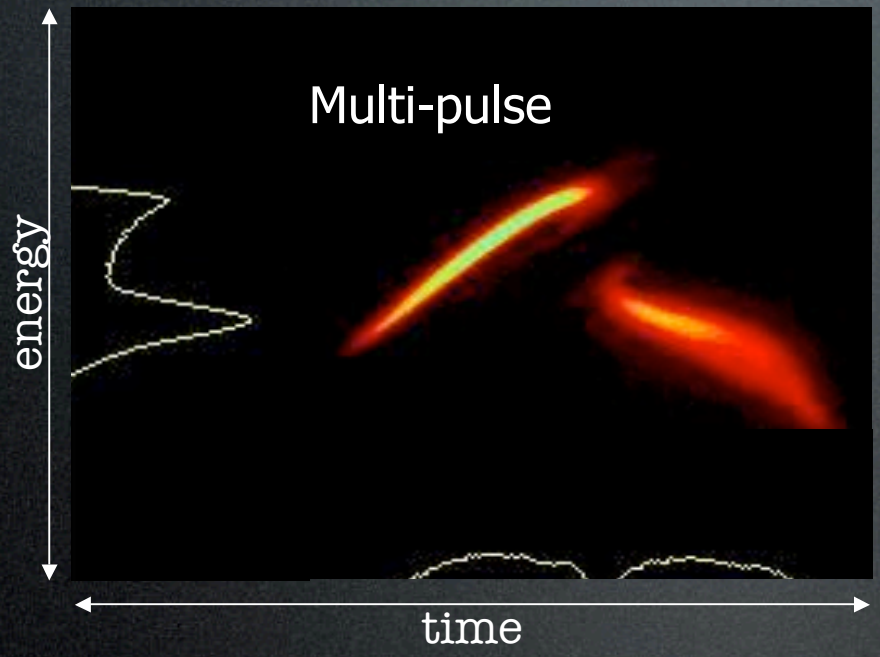
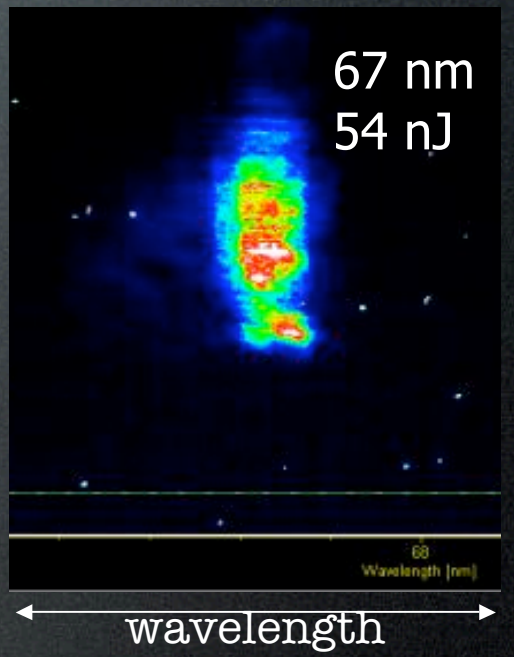
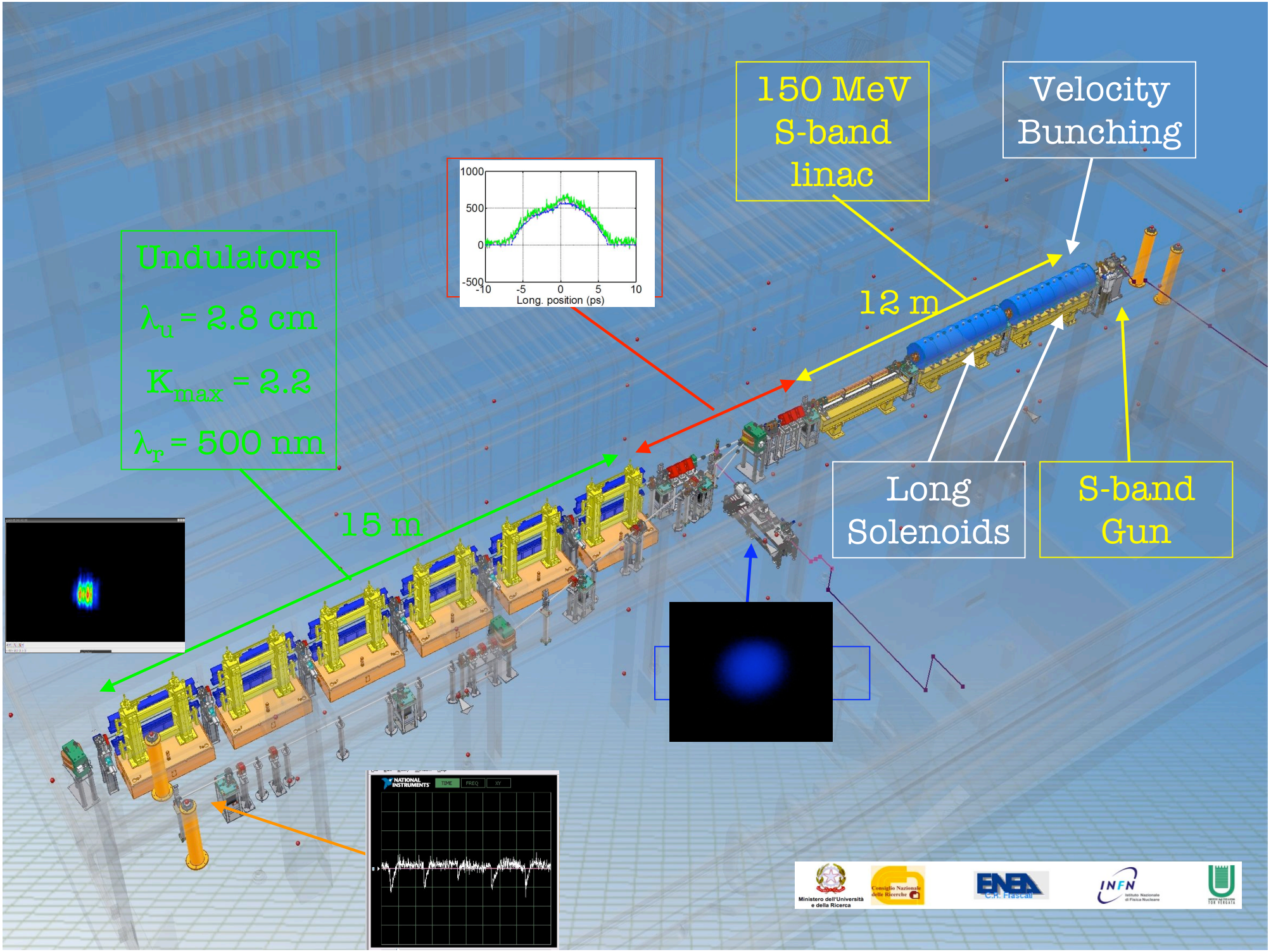
Recent results at SPARC

Massimo Ferrario
on behalf of the SPARC team



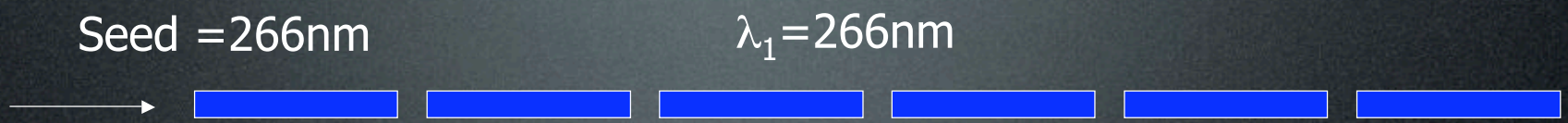


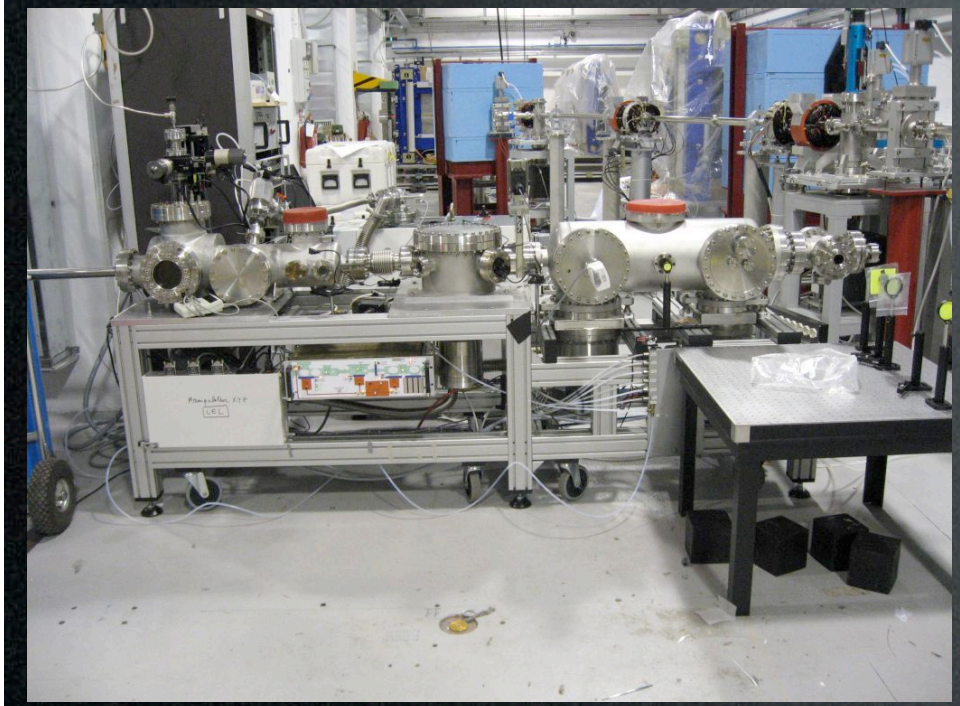
40th LNF Scientific Committee Meeting - June 24, 2010

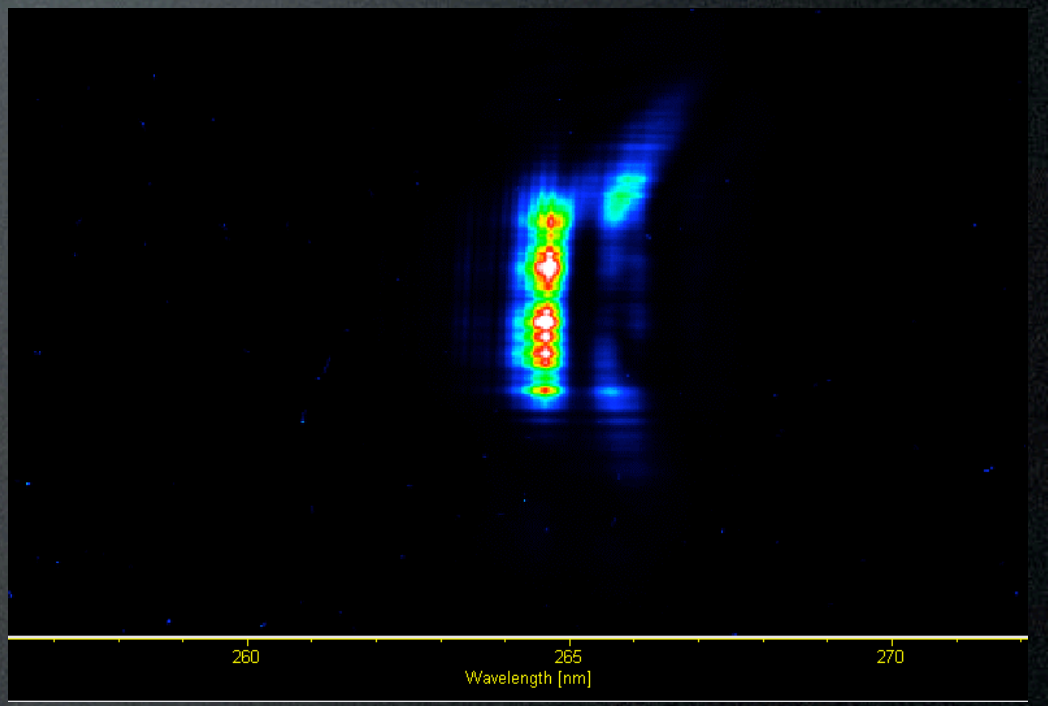

150 MeV
S-band
linac
Velocity
Bunching
Undulators
λ_u = 2.8 cm
K_{max} = 2.2
λ_r = 500 nm
12 m
15 m
Long
Solenoids
S-band
Gun
1000
500
0
-500
-10
-5
0
5
10
Long. position (ps)
NATIONAL INSTRUMENTS
TIME
FREQ
XY
Ministero dell'Università e della Ricerca
Consiglio Nazionale delle Ricerche
ENEA
C.R. Frascati
INFN
Istituto Nazionale di Fisica Nucleare

