PARMELA simulations on PITZ1.5: first machine studies and interpretation of measurements

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on behalf of the PITZ Team

Istituto Nazionale di Fisica Nucleare

Outline

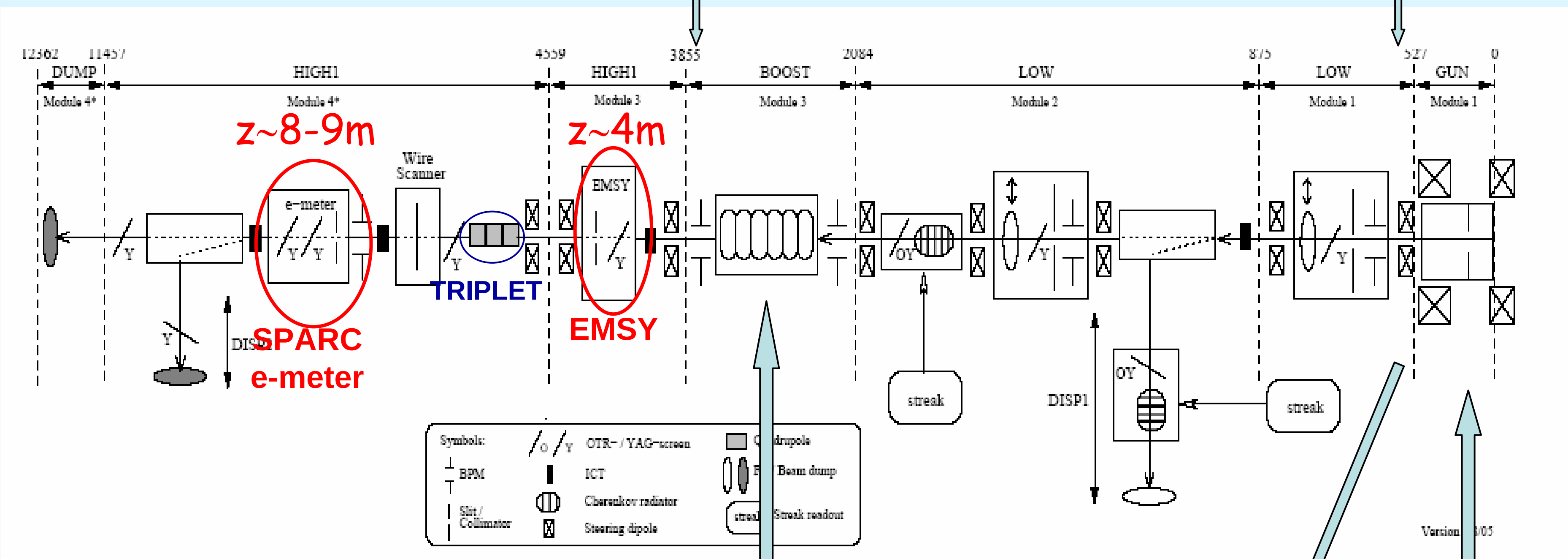
- Machine layout and parameters
- First PARMELA simulation studies
- Comparison measurements/simulations
- Conclusions

PITZ1.5 layout

[A.Oppelt *et al.*, FEL05]

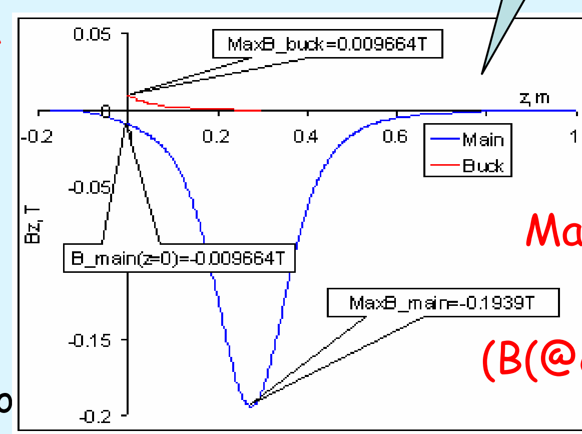
E~13MeV

E~5 MeV



Booster:
normal conducting Tesla
prototype cavity

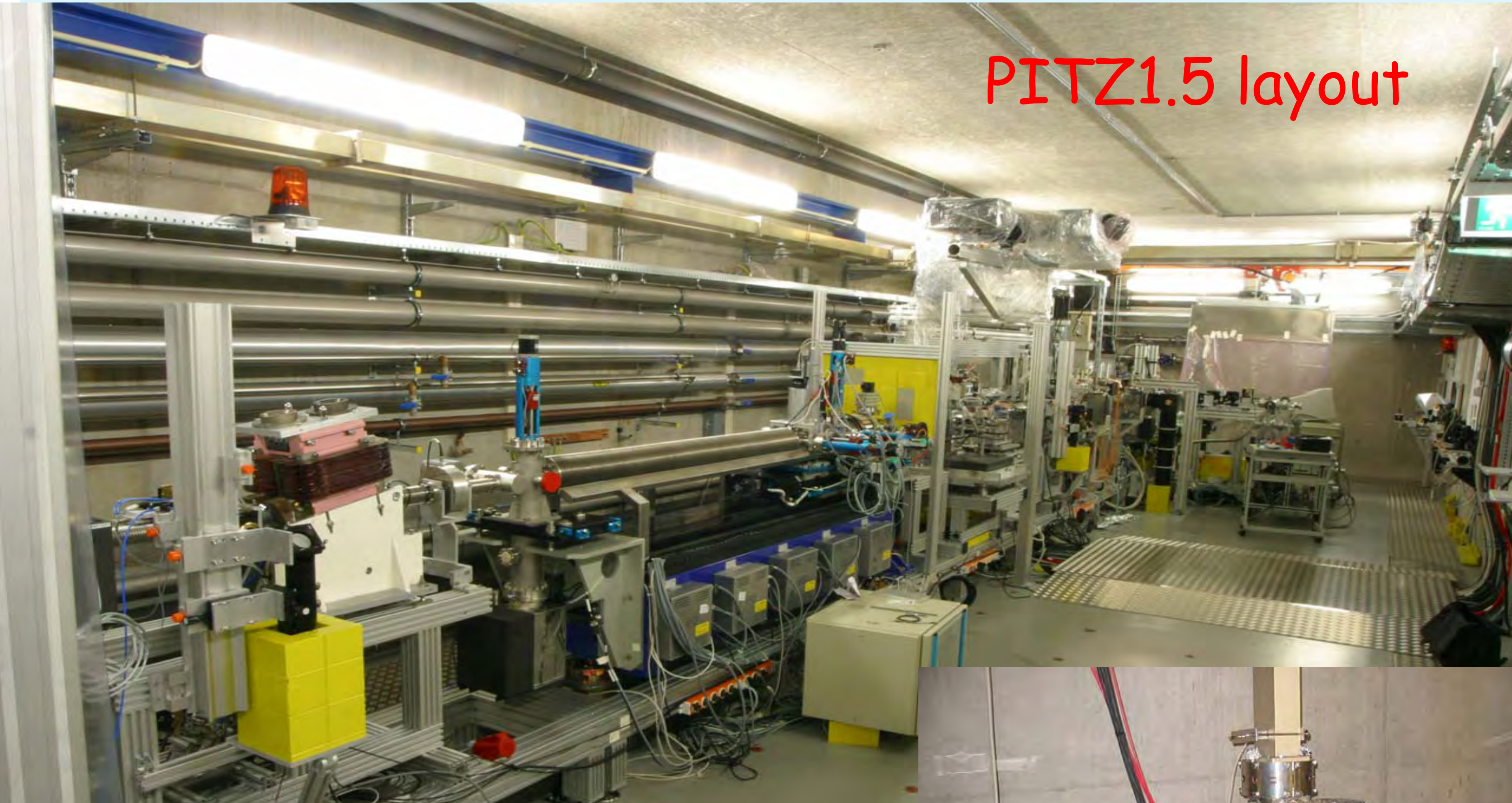
Gun
1.3GHz

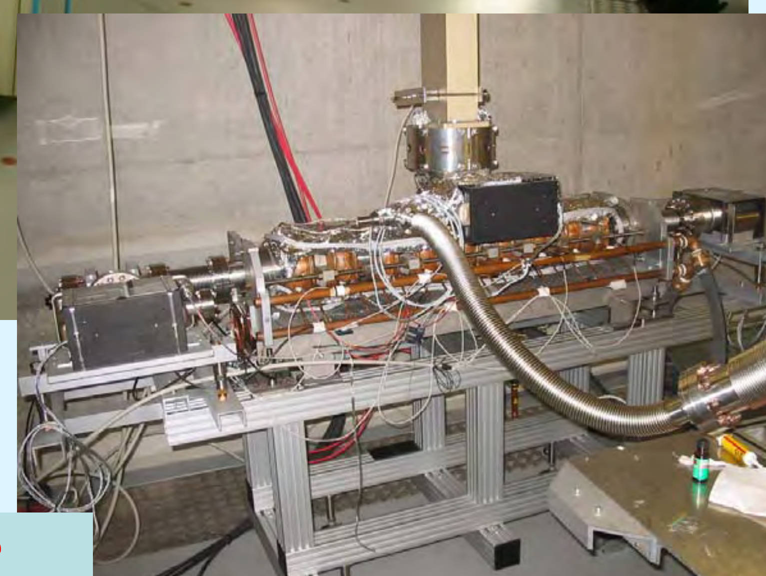


Main +Bucking
solenoid

(B(@cathode)=0T)

PITZ1.5 layout





SPARC e-meter

Nominal beam parameters @PITZ1.5

- Bunch charge = 1 nC
- Temporal bunch length = 20ps
- Laser pulse rise time = 2ps
- Photocathode rms beam size =0.6mm
- Thermal emittance ε_{th}=0.6μm
- Peak solenoid field @ 0.276m = -0.1939T
- Bucking solenoid @cathode plane= 0.0097T
- Ekin(@end_gun) ~ 5.1 MeV (Epeak= 45MV/m)
- Ekin(@end_booster) ~ 13.2 MeV (E~15MV/m)

These parameters change from measurement to measurement, so for simulations they are changed accordingly

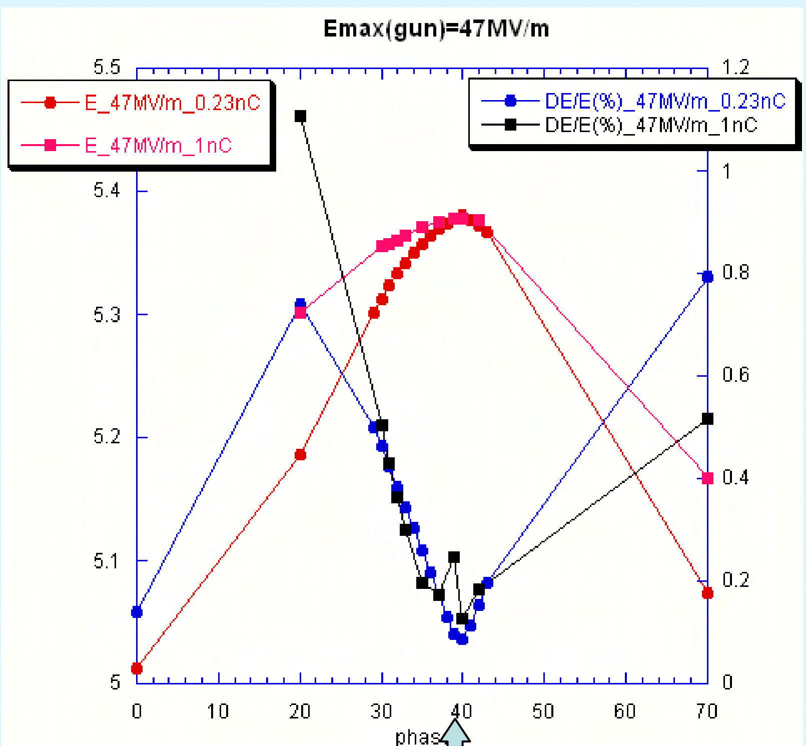
Energy scan (@gun exit) vs injection phase

