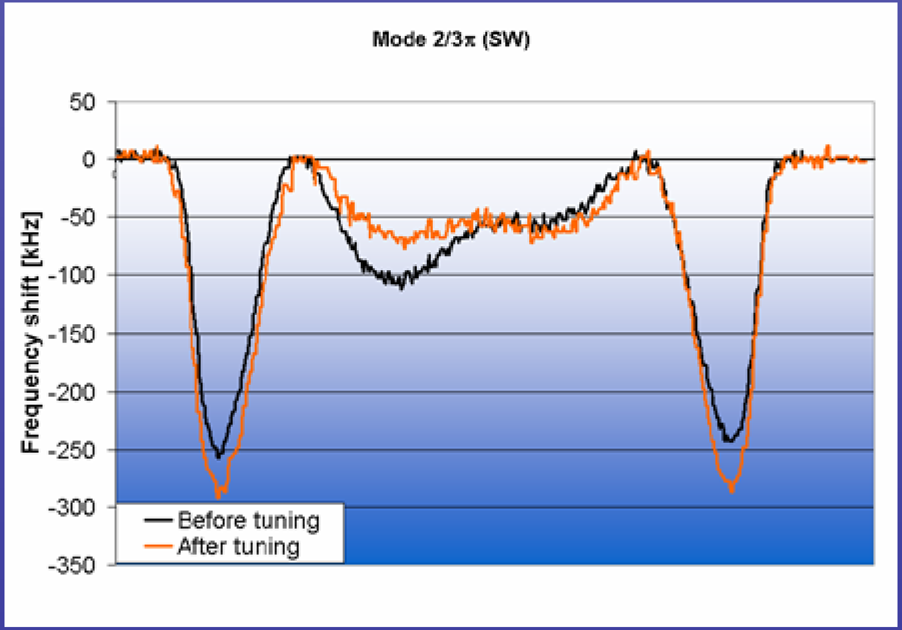
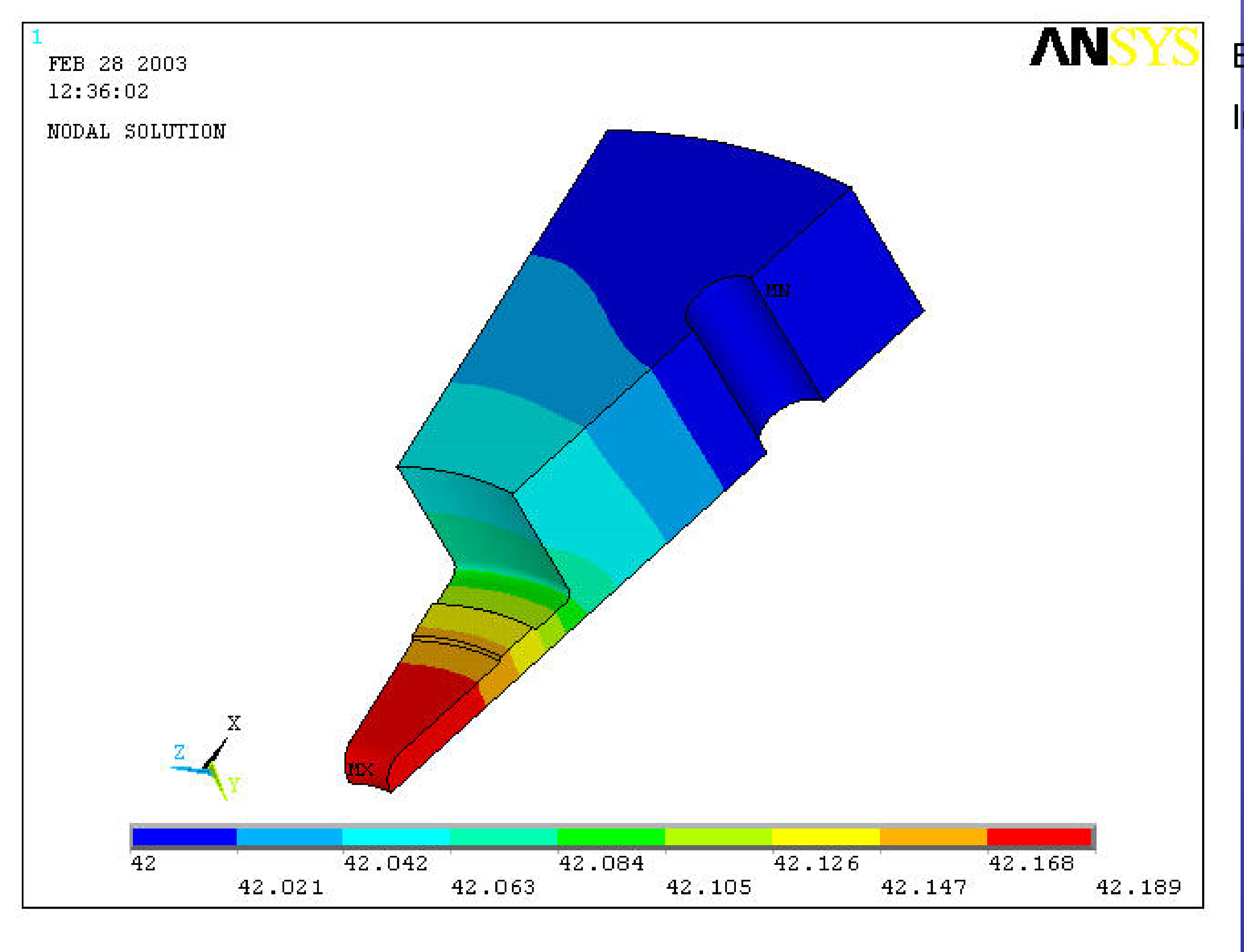
SPARC