SEEDED FEL

Seeding at 266 nm from Ar gas, 50 nJ
6 undulators on resonance at 266 nm

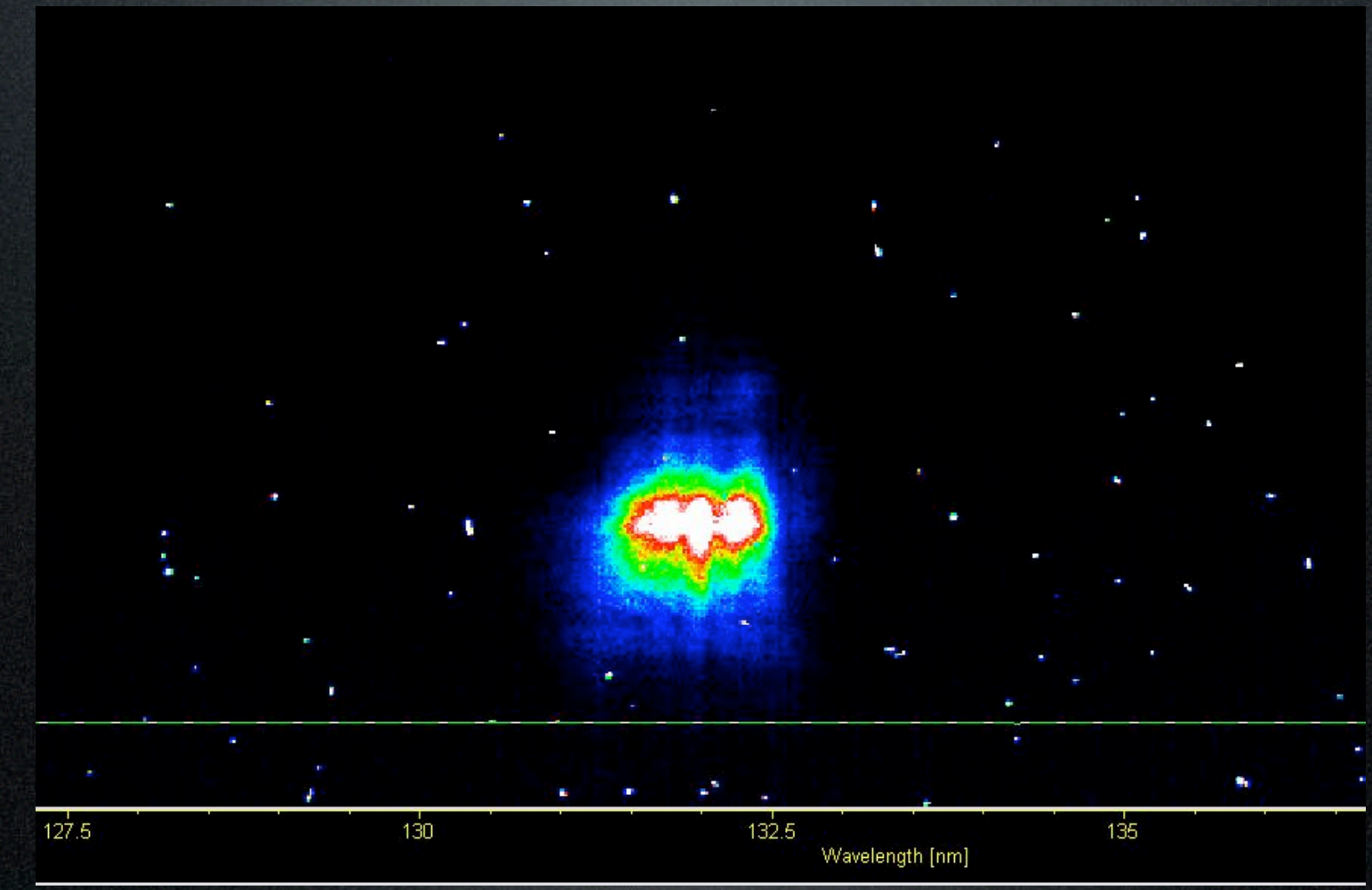






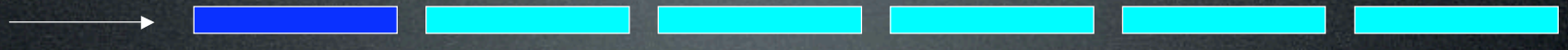
FEL Cascate: 133 nm afterburner

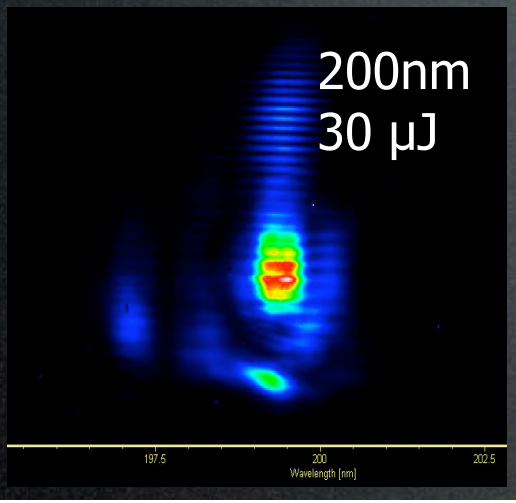
Seed =266nm λ_1=266nm λ_2= 133nm

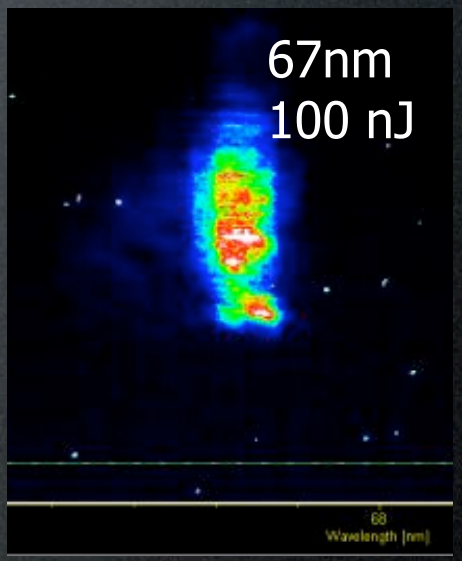


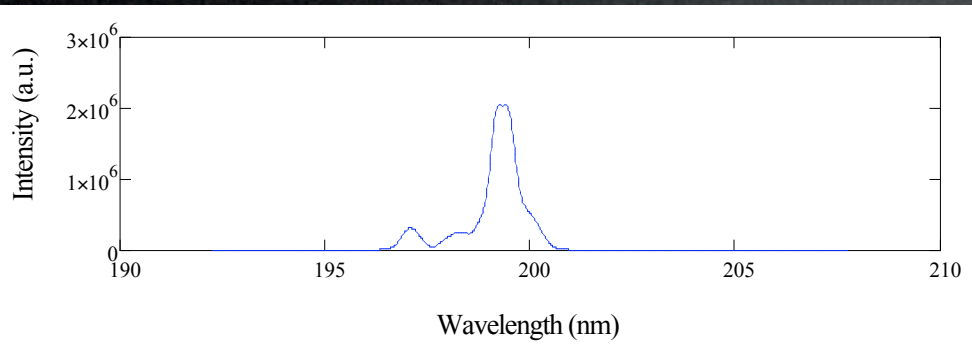
Seeding at 400 nm from Crystal, 2 μJ
5 undulators on resonance at 200 nm

Seed =400nm λ_1=400nm λ_2= 200nm









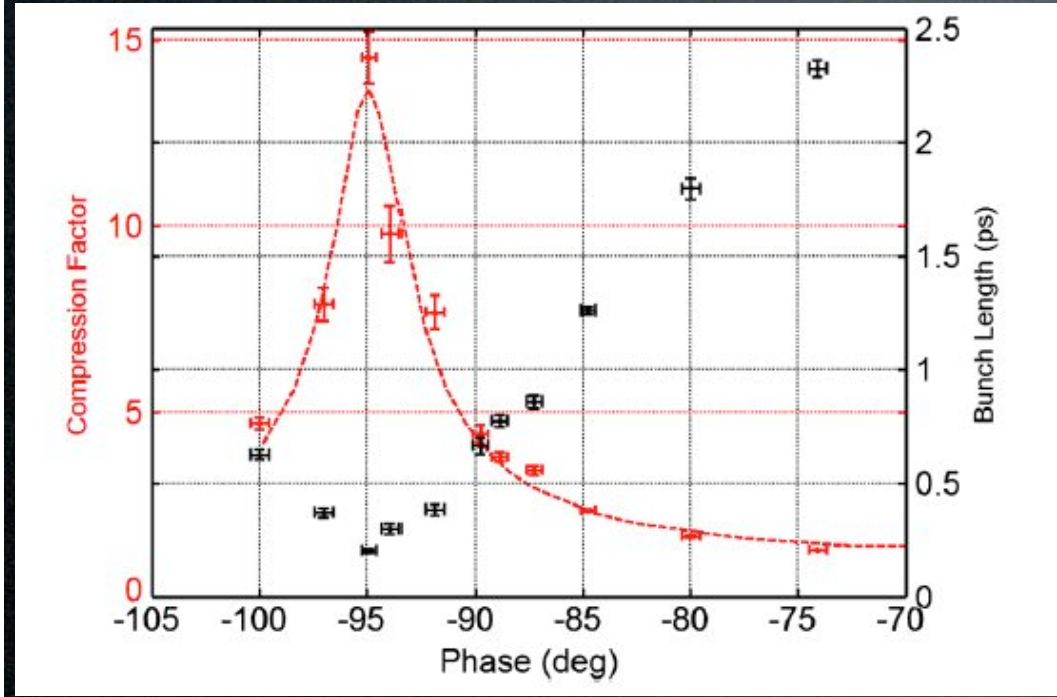
Third Harmonic

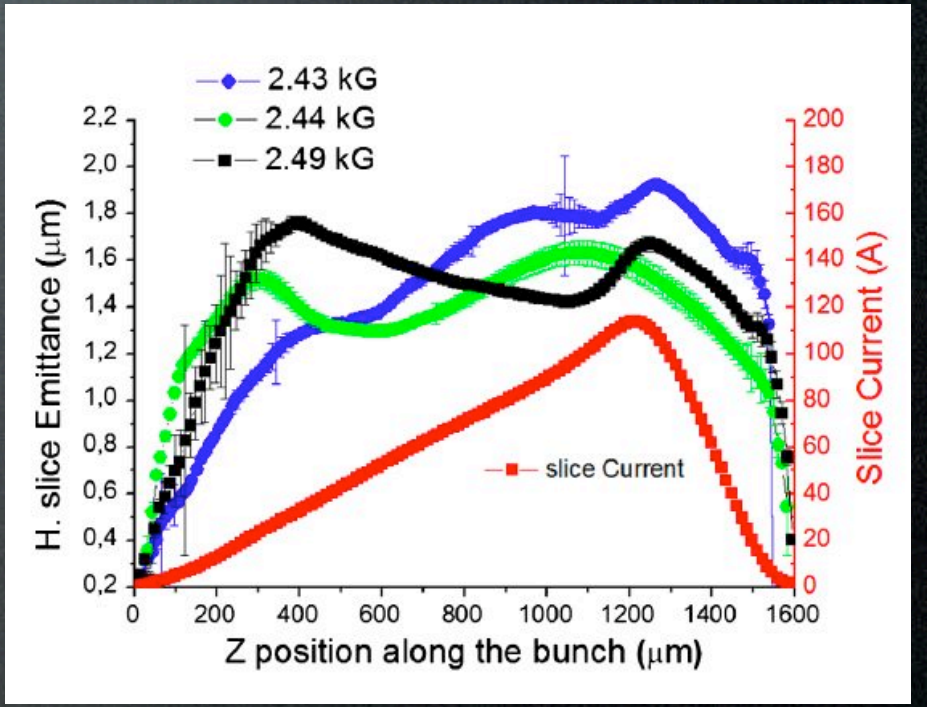
Experiments with Velocity Bunching

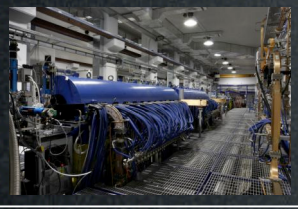
PRL **104,** 054801 (2010) PHYSICAL REVIEW LETTERS week ending 5 FEBRUARY 2010