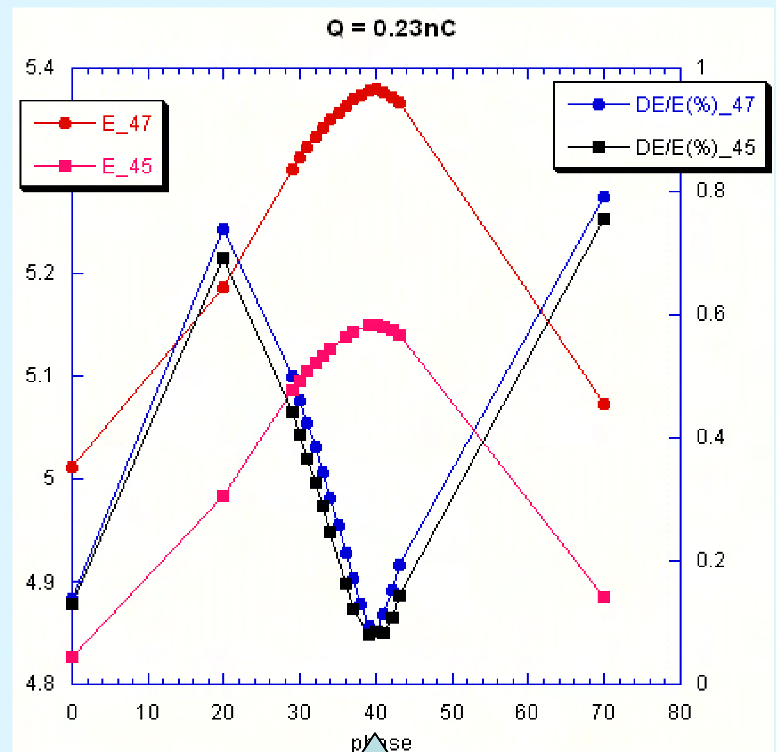
Measurement:
E ~ 5.1 MeV
with Epeak= 45MV/m

Simulation: the gun accelerating field is tuned to have the same measured energy

Experimentally injection phase is found by minimizing energy spread

Same for PARMELA simulations





40° is the optimum phase

Some PARMELA simulations studies to investigate the machine in **ideal conditions** with booster on and off

- Bunch charge = 0.23 nC
- Ideal flat top pulse=20ps and included r.t.=2ps
- Photocathode rms x-y size =0.5mm
- Thermal emittance ε_{th}=0.6μm

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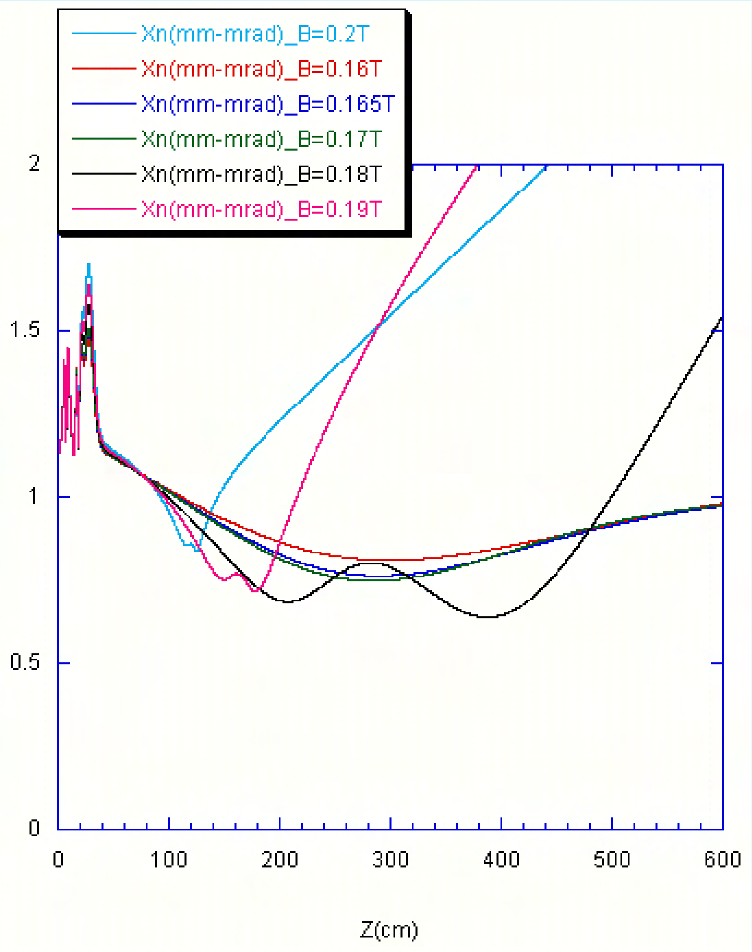
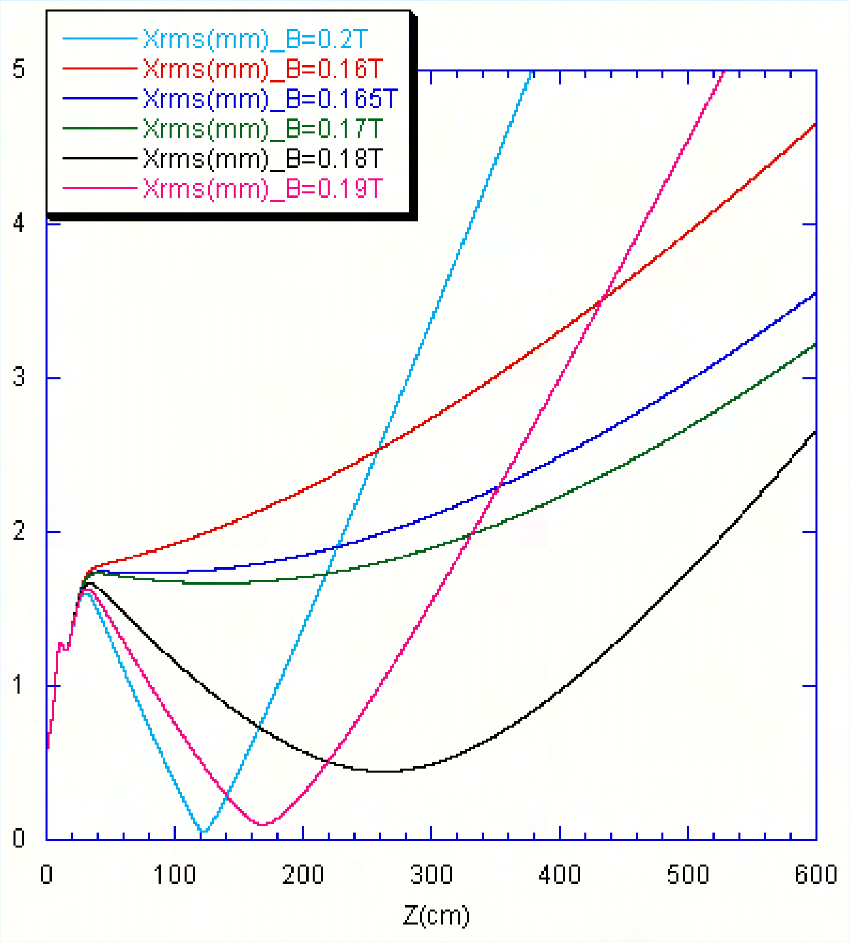
B scan for the low charge (Q=0.23nC) configuration without acceleration



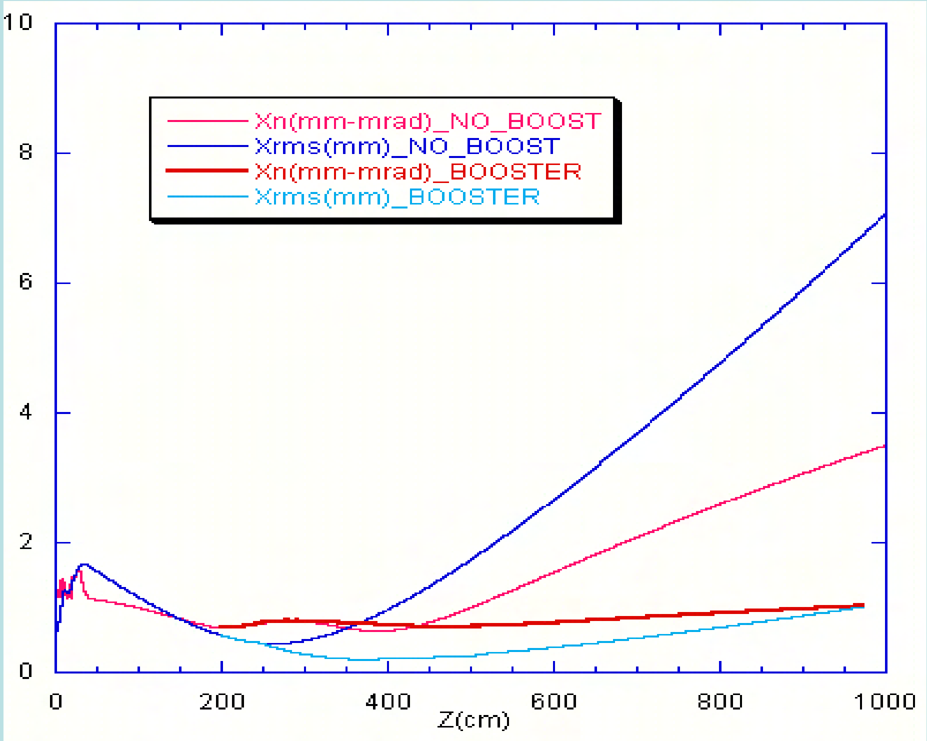


Simulations indicate B=0.18T a good value for emittance compensation

for simulations with booster we take this B value

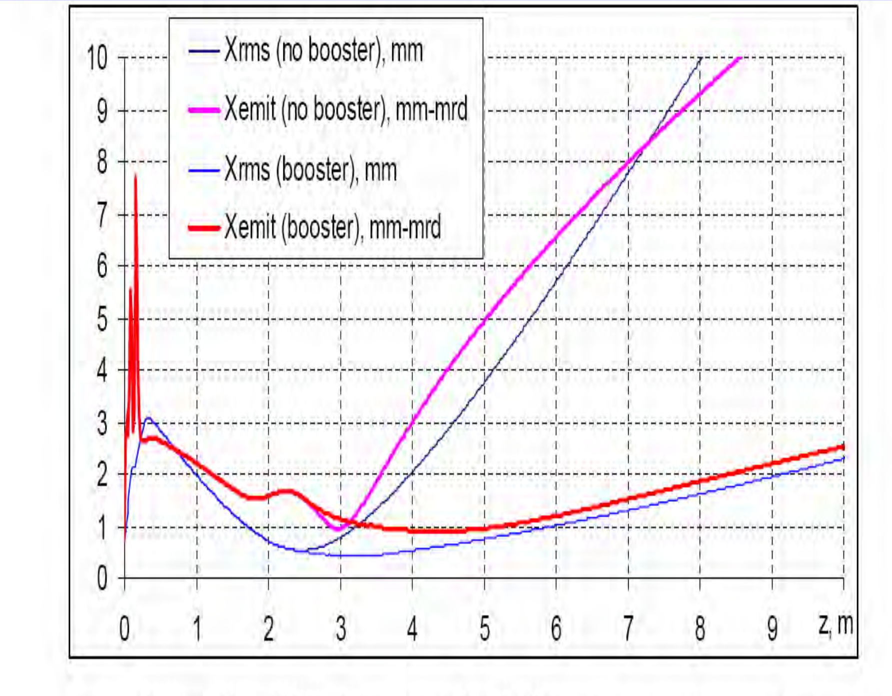
Booster ON/OFF simulations

Parmela



- Q=0.23nC
- Xrms = 0.5mm
- L=20ps flat-top
- B_{sol} = 0.18T
- εth = 0.6 mm mrad

Astra



- Q = 1nC
- Xrms = 0.6mm
- L=20ps flat-top
- B_{sol} = 0.1939T
- εth = 0.6 mm mrad