Aluminum Model (3 cells) Built and Measured



Thermal Analysis



E_0=20MV/m

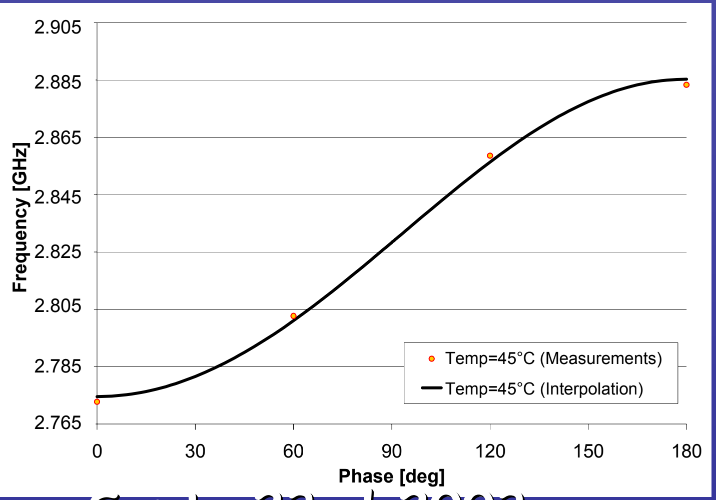
Impulso: 5μs a 10 Hz

Misure termiche

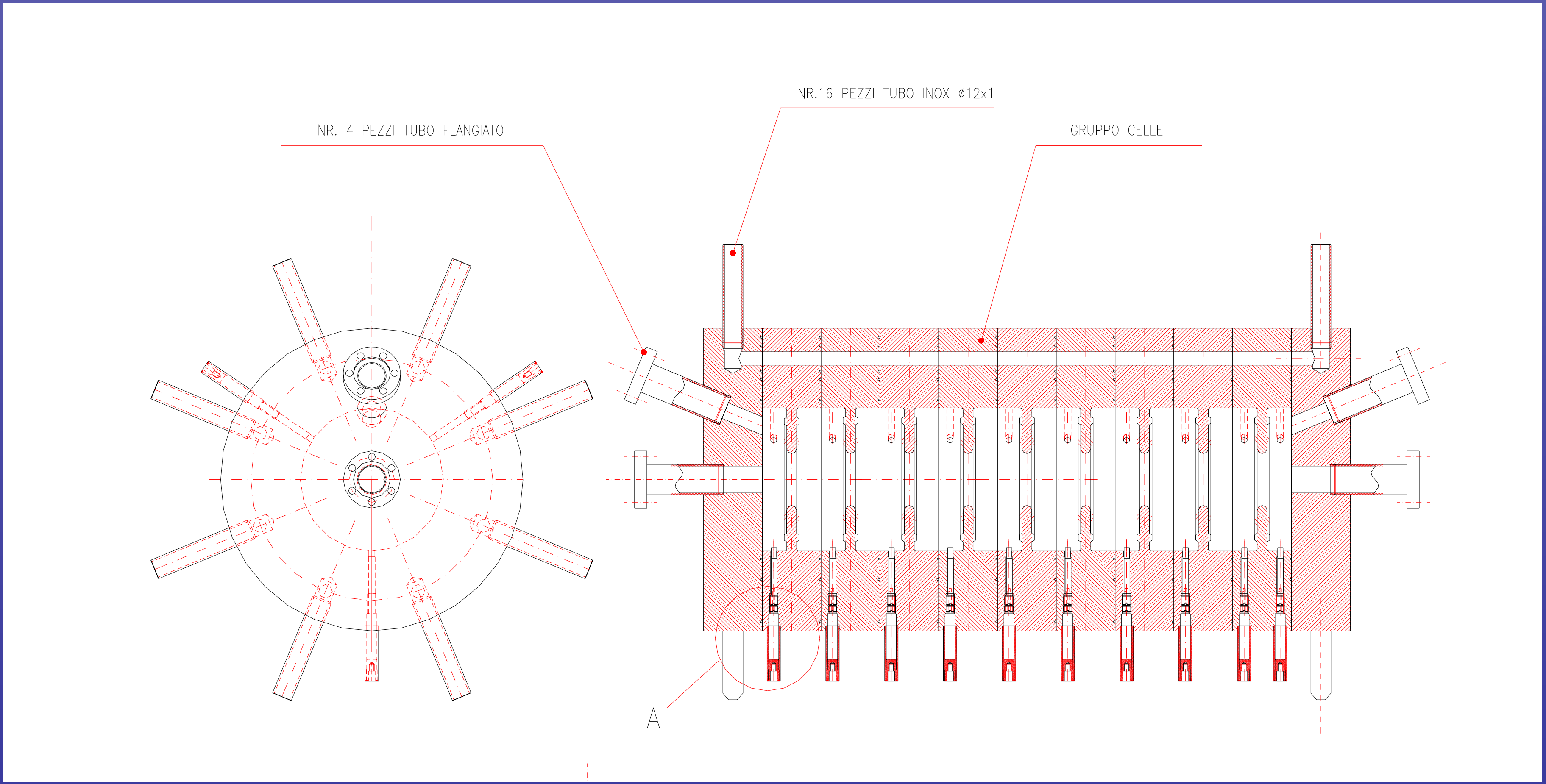
Il forno (per piccole strutture) termostatato con fluttuazioni di 0.1°C ha consentito la caratterizzazione del modello in alluminio.
In particolare :

•misura preliminare della sensibilità termica della velocità di fase nell'intervallo 25°C-45°C

I risultati delle misure sono in buon accordo con i valori attesi (errore massimo entro il 15%).



9 Cell Model with 3% group velocity (0.1 °C stability)



- Preliminary measurements showed that is possible to stabilize to 0.3 °C a short model (3 cells) with 3% group velocity (corresponds to 0.1% stability in phase velocity)
- Build and Measure a 6% group velocity 9 Cell Model (with couplers) to improve temperature stability (hence phase velocity control) and/or relaxing demands
- Temperature stability tests on the 3 m SLAC section presently at LASA (under vacuum, flanges applied) on loan from UCLA

2003	Travels abroad
S. Cialdi @ UCLA	7
LS @ DESY for JRP	1
IB @ CERN for JRP	1
CONFERENCES: PAC, FEL, ORION	12
Total	**21**