Experimental Demonstration of Emittance Compensation with Velocity Bunching

M. Ferrario,[1] D. Alesini,[1] A. Bacci,[3] M. Bellaveglia,[1] R. Boni,[1] M. Boscolo,[1] M. Castellano,[1] E. Chiadroni,[1] A. Cianchi,[2] L. Cultrera,[1] G. Di Pirro,[1] L. Ficcadenti,[1] D. Filippetto,[1] V. Fusco,[1] A. Gallo,[1] G. Gatti,[1] L. Giannessi,[4] M. Labat,[4] B. Marchetti,[2] C. Marrelli,[1] M. Migliorati,[1] A. Mostacci,[1] E. Pace,[1] L. Palumbo,[1] M. Quattromini,[4] C. Ronsivalle,[4] A. R. Rossi,[3] J. Rosenzweig,[5] L. Serafini,[3] M. Serluca,[6] B. Spataro,[1] C. Vaccarezza,[1] and C. Vicario[1]







Velocity Bunching

Blow Out

THz Radiation

LWFA_ext

Laser Comb

THz Radiation

PWFA

DWFA

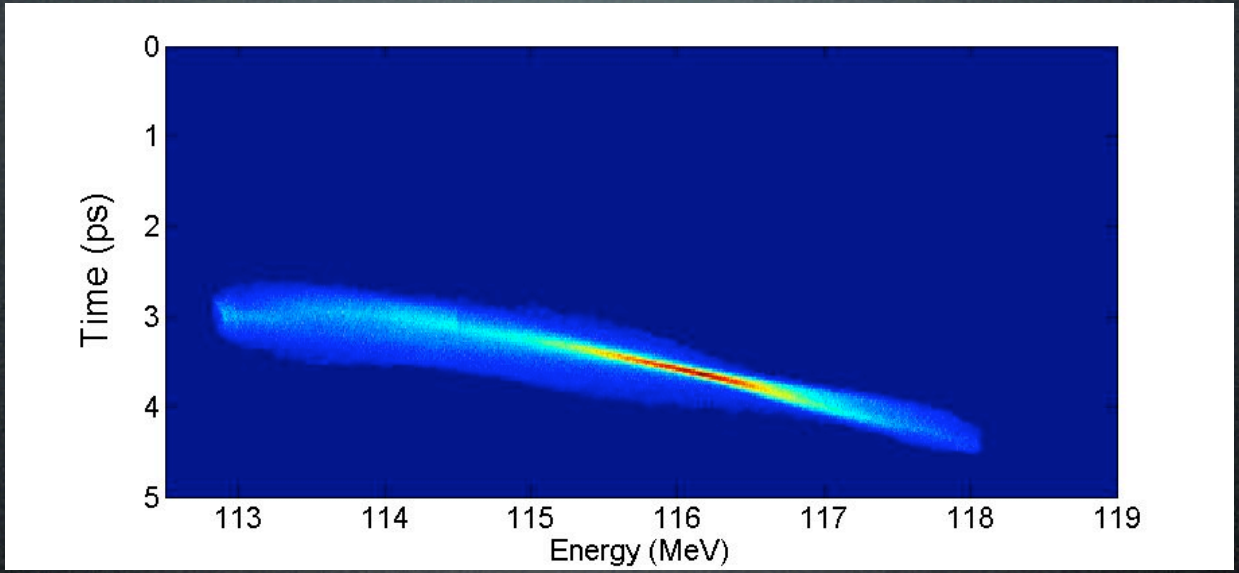
FEL

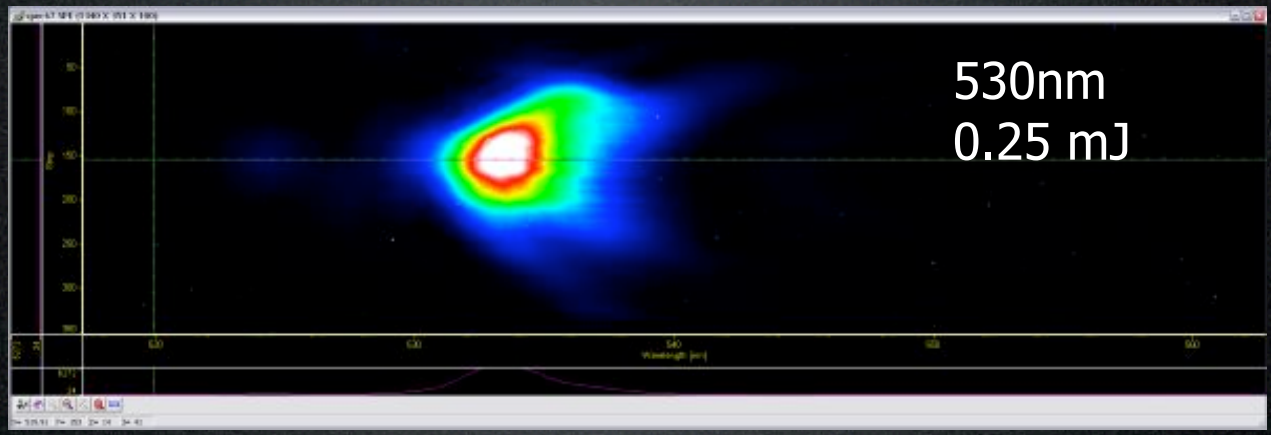
Thomson

FEL Single Spike

FEL
Single Spike

SASE at 530 nm with chirped electron beam and tapered undulators



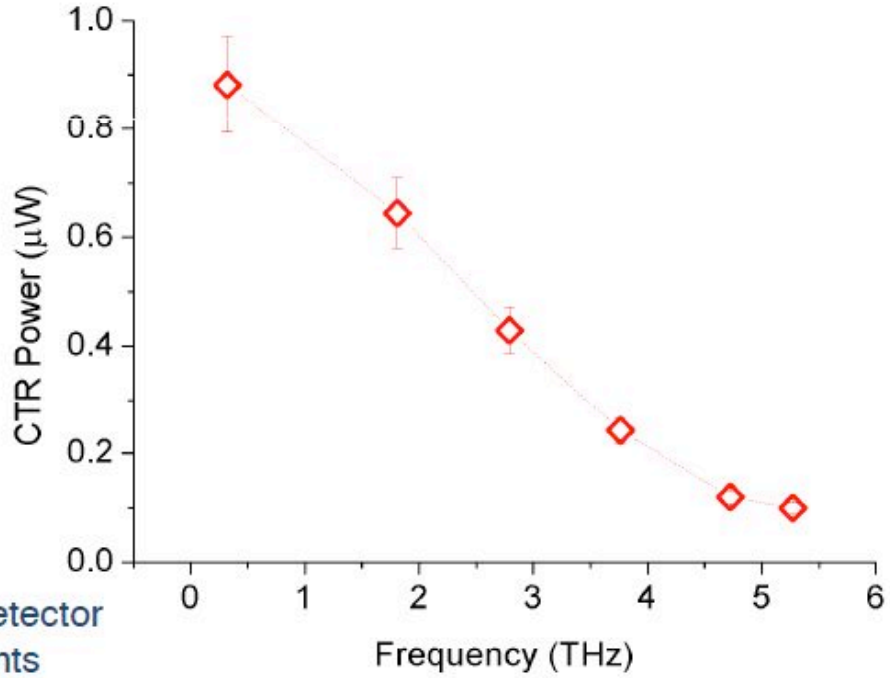


THz radiation

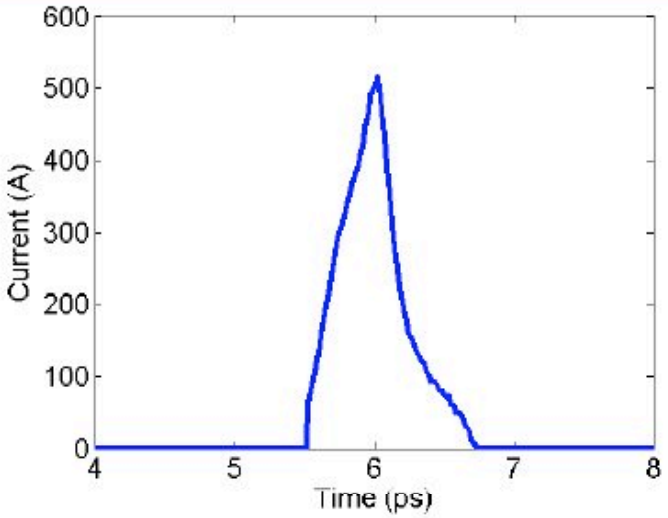
THz RADIATION FROM HBEBs

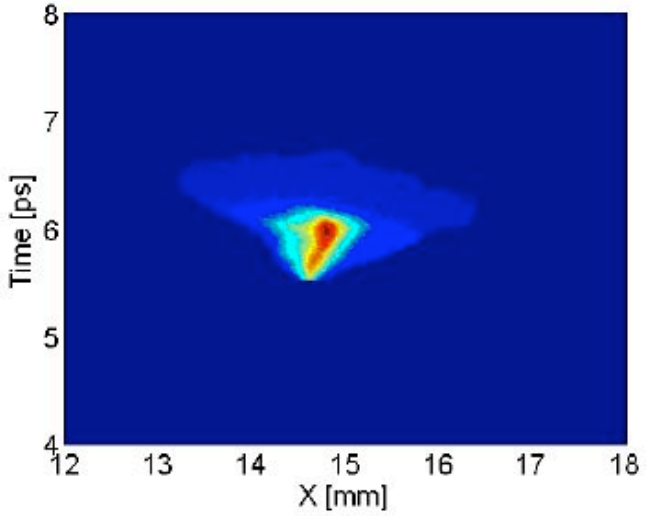
Velocity bunching with compression factor 14 and emittance compensated