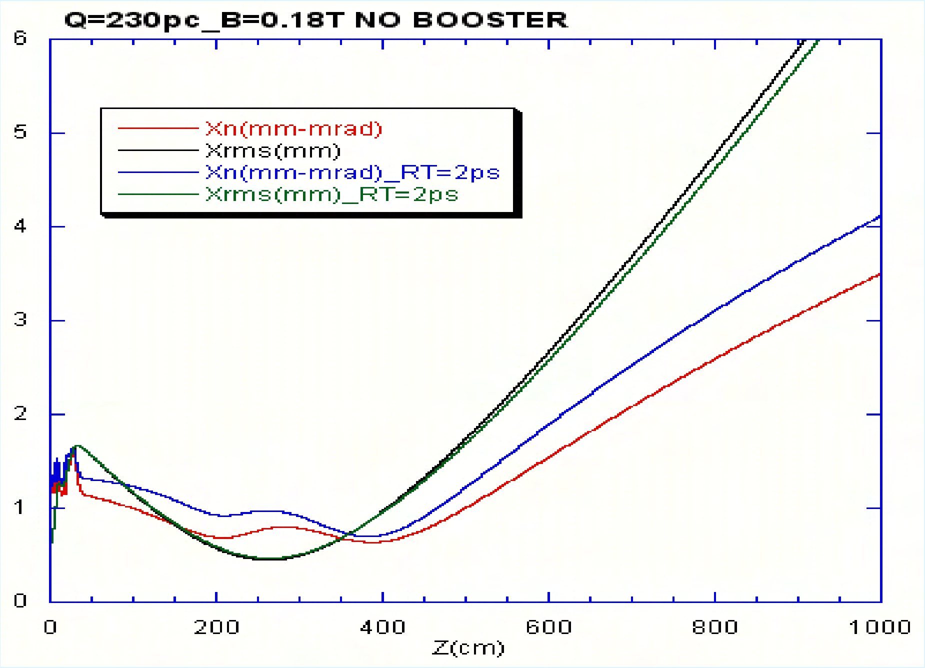
Low charge regime simulations

red curve: FLAT TOP laser pulse

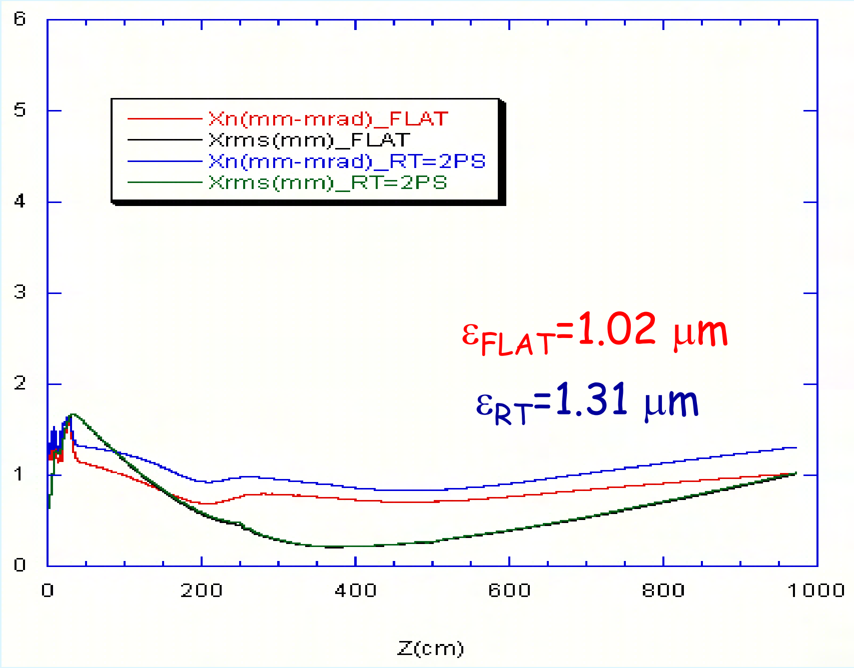
blue curve: +RISE TIME=2ps

- Q=0.23nC
- Xrms = 0.5mm
- B_{sol} = 0.18T
- εth = 0.6 mm mrad
- phi_inj=40°

NO BOOSTER



BOOSTER



30% increment of emittance at z=10m with rise time

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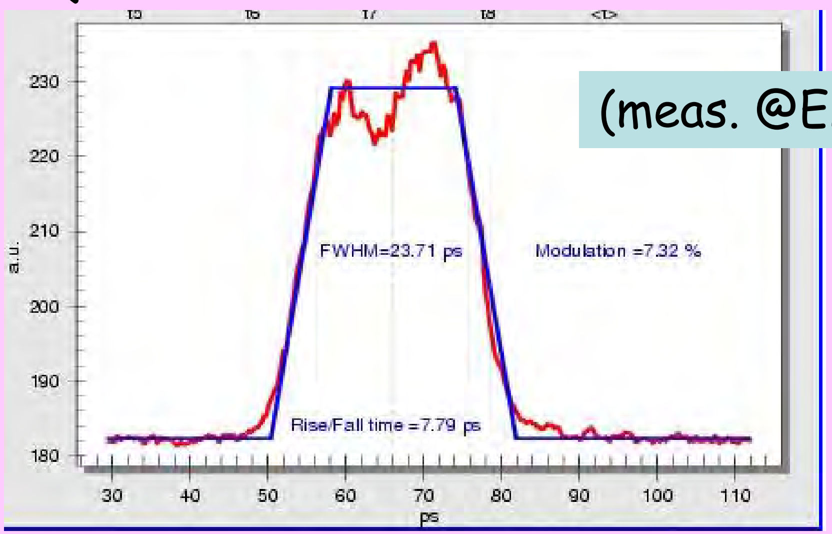
We selected different machine configurations for comparison with simulations

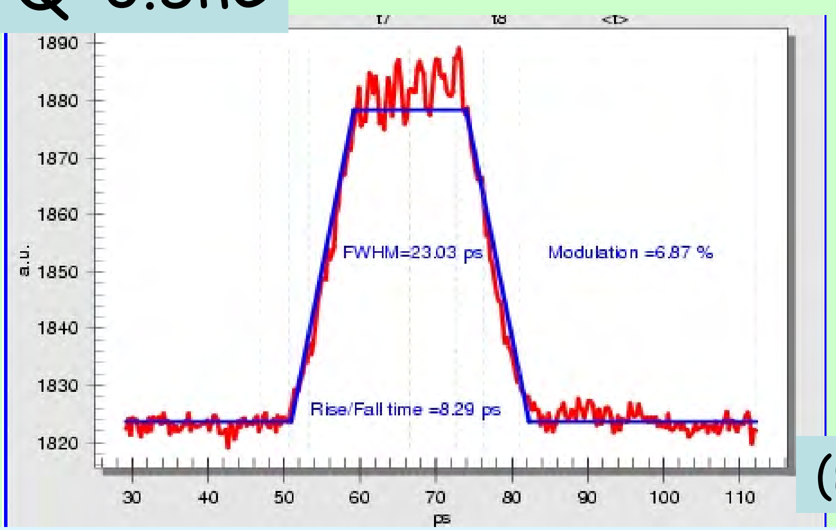
with BOOSTER on and triplet off

Q=1nC



(meas. @EMSY)

Q=0.5nC



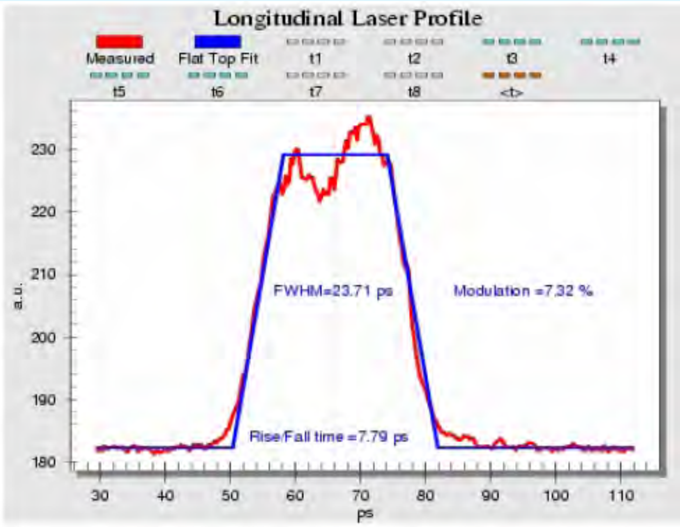
(meas. @e-meter)

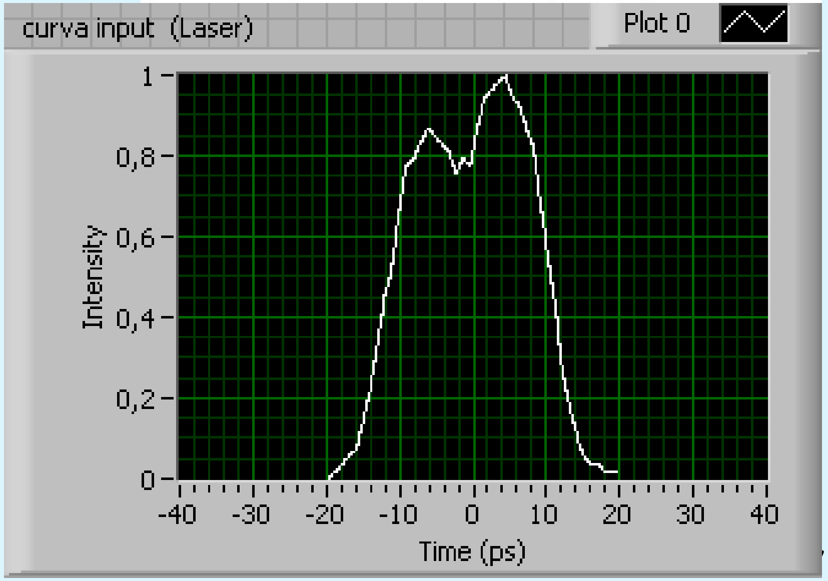
MEASURED PARAMETERS:

- Energy and energy spread
- rms spot size vs B(I)
- Emittance vs B(I)

Simulation studies with real laser profile

(measurement 28-29 Sept.05)





Q = 1nC

I(B) = 295A

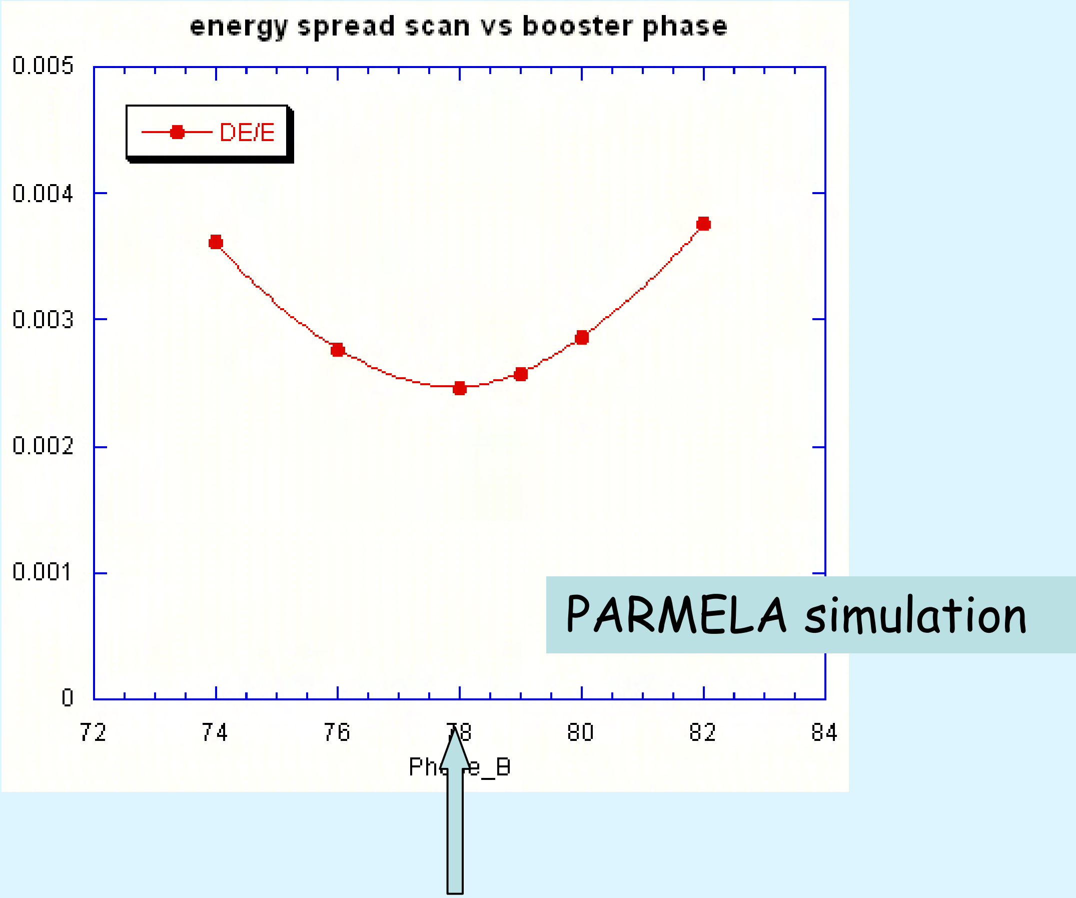
at optimum phase at booster
a solenoid scan and energy spread
measurements have been done