Q = 260 pC
σ_t = 260 fs (after compression)
Beam Energy= 100 MeV



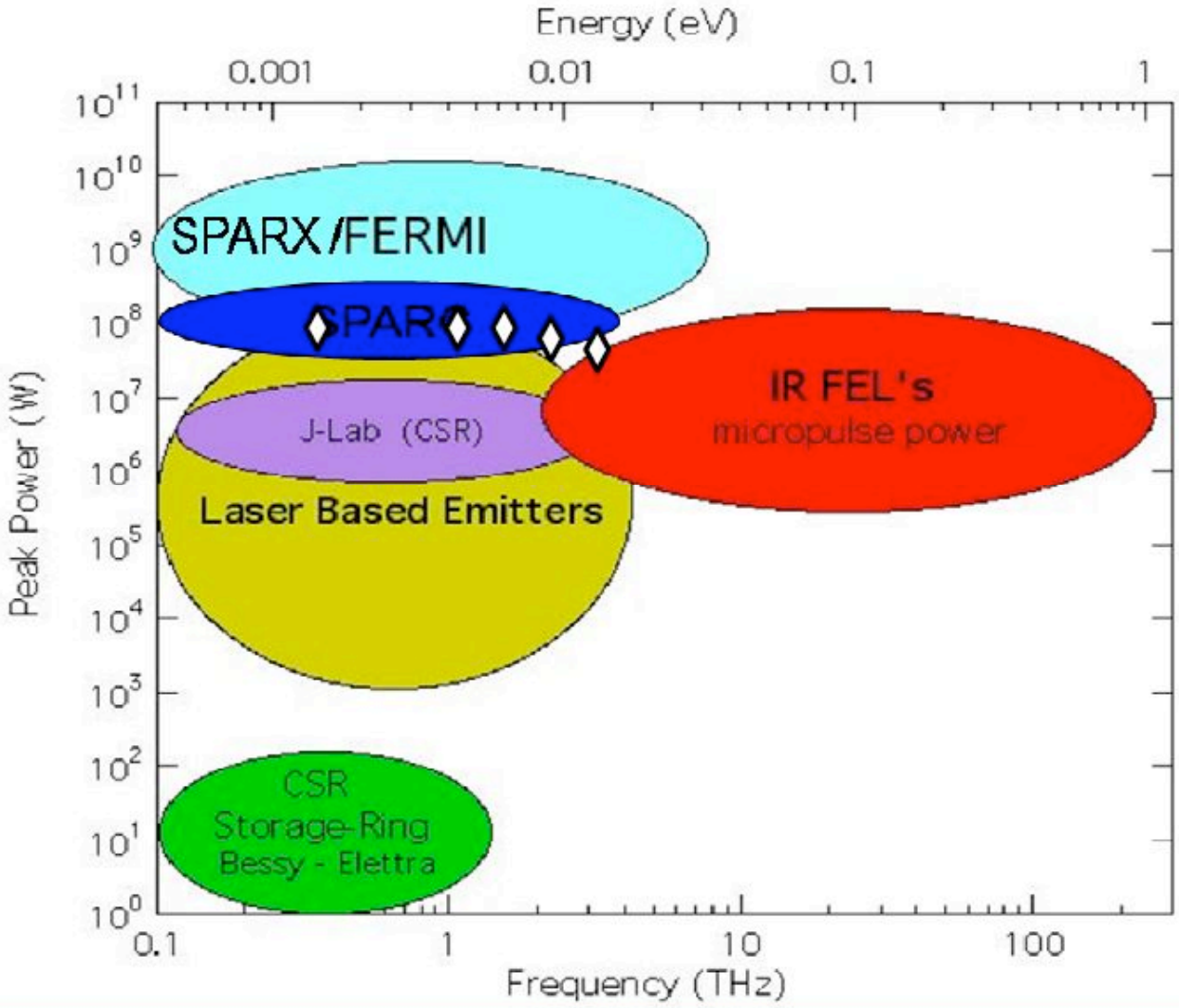
Golay cell detector measurements





Enrica Chiadroni
(INFN/LNF)

PERFORMANCE ACHIEVED



Enrica Chiadroni
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Laser Comb technique

Laser Comb: a train of THz bunches

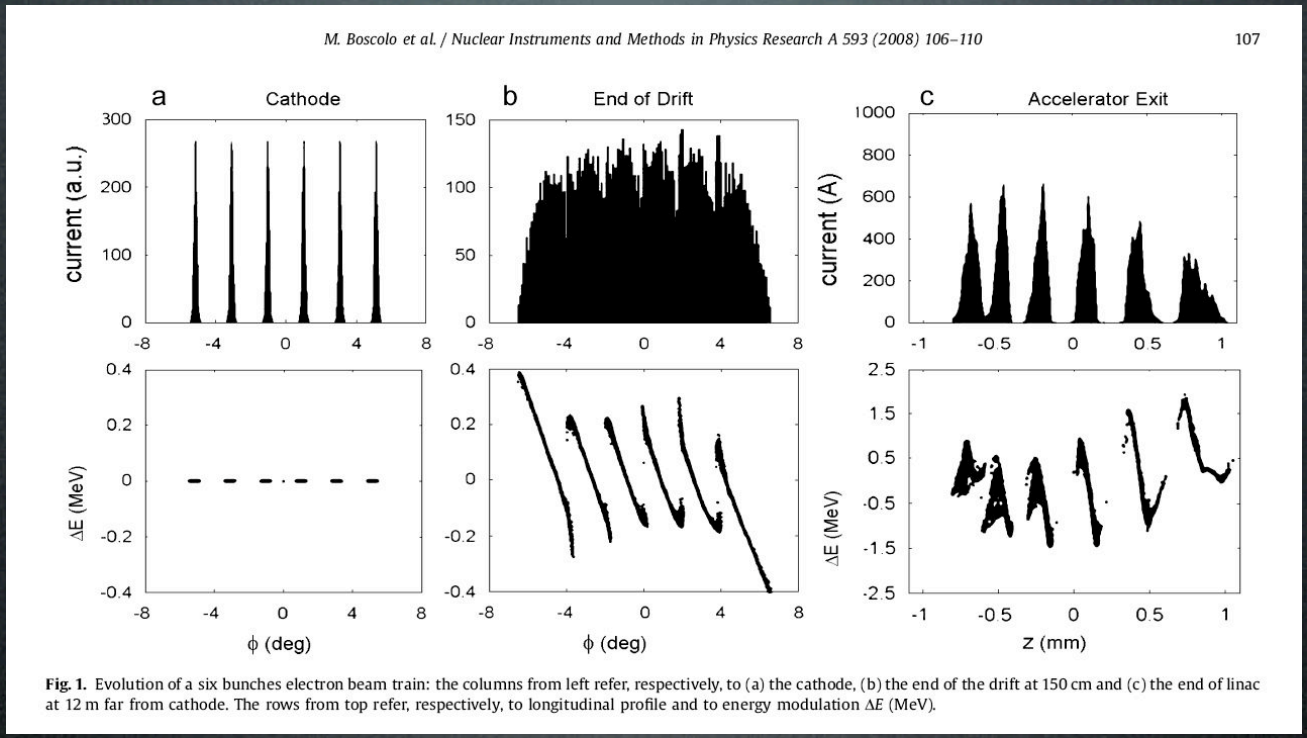
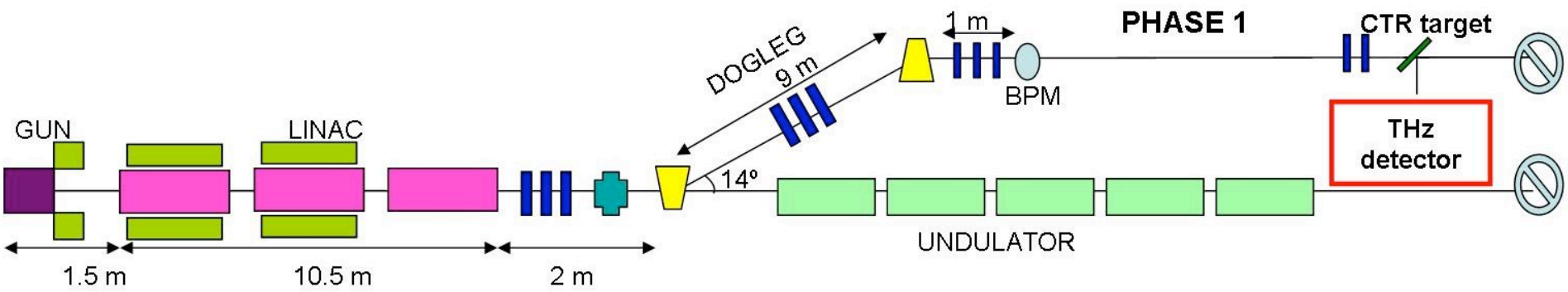
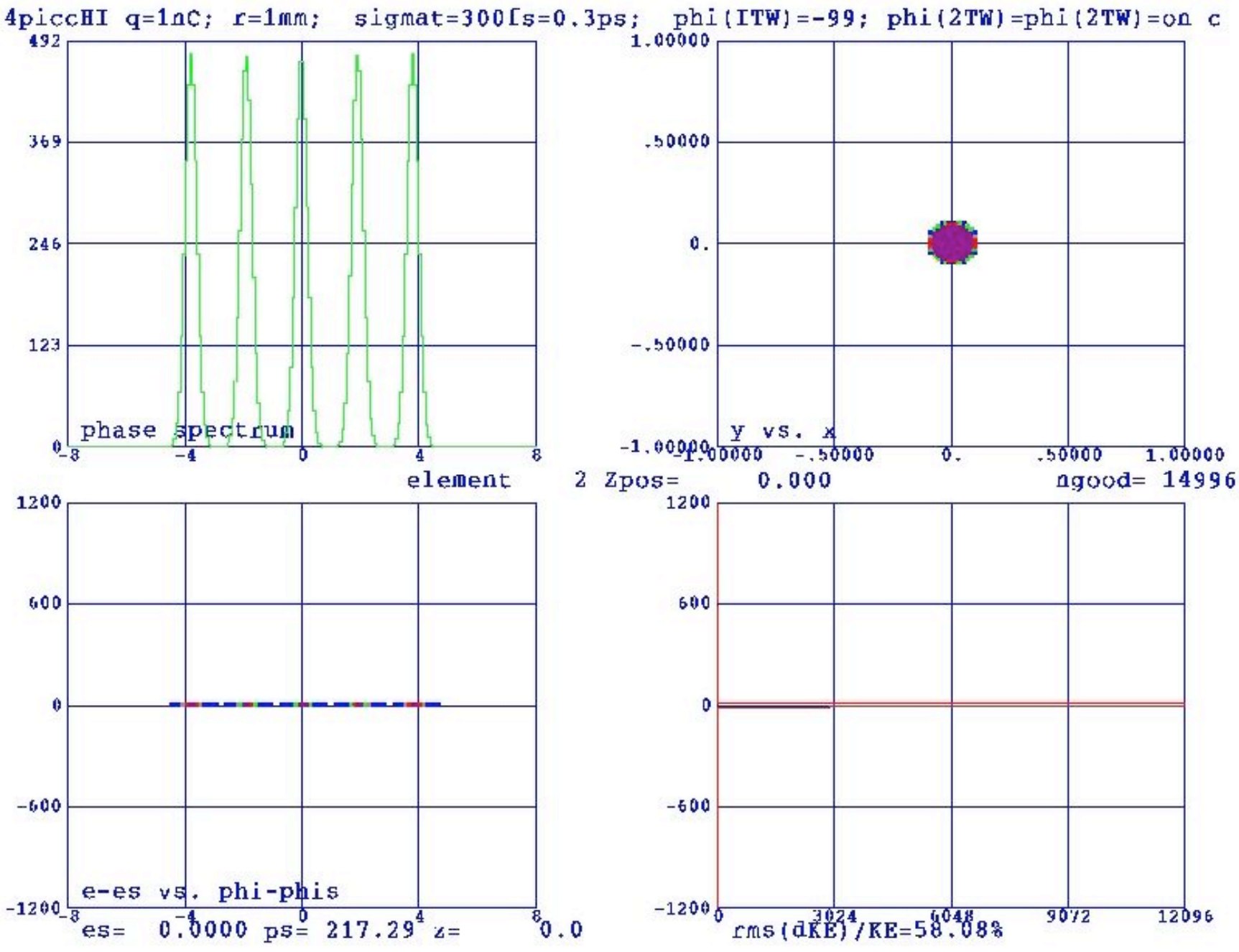


Fig. 1. Evolution of a six bunches electron beam train: the columns from left refer, respectively, to (a) the cathode, (b) the end of the drift at 150 cm and (c) the end of linac at 12 m far from cathode. The rows from top refer, respectively, to longitudinal profile and to energy modulation ΔE (MeV).



- P.O.Shea et al., Proc. of 2001 IEEE PAC, Chicago, USA (2001) p.704.
- M. Ferrario. M. Boscolo et al., Int. J. of Mod. Phys. B, 2006 (Taipei 05 Workshop)


4piccHI q=1nC; r=1mm; sigmat=300fs=0.3ps; phi(1TW)=-99; phi(2TW)=phi(2TW)=on c
492
369
246
123
0
-8
-4
0
4
8
phase spectrum
element 2 Zpos= 0.000 ngood= 14996
1.00000
.50000
0.
-.50000
-1.00000
-1.00000
-.50000
0.
.50000
1.00000
y vs. x
1200
600
0
-600
-1200
e-es vs. phi-phis
es= 0.0000 ps= 217.29 z= 0.0
0
3024
6048
9072
12096
rms(dKE)/KE=58.08%

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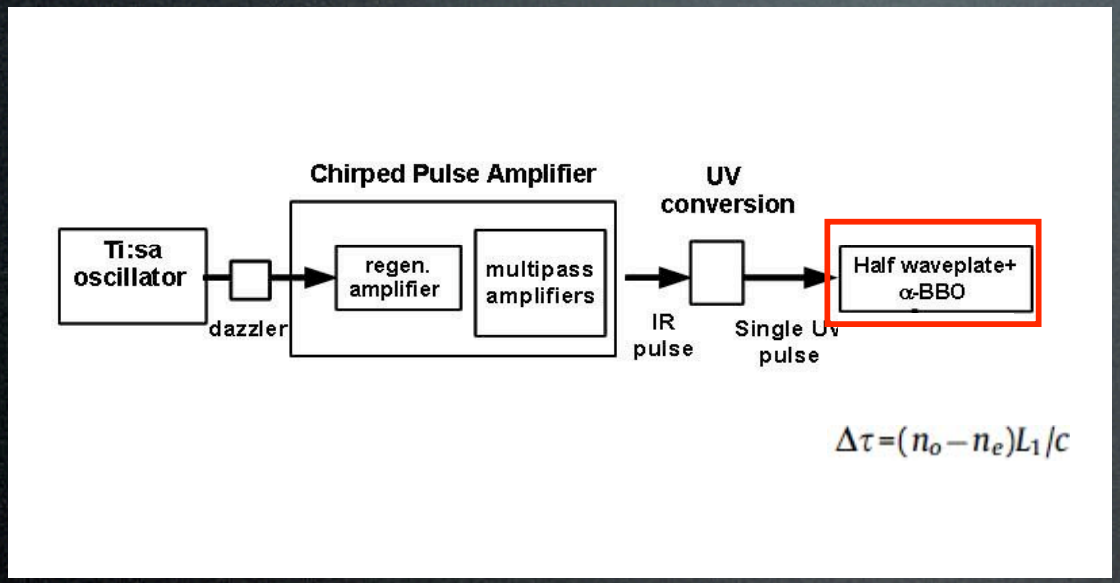
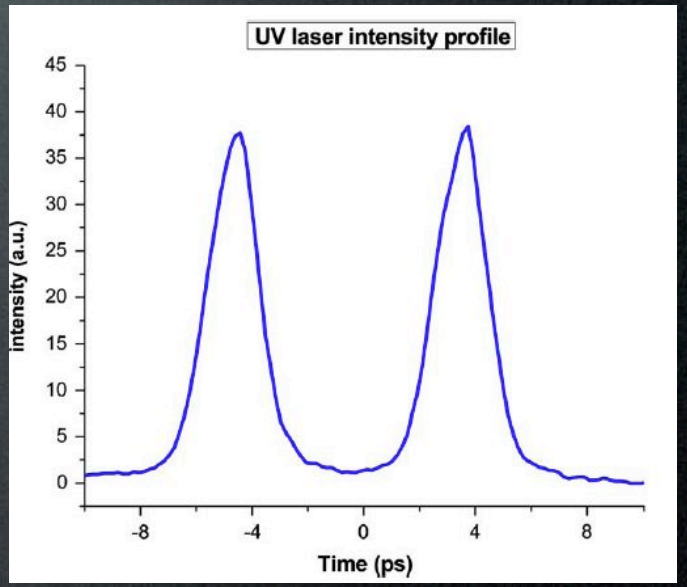
Laser comb with velocity bunching: Preliminary results at SPARC



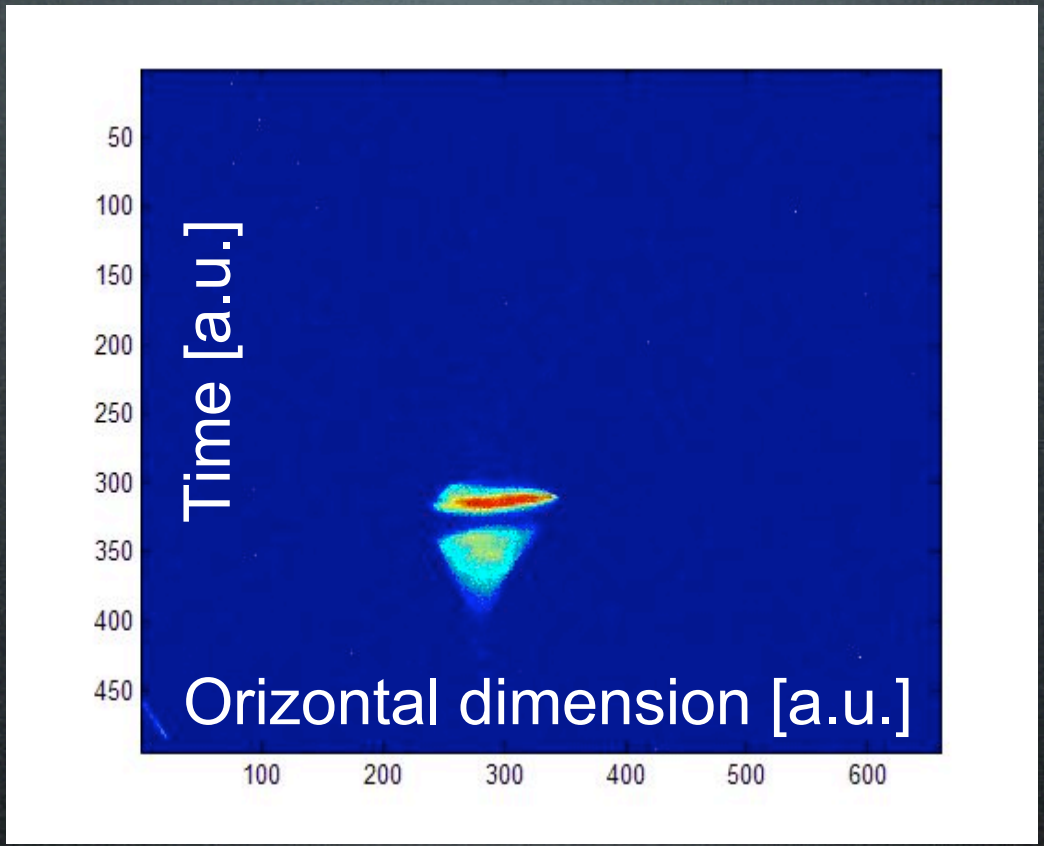


35 pC/pulse

The technique used for this purpose relies on a birefringent crystal, where the input pulse is decomposed in two orthogonally polarized pulses with a time separation proportional to the crystal length.

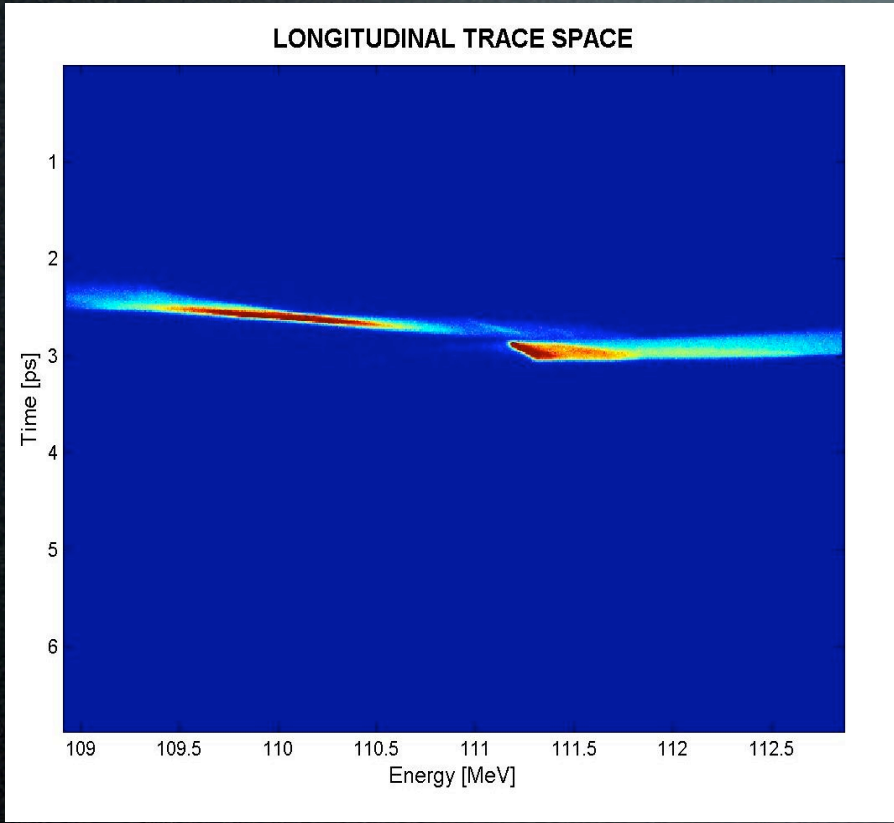
The crystal thickness is 10.353 mm

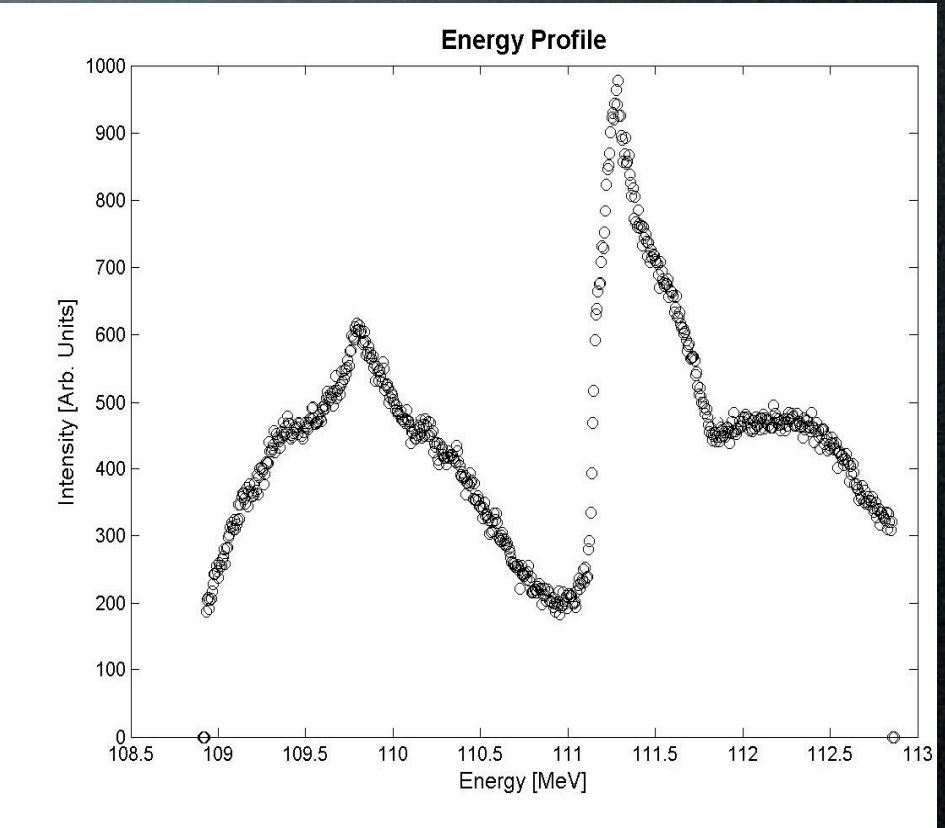
Observation of Pulse Separation in Overcompression Regime



After a tuning of the VB injection phase we observed on the screen downstream the RF Deflector two distinct pulses separated by ~1 ps with σ_{t1} = 0.24 ps and σ_{t2} =0.29 ps respectively.
The charge unbalance was ~ 40%.