Realistic pulse used for
PARMELA simulations

ASSUMPTIONS for simulations:

- beam pulse shape=laser pulse shape
- laser/beam pulse radially uniform

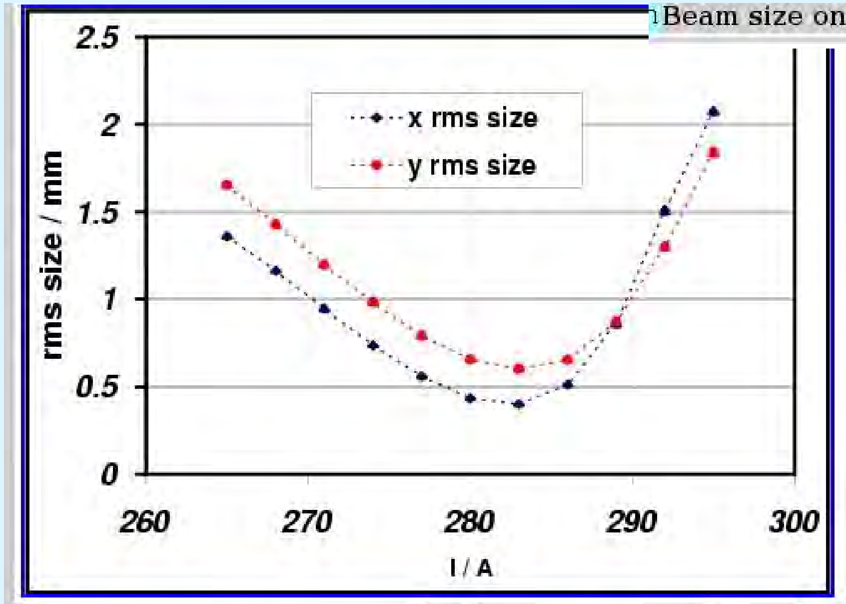
The optimum phase is found minimizing energy spread both experimentally and with simulations



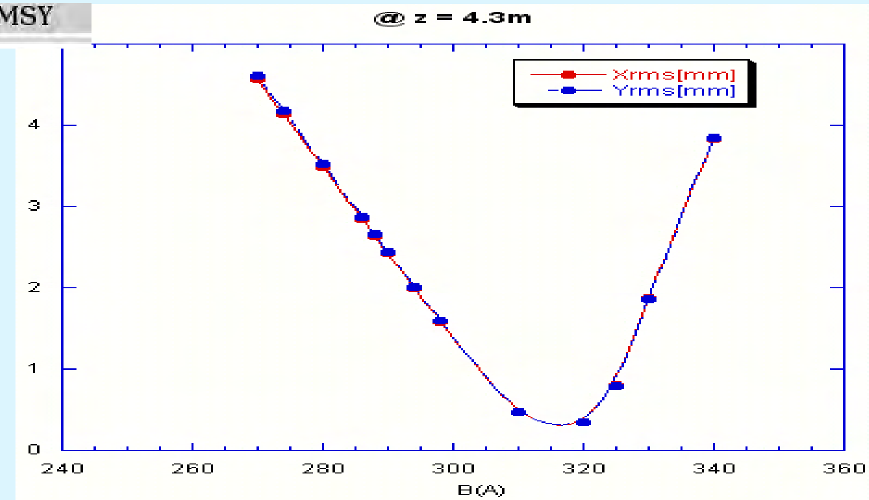
ϕ= 78º
at booster

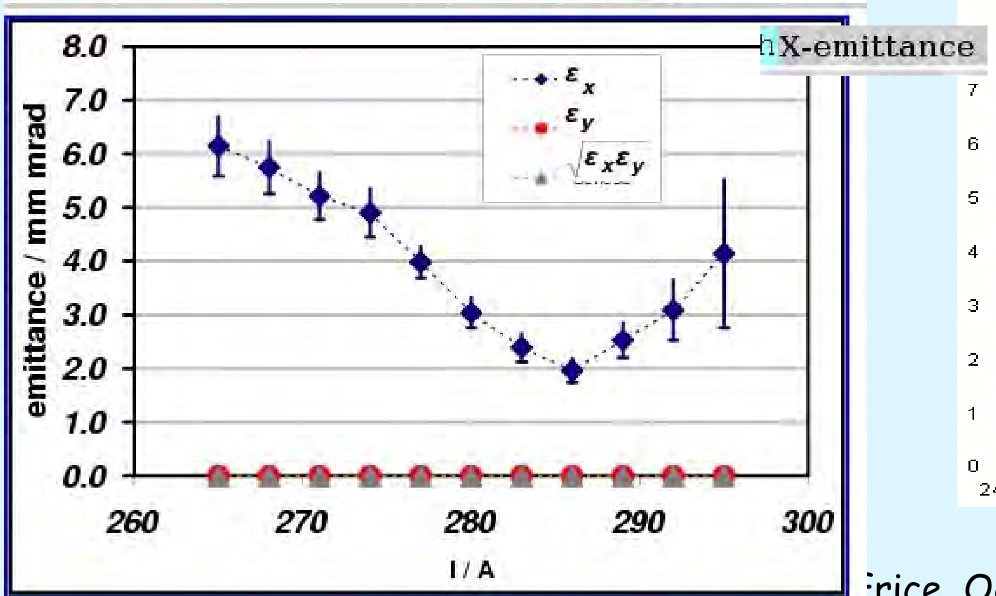
Gun Solenoid scan

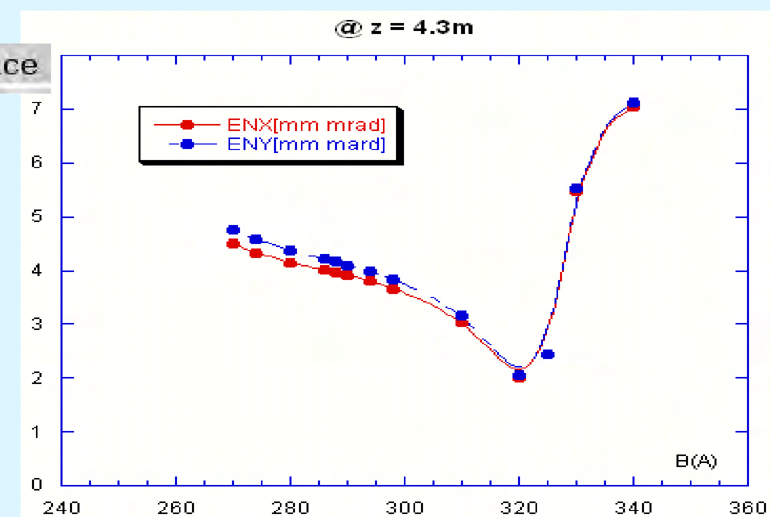
Measurement @EMSY (z=4.3m)



PARMELA simulation







Measurement and simulation

If we consider a 10% mismatch between the solenoid current and strength

Measurements including a shift in B(I)

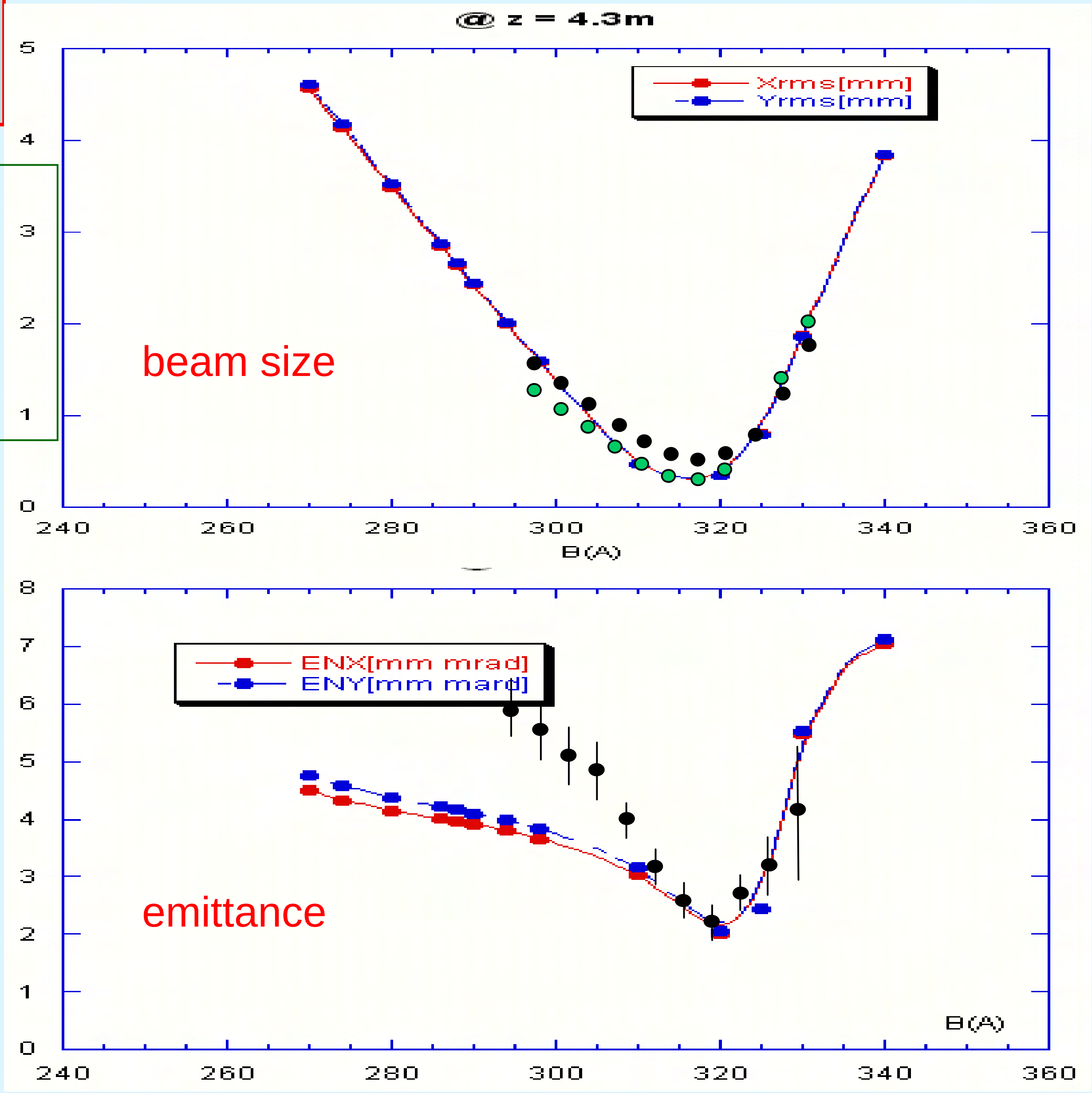
Black dots: horizontal

Green dots: vertical

PARMELA simulations

red: horizontal

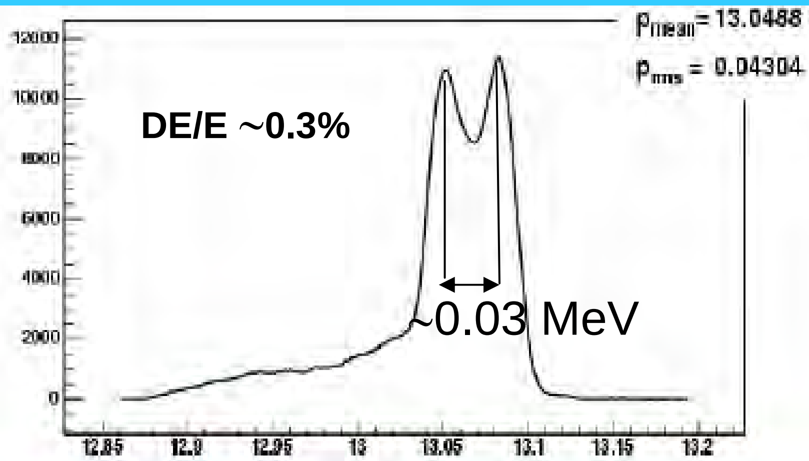
blue: vertical



Energy Measurement

Δφ=optimum

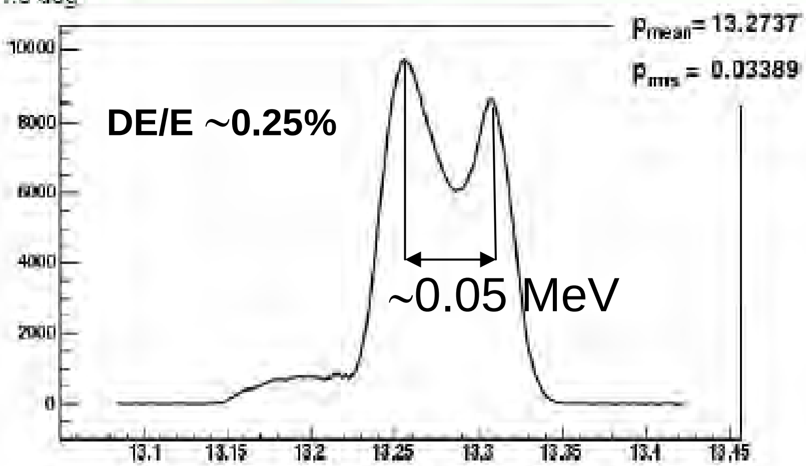
(minimum DE/E)

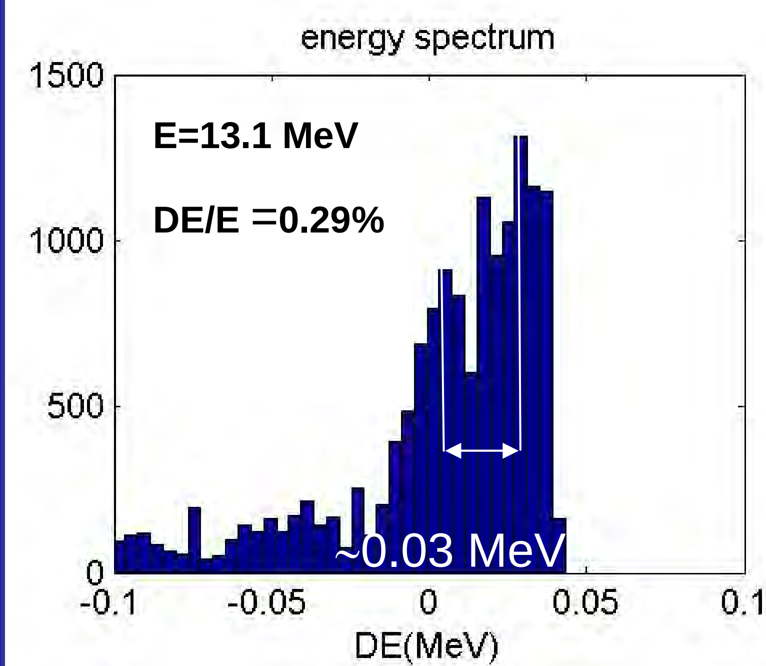


28.09.2005 18:50:30 Author: V. Boccone S. Khodyachykh Title: Momentum Distribution

Gun SPP = 58.5 deg

Booster SPP = -4.0 deg

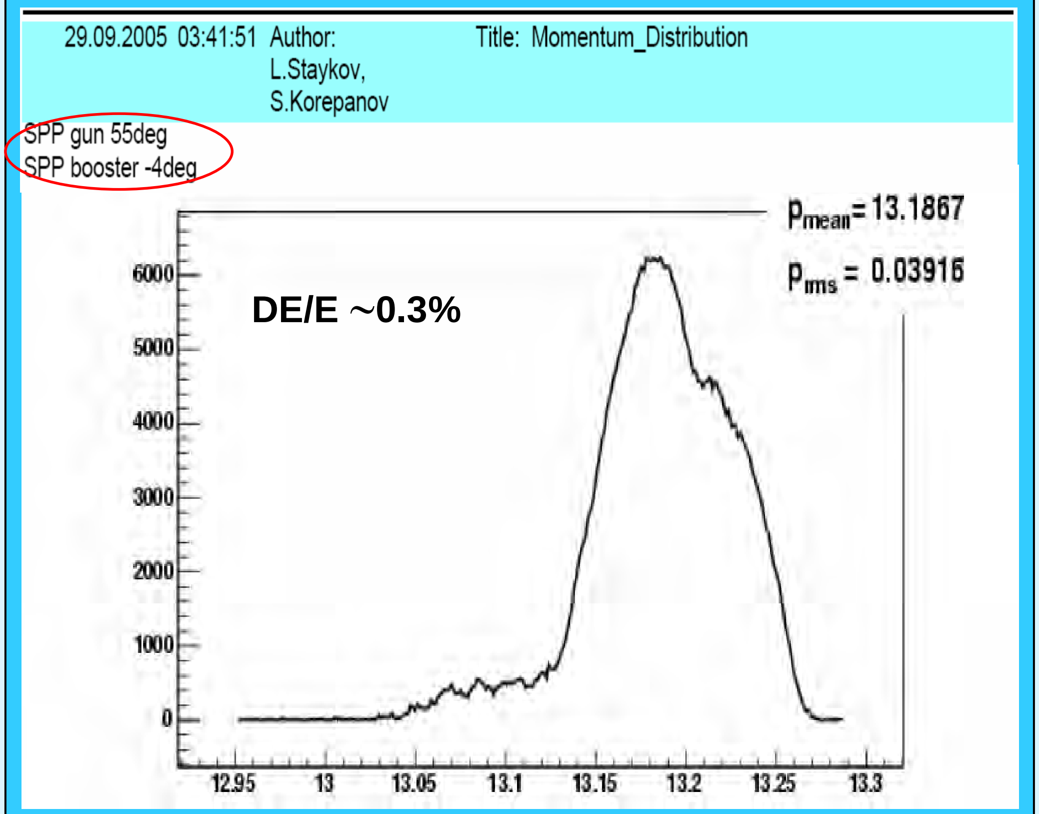


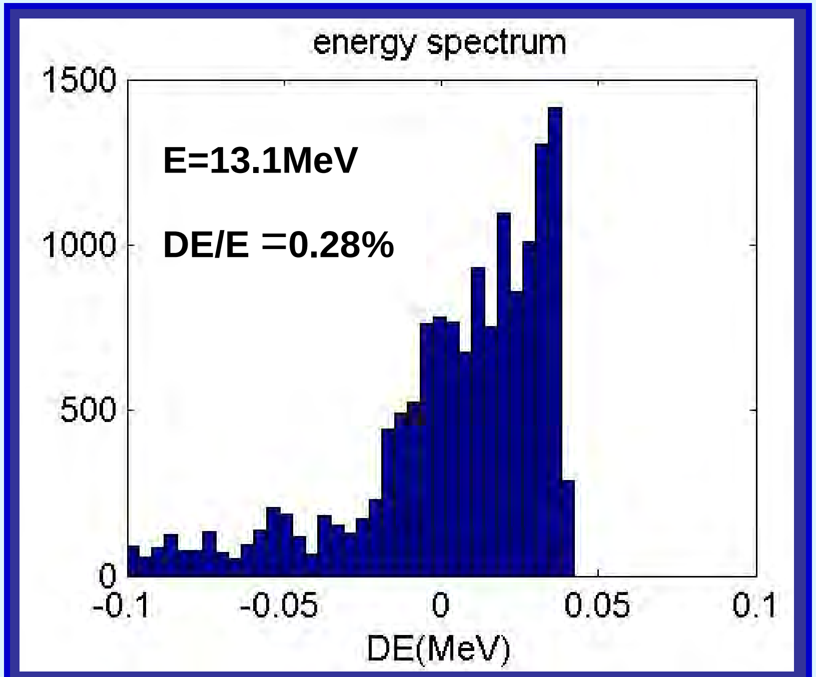


PARMELA simulation

$\Delta\phi = -3°$ at injection

Measurement





PARMELA simulation

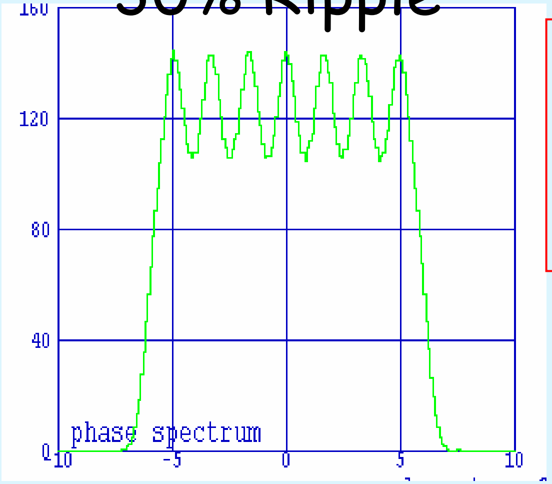
The measured energy spread behaviour versus injection phase is reproduced by simulations,

this measurement is a confirmation on studies carried on SPARC

Sensitivity studies for SPARC

[M. Ferrario et al. PAC03]