Measured Longitudinal Phase Space and Energy Profile



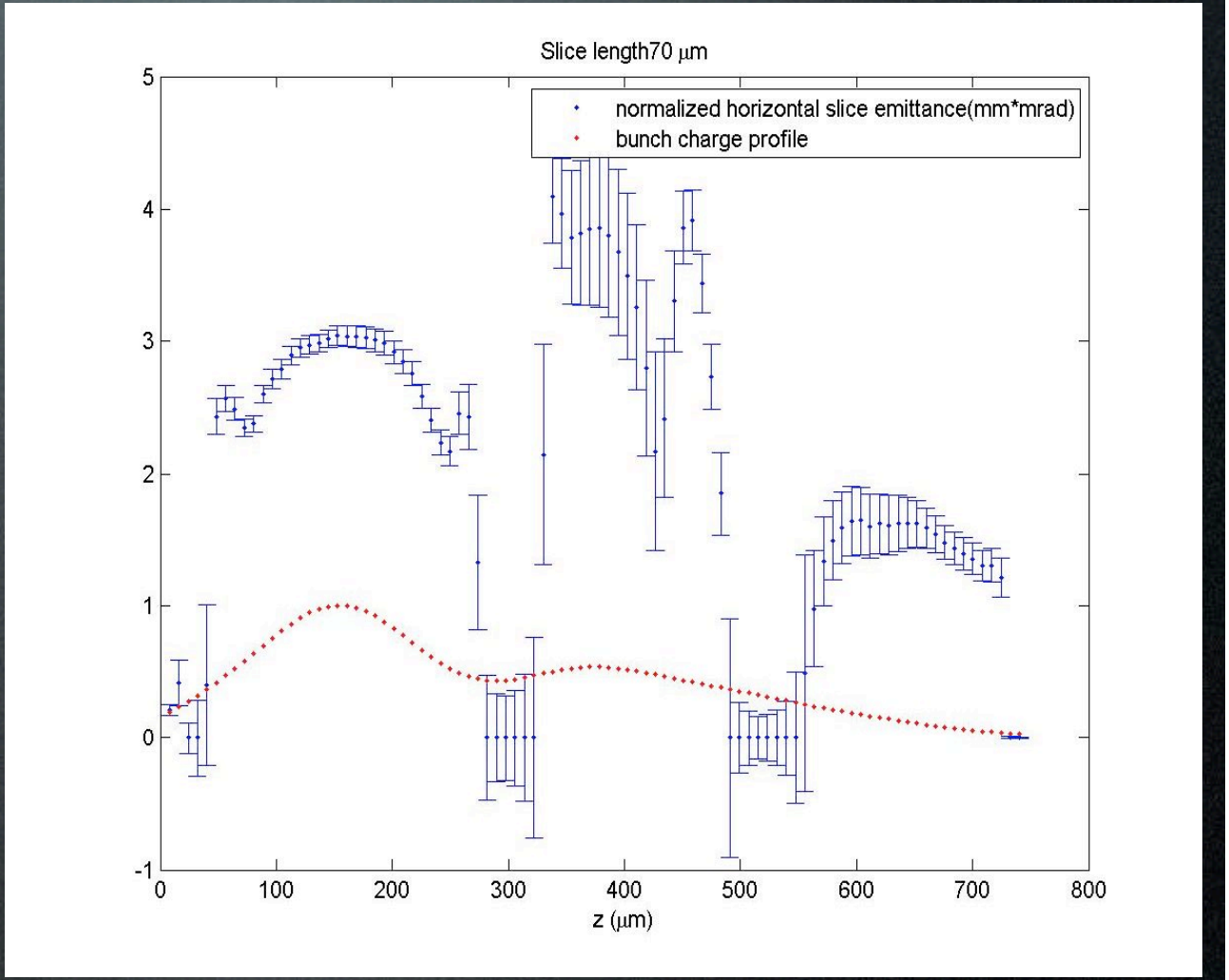


The energy profile shows an energy difference between the two pulses of ~ 2 MeV with a final average energy of 111 MeV.
The rms energy spread of the two pulses was 0.3 % and 0.7 %

Slice emittance Measurement

The slice emittance measuremenet is the only way to get realistic information about the transverse beam quality of the two pulses. Notice that the higer current pulse is probably better matched and results to have the lower emittance.

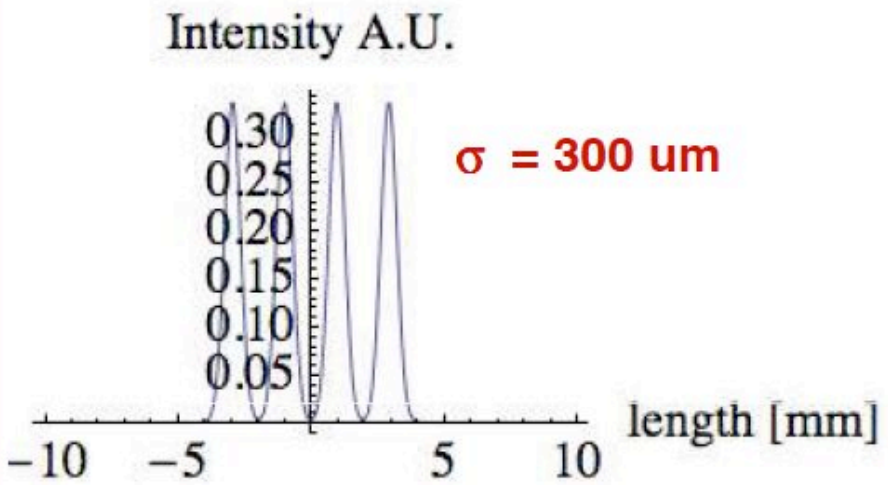
The total projected emittance under this condition was ~ 4 mmrad in both planes



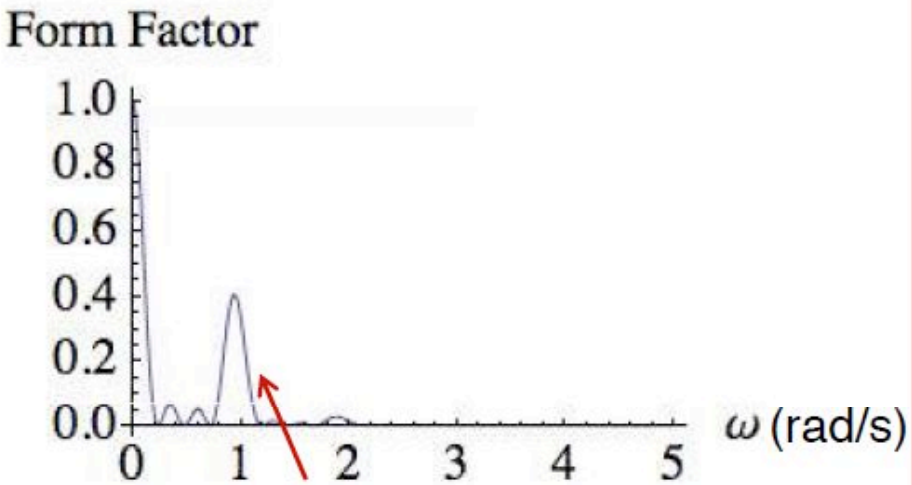
Narrow band THz radiation

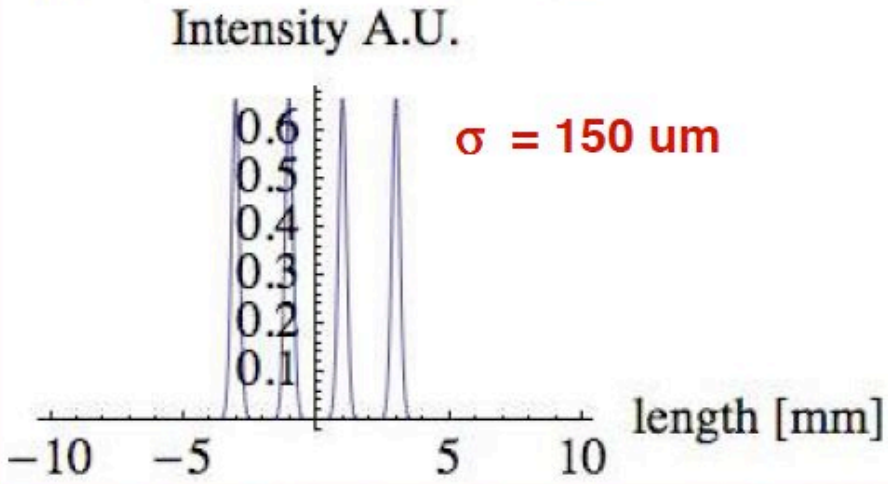
THE SPARC THz SOURCE

Pulses Rep. rate: 2 mm (7 ps) ⇔ 0.15 THz

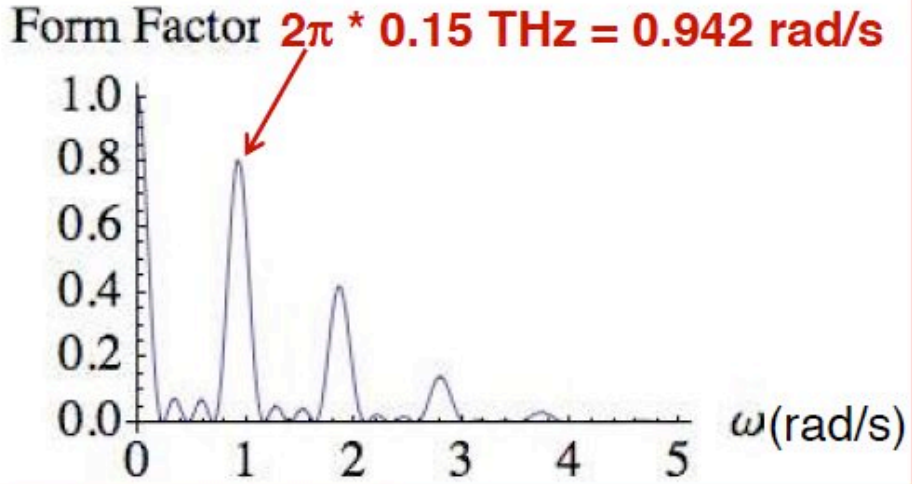


σ = 300 um





σ = 150 um



2π * 0.15 THz = 0.942 rad/s

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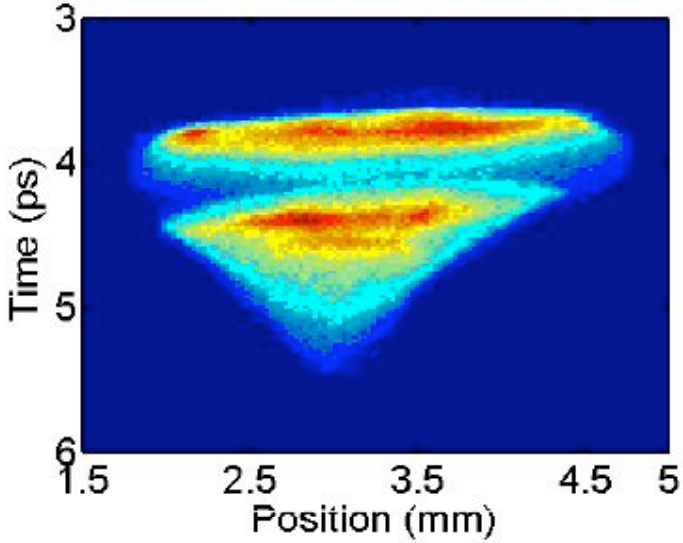
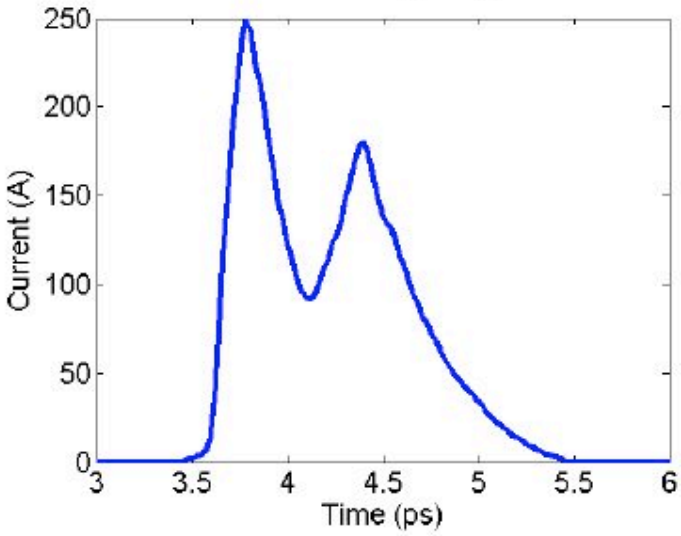
THz RADIATION FROM COMB

Two pulses train electron beam
Velocity bunching (over-compression)

By changing the over-compression factor, the pulses spacing can be adjusted in order to emit at the THz scale.