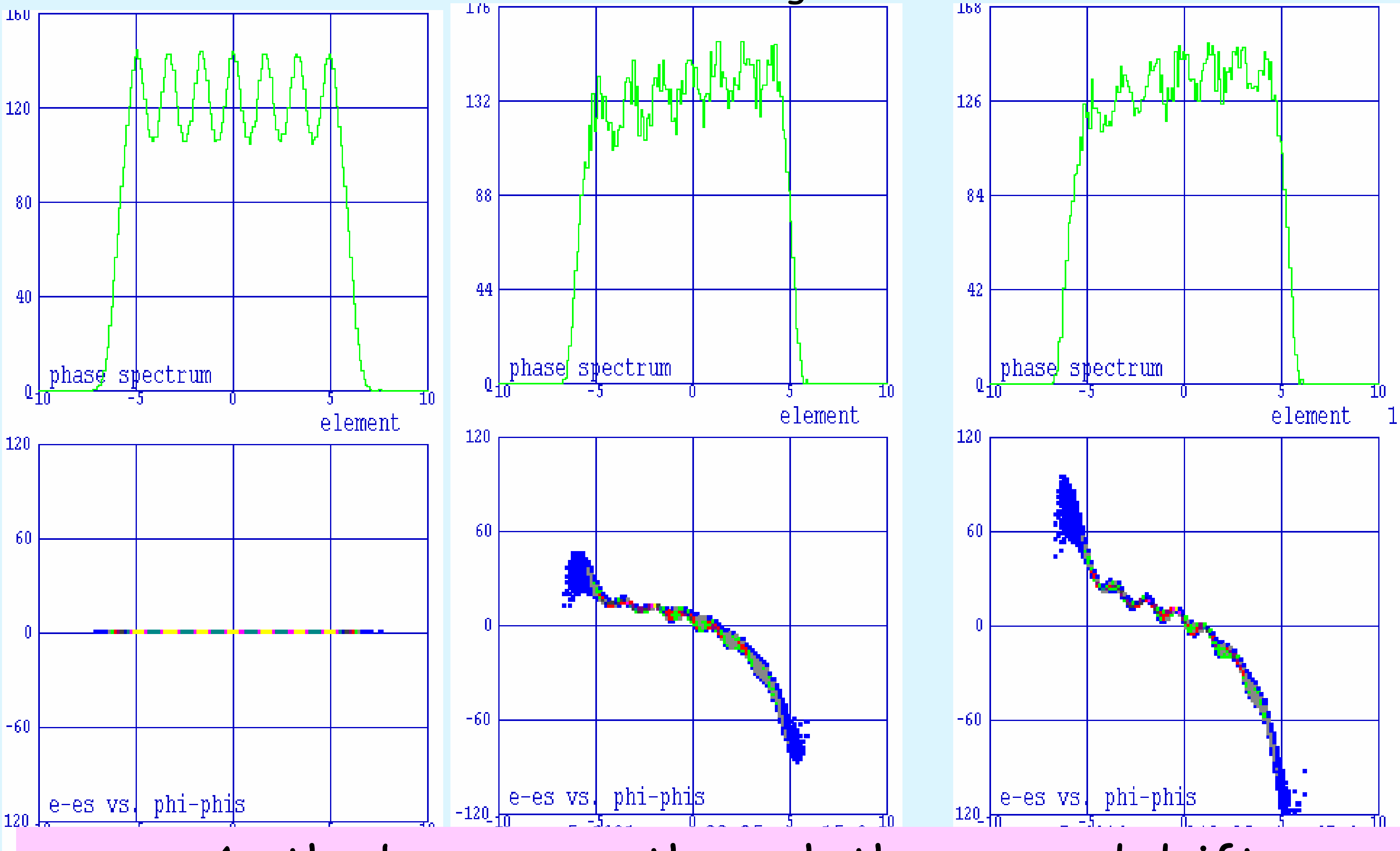
30% Ripple



L=10ps r.t.=1ps

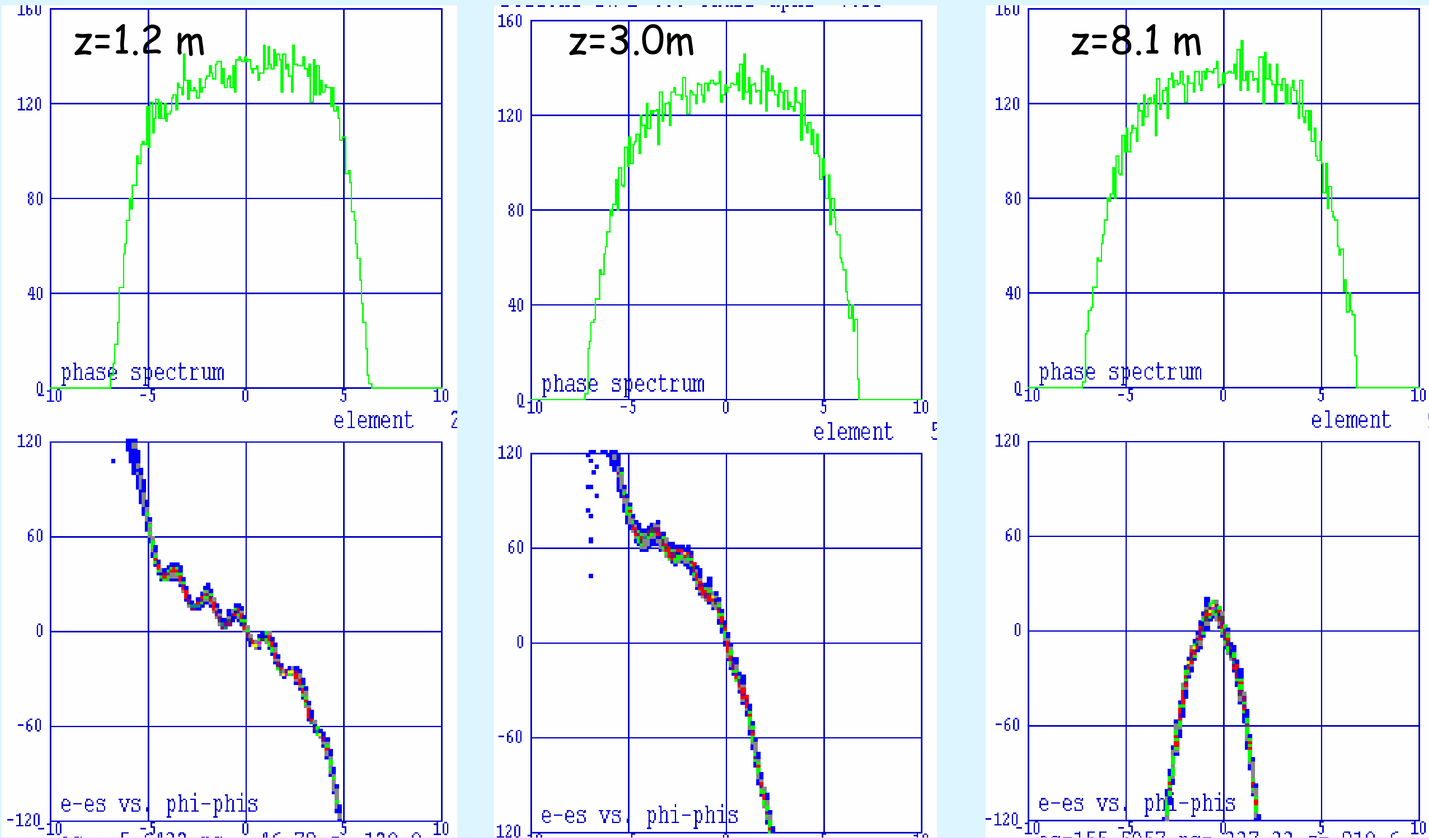
Even with a 30% longitudinal irregularity emittance is not affected substantially

there is a space-charge induced compensation of longitudinal laser irregularity (but transversely uniform) z=0 @cathode | z=15cm end gun | z=65cm



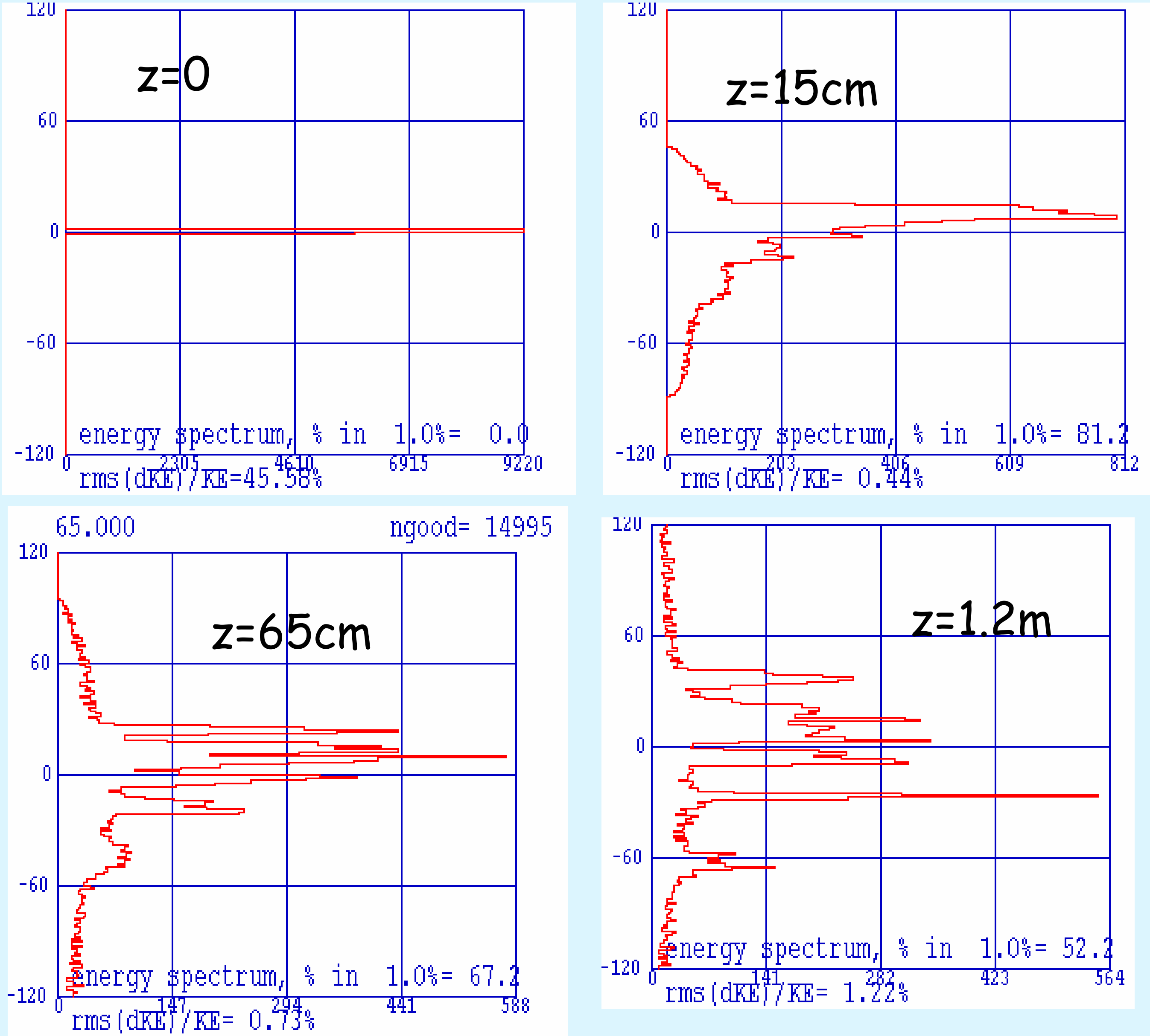
As the beam goes through the gun and drifts temporal oscillations transform into energy oscillations.

PARMELA simulation for the SPARC case



At the entrance of the first acceleration structure the beam has lost temporal ripples which have converted into energy ripples through a fractional plasma oscillation.

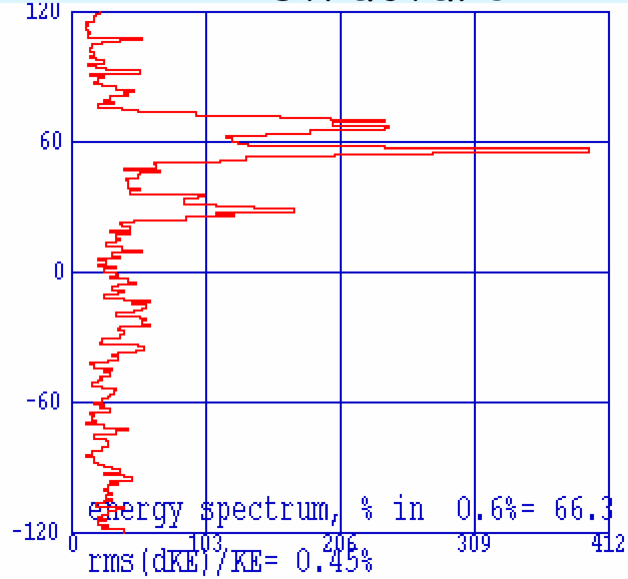
In the first acc. cavity energy ripples are suppressed, so energy spread at the end of the linac is not affected by this initial pulse shape



PARMELA simulation for the SPARC case

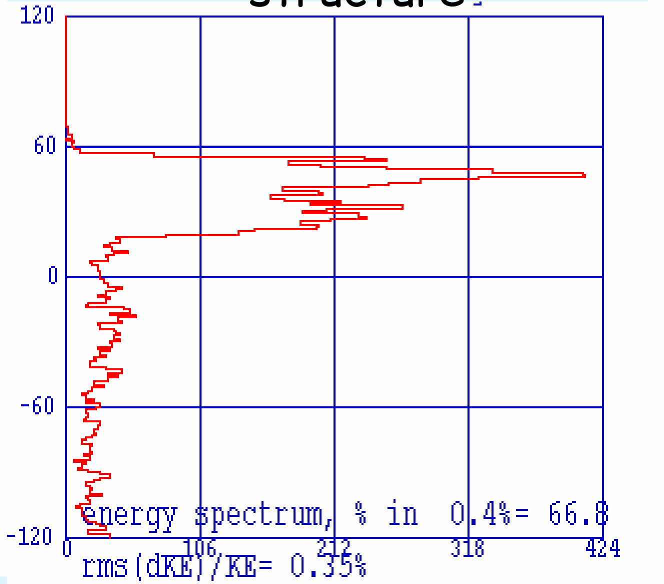
z=3m

in the first acc. structure



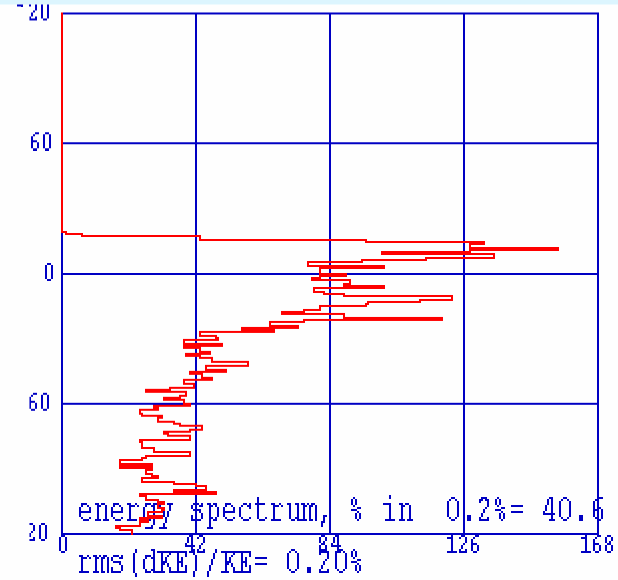
z=4m

end first acc. structure



z=8.1m

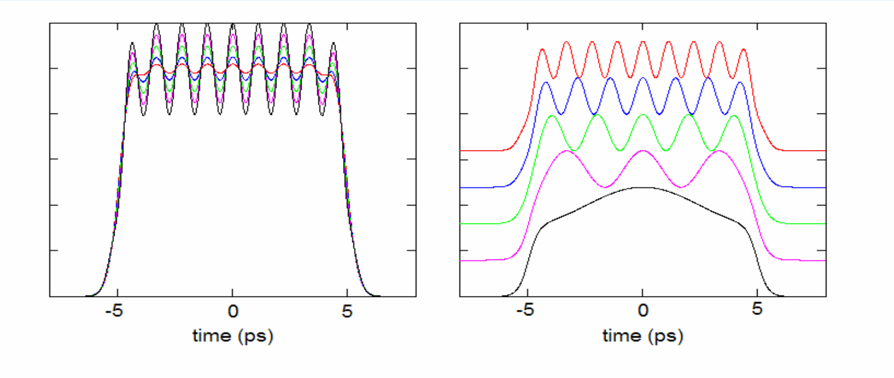
end linac



Energy spectrum in the end of the linac is not affected by these modulations: DE/E=0.2%