Beam Energy= 100 MeV
Total charge = 180 pC
Pulses inter-distance = 0.7 ps





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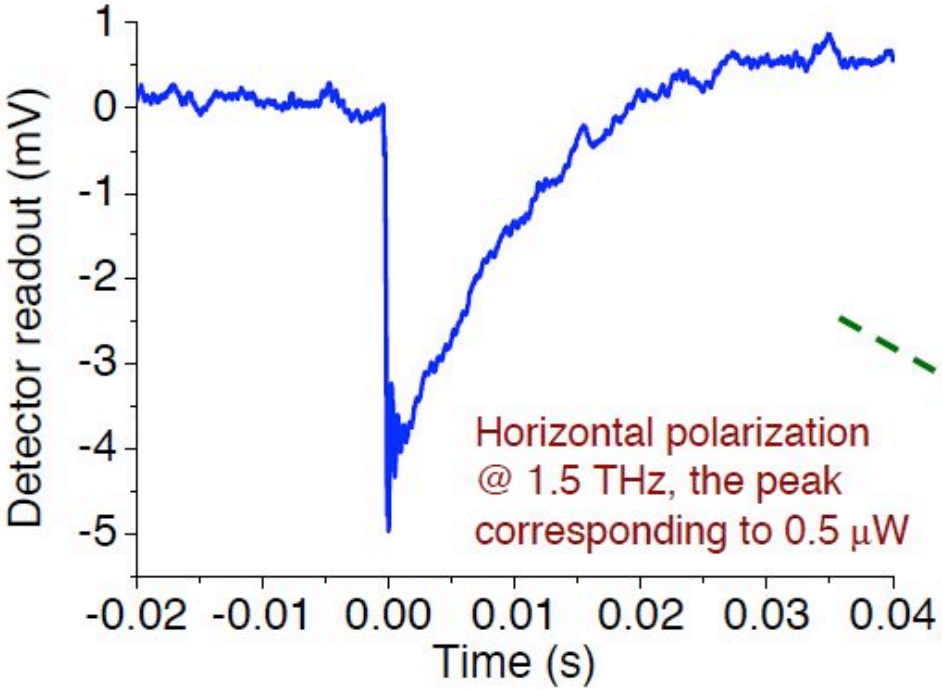
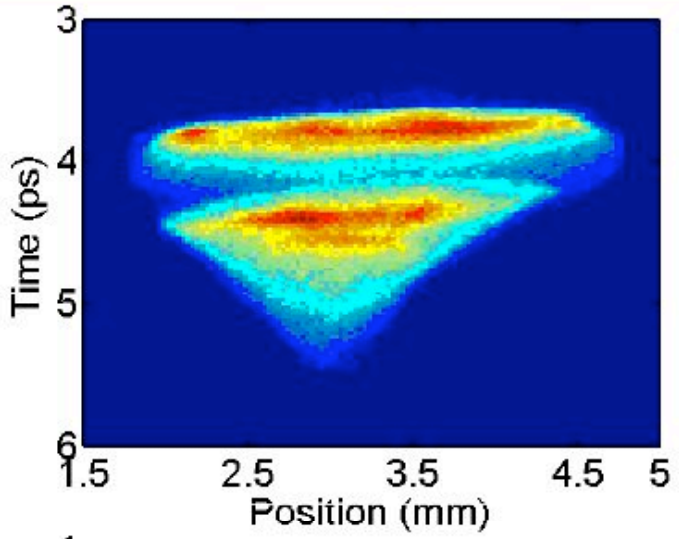
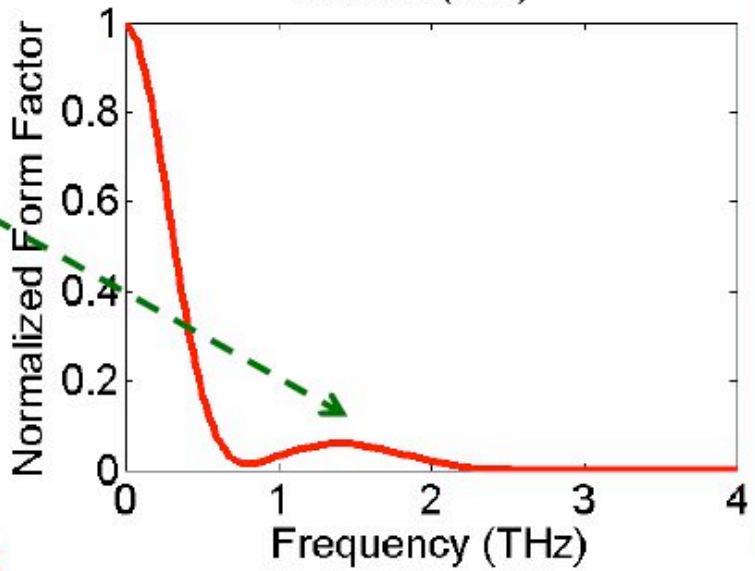
THz RADIATION FROM COMB

Two pulses train electron beam
Velocity bunching (over-compression)







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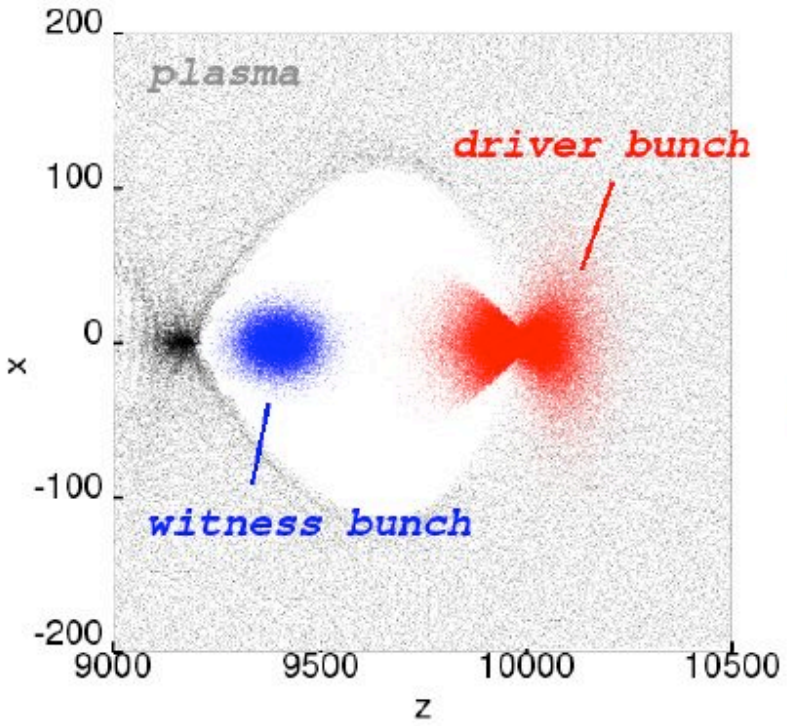
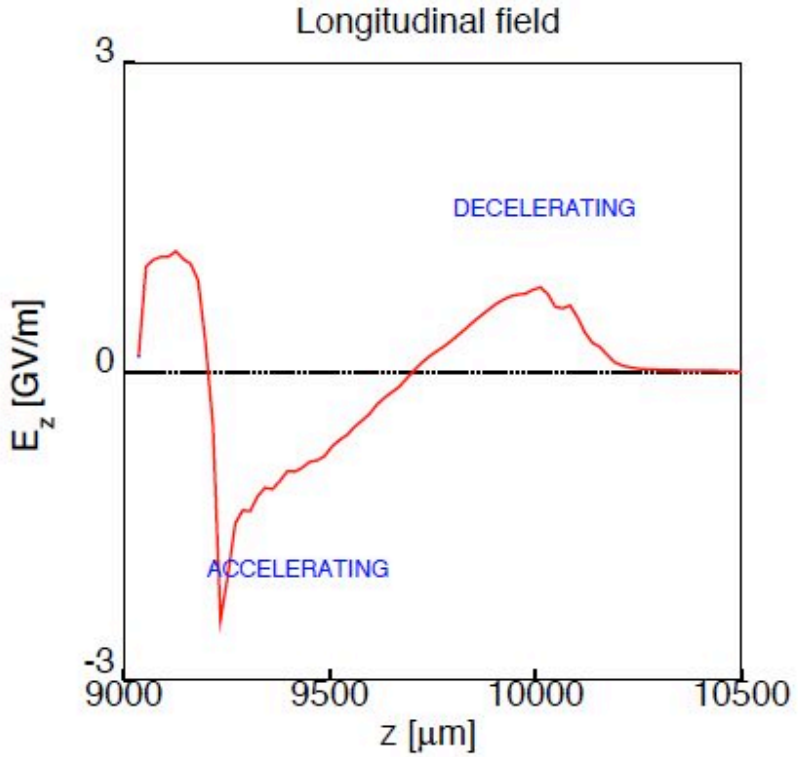
Particle Wake Field Acc.