PARMELA simulations for the SPARC case

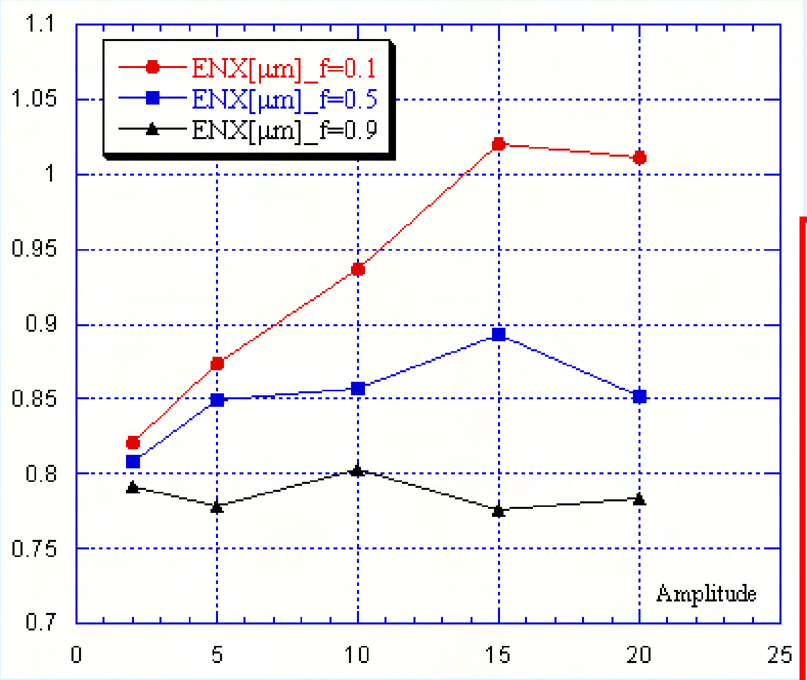
Laser pulse shaping effects in SPARC



Intensity temporal profiles with different amplitude oscillations

Intensity temporal profiles with different oscillation frequencies

PARMELA simulations



Projected horizontal emittance at the end of the SPARC linac

The value of the emittance remains substantially constant increasing the amplitude of the oscillations, as long as the frequency is sufficiently high.
The slope of the emittance-amplitude line decreases with the increase of the frequency.

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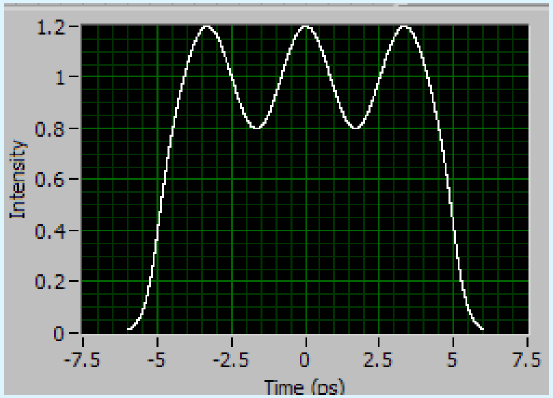
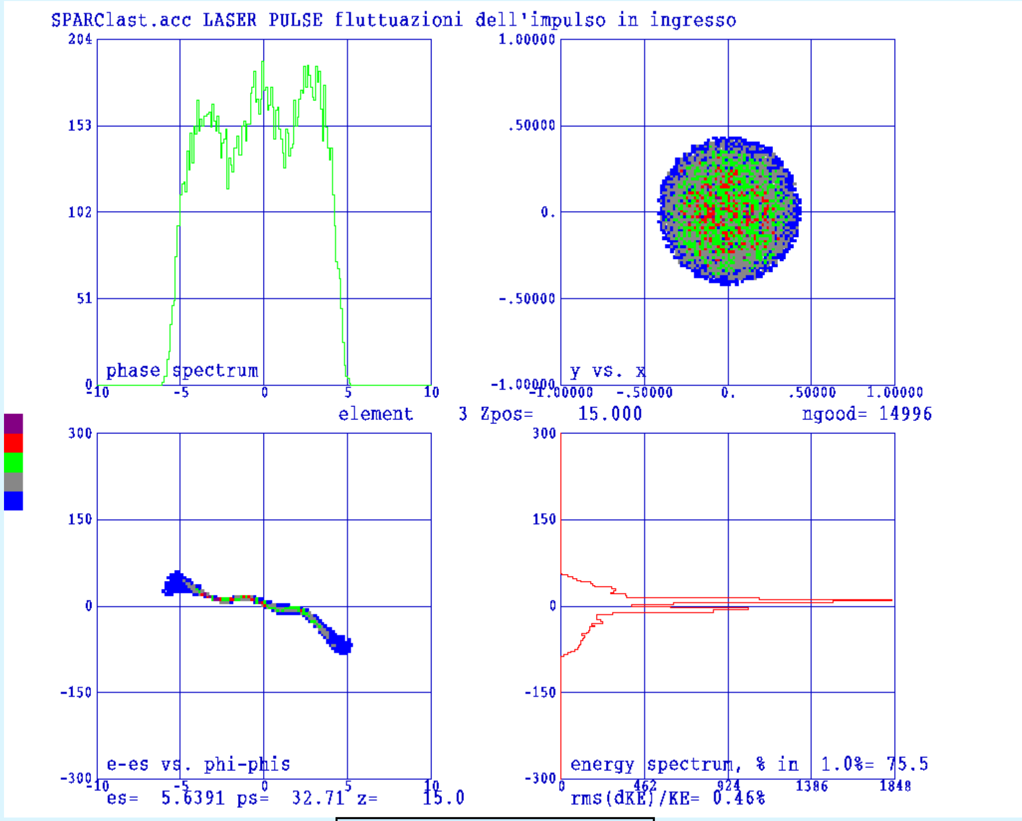
[M. Boscolo et al. PAC05]

PARMELA SIMULATION for SPARC



L=10ps r.t.=1ps
ampl. modulation on plateu=20%
low freq. ripples

@ Gun exit

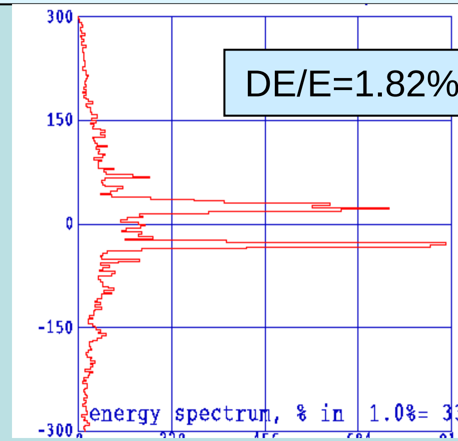


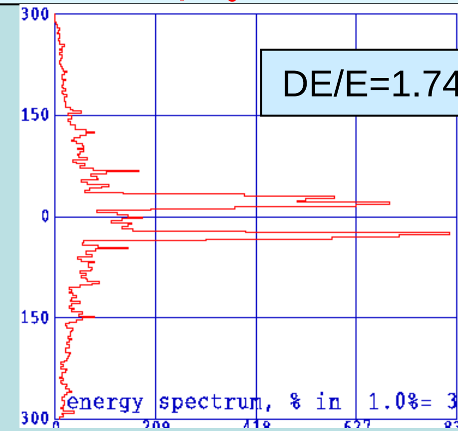
z=0.15m
E=5.6MeV
DE/E=0.46%

ON PHASE | $\phi_{inj}=-3°$

@ entrance 1° cav.

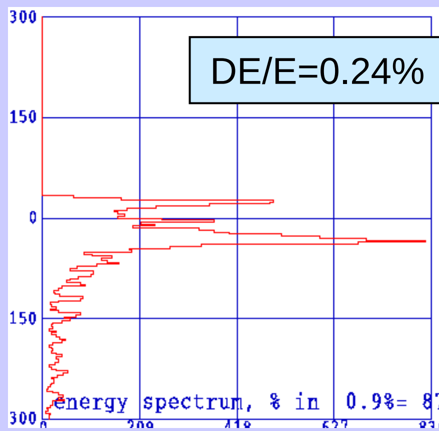
z=1.5m
E=5.6MeV

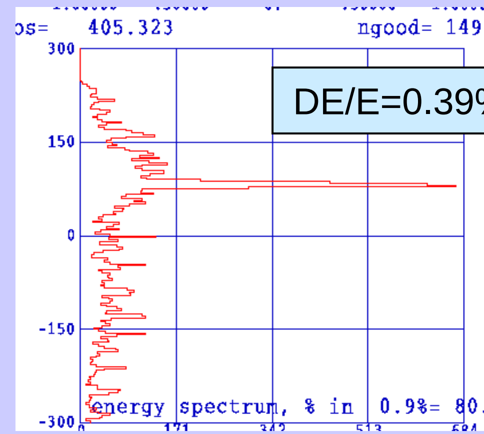




@ entrance 2° cav.

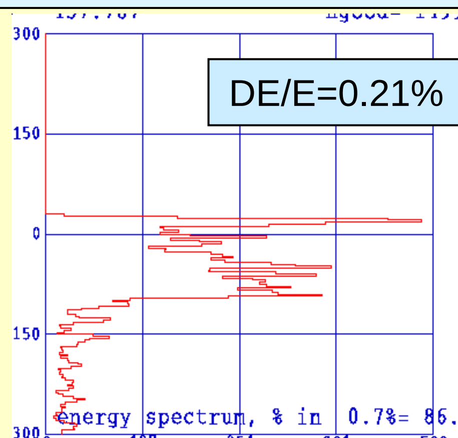
z=4.0m
E~68.6MeV

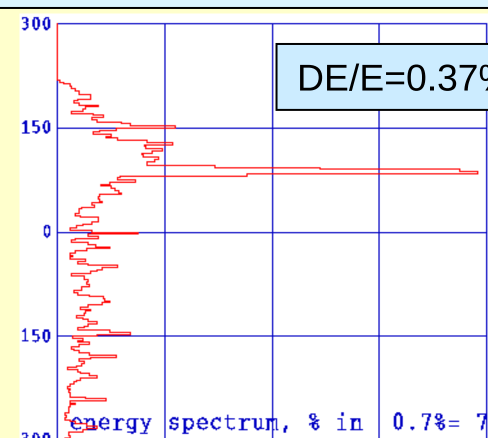




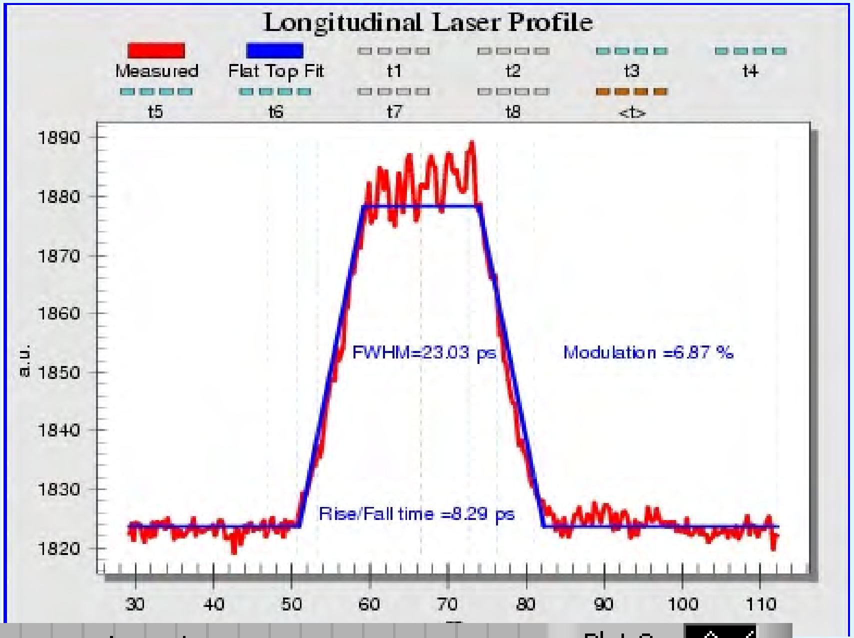
@ exit 2° cav.

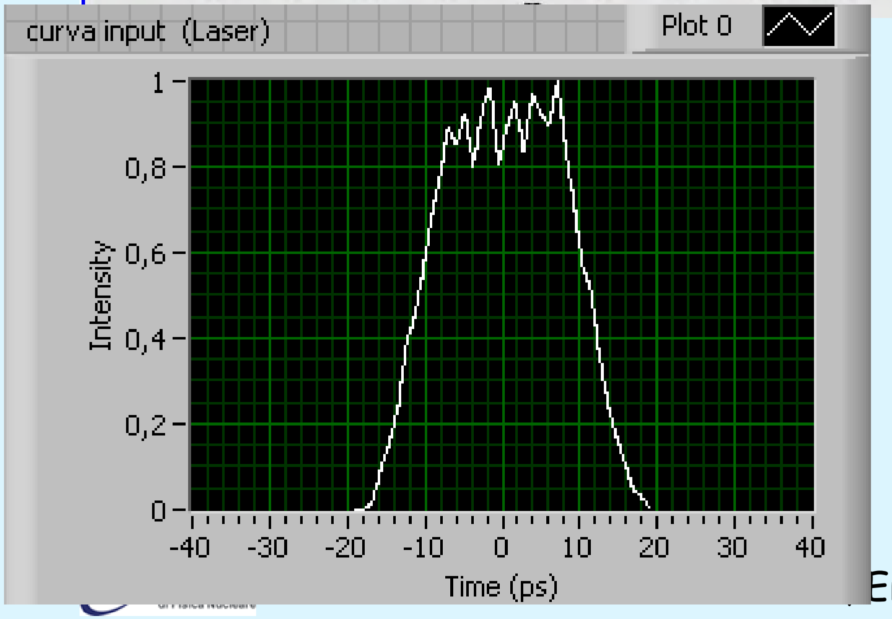
z=4.6m
E ~80.8MeV





Simulation with real laser profile
(measurement 29/09/05)





Q = 0.5nC

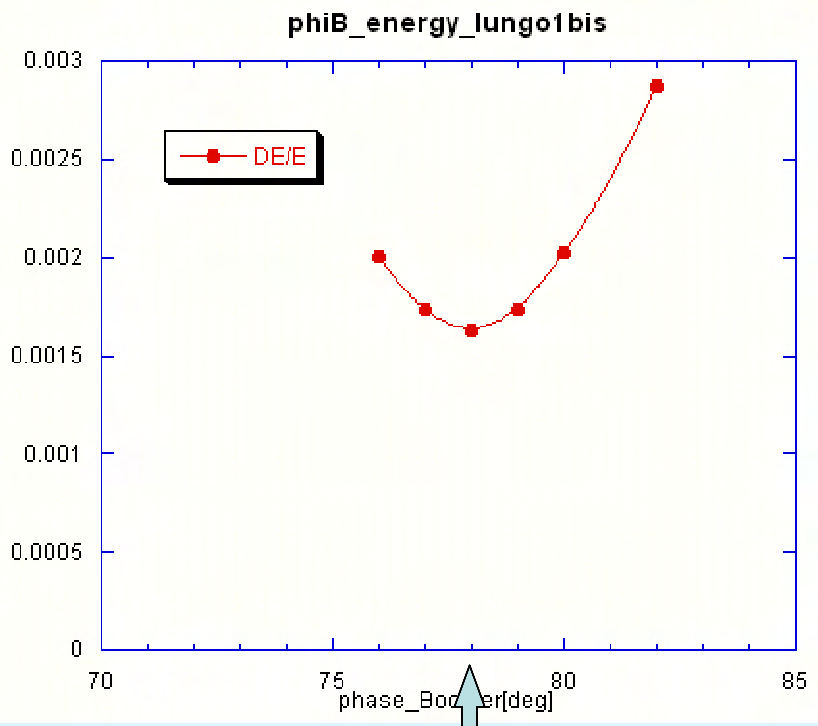
I(B) = 265A

at optimum phase at booster
a solenoid scan at e-emeter
and energy spread measurements
have been done

Solenoid scan at low beam current (0.5nC) emittance measurement at e-meter

At the optimum phase i.e.

phase that corresponds to a minimum energy spread

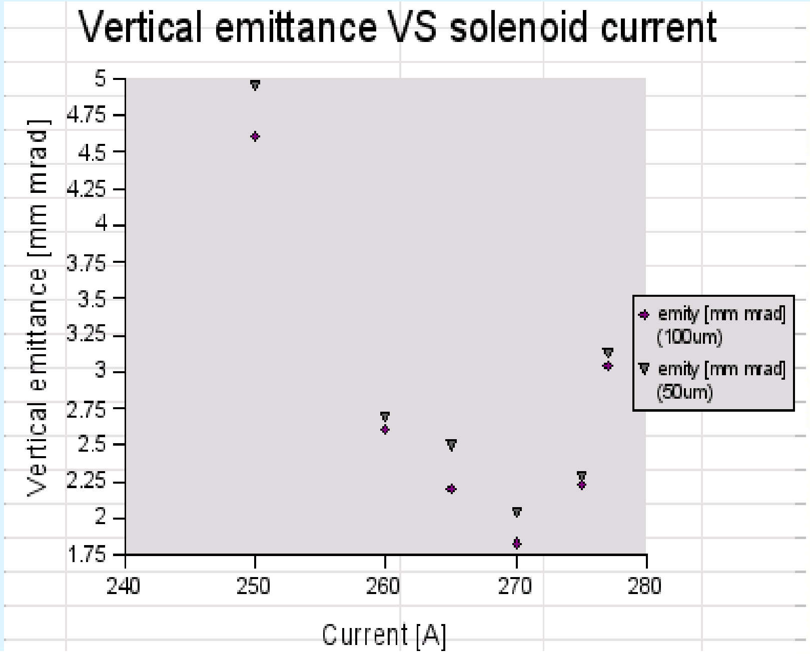


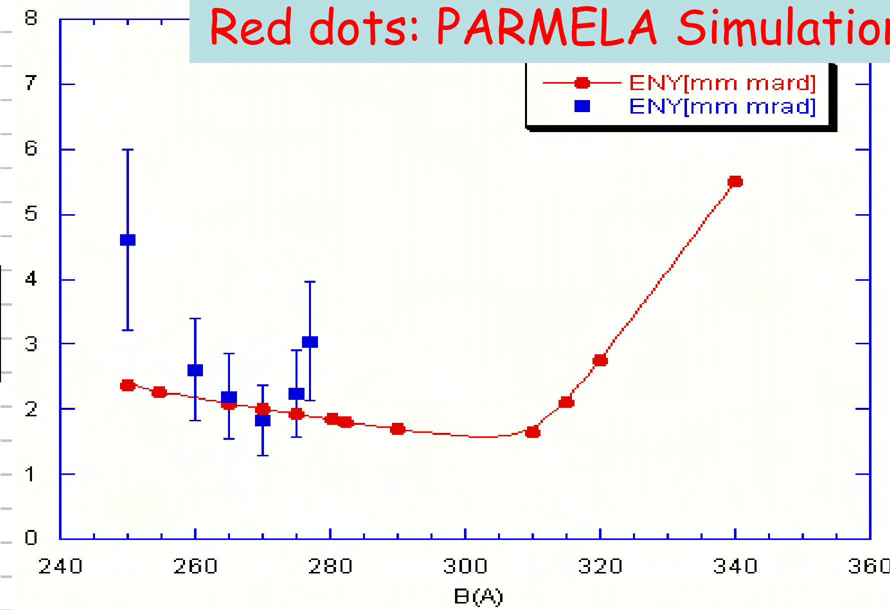
78º
at booster

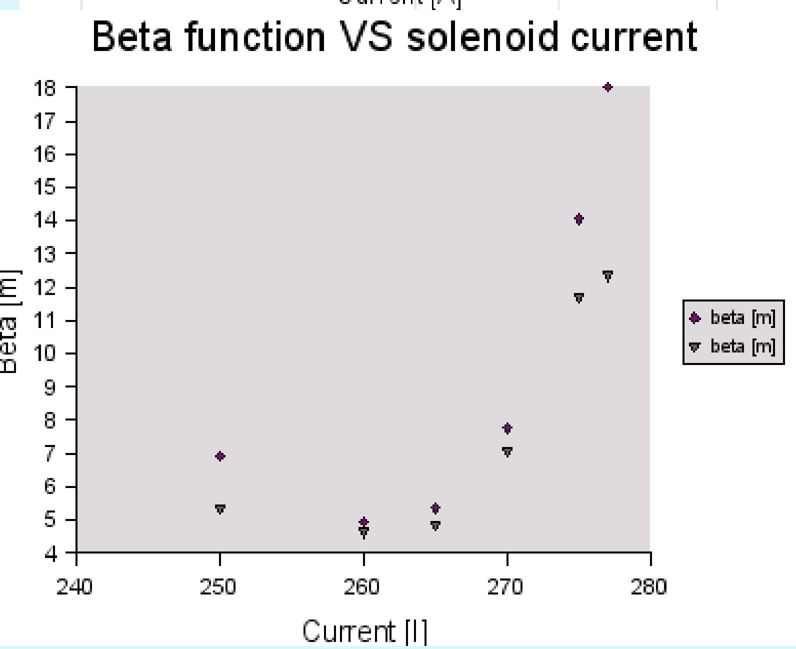
Measurement and simulations @e-meter z=7.7m

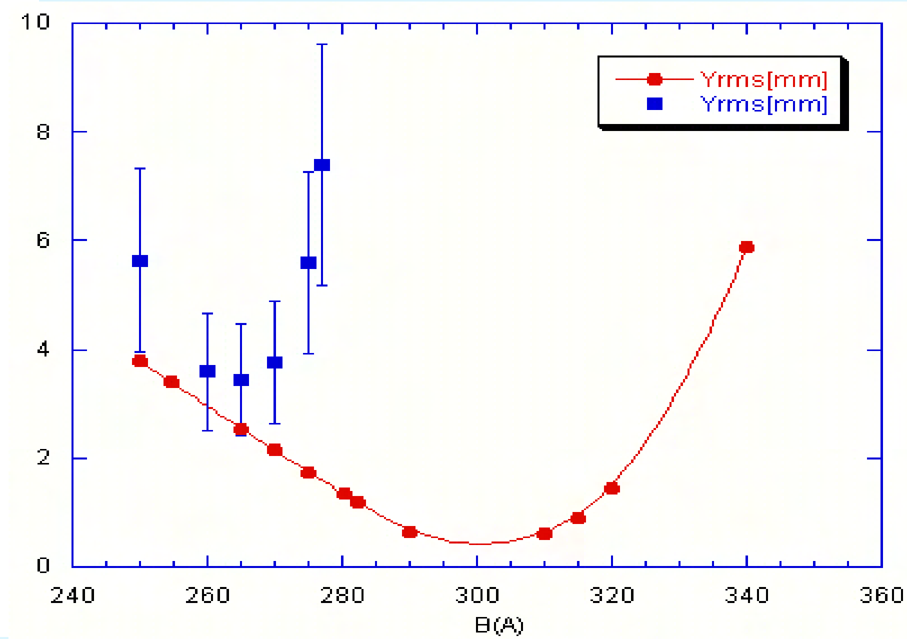
Blue dots: Measurements

Red dots: PARMELA Simulations