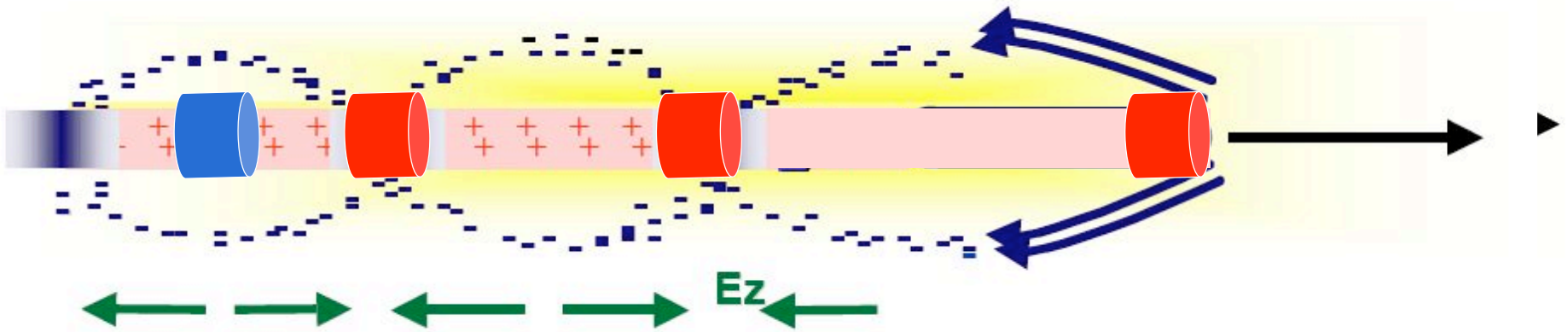
E	145.9 MeV
$\delta E/E$ (rms)	$8.8 \cdot 10^{-3}$
Q	1.75 nC
σ_x	34.74 μm
σ_y	34.80 μm
σ_z	63.08 μm
ϵ_x	3.06 mm mrad
ϵ_u	3.06 mm mrad

$$E_{acc}\left[MV/m\right] = 27.5\,\frac{Q\left[pC\right]}{\left(\sigma_z\left[\mu m\right]\right)^2}$$

E [MeV]	$\Delta E/E$ [rms]	$\sigma_{x,y}$ [μm]	$\epsilon_{x,y}$ [mm mrad]	Q [pC]	σ_z [μm]
145.9	$5 \cdot 10^{-3}$	7	2	20	2.5

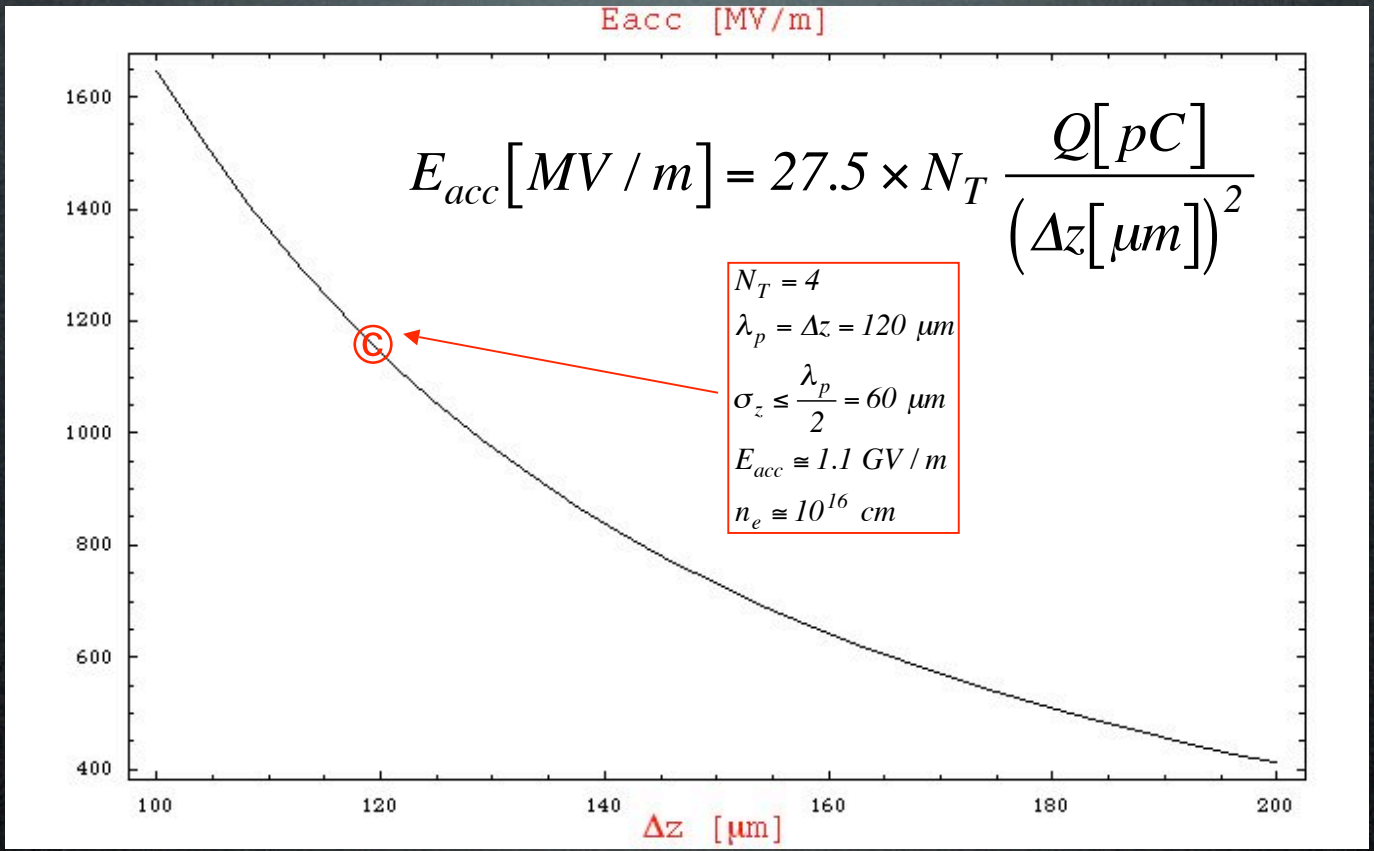
Plasma wakefield multibunch excitation

- Space charge of drive beam displaces plasma electrons



- Plasma ions exert restoring force => Space charge oscillations

150 pC/pulse x 4 pulses

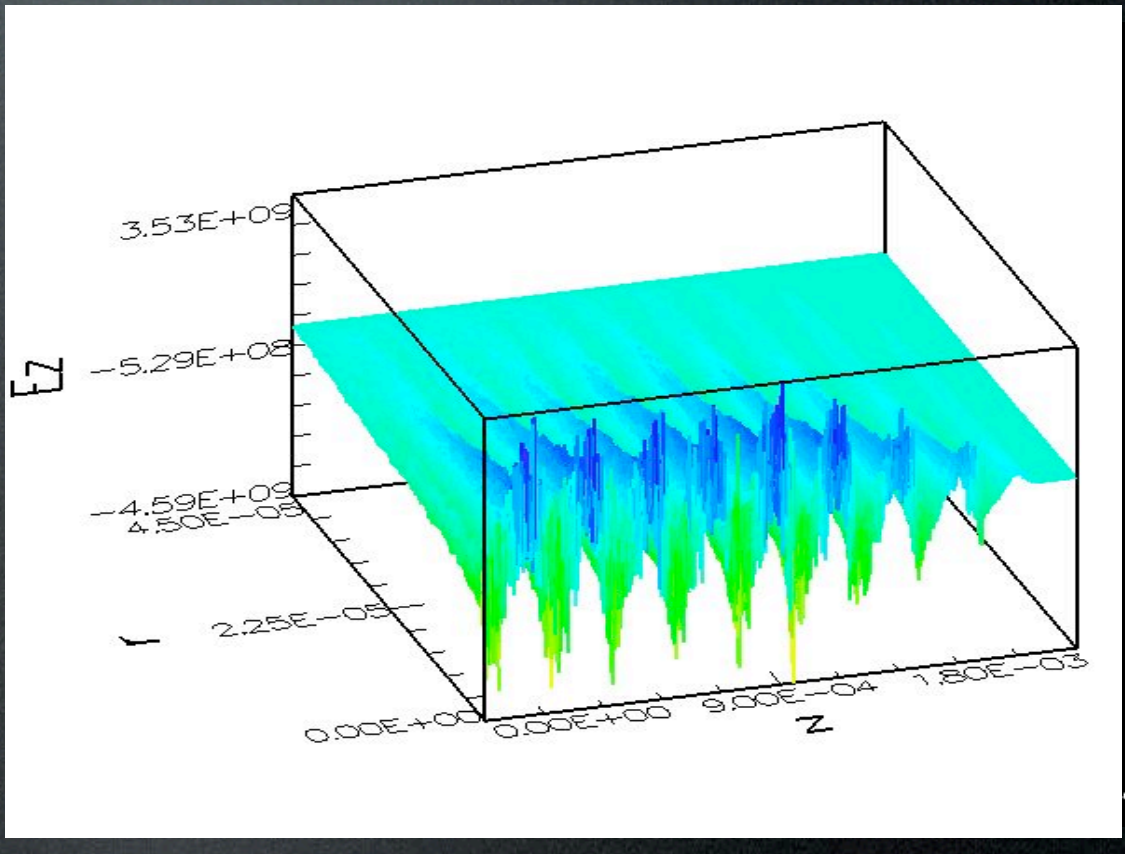


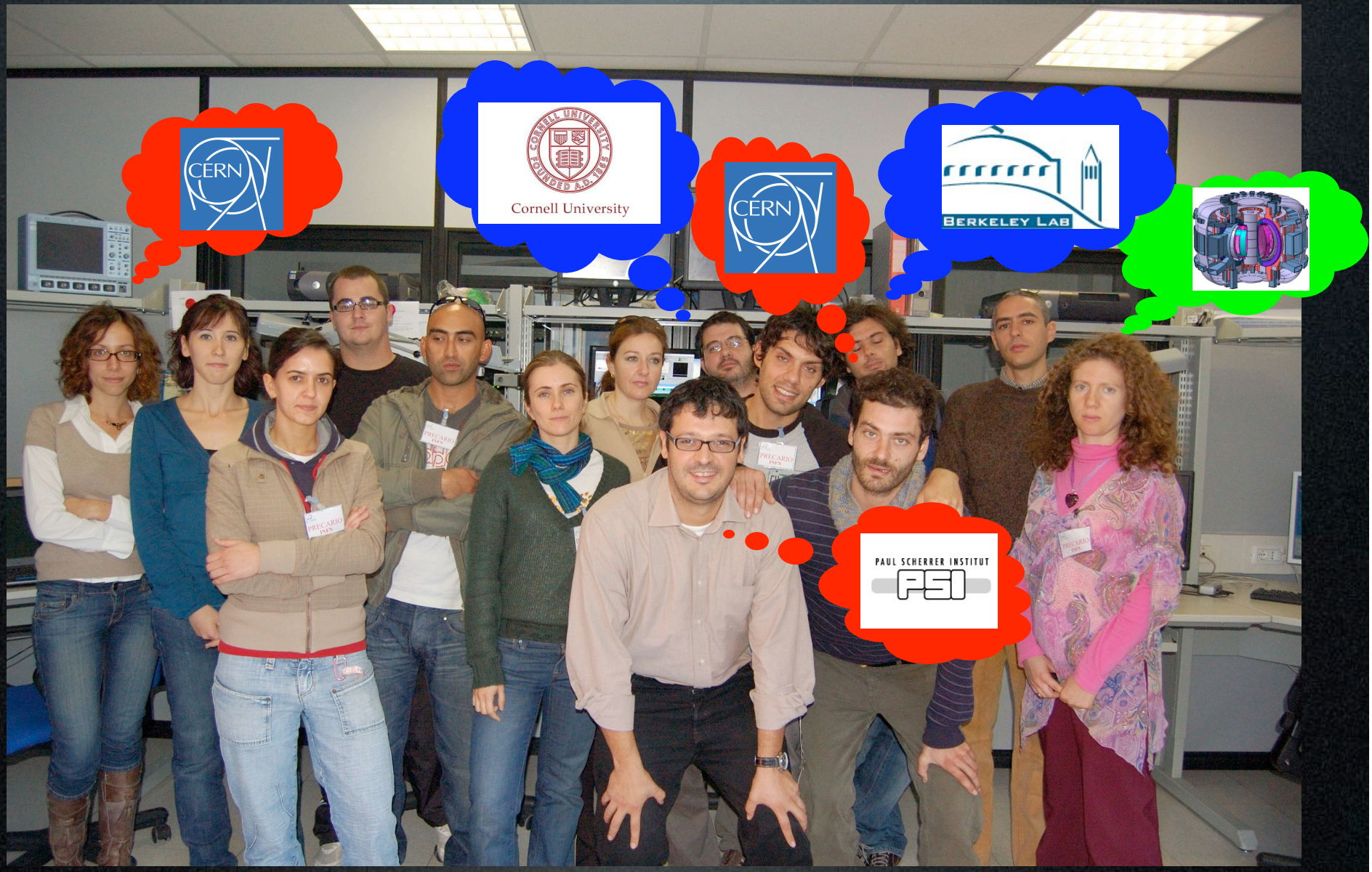
200 MeV in 18 cm

Multipulse operation

- Resonance works well
- SPARX example gives 3 GV/m

Example:
 # pulses=4
N_b=1E8
n_e=3E22 m^{-3}
λ_p=190 μm
$Q\tilde{}_1$=0.117

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Thank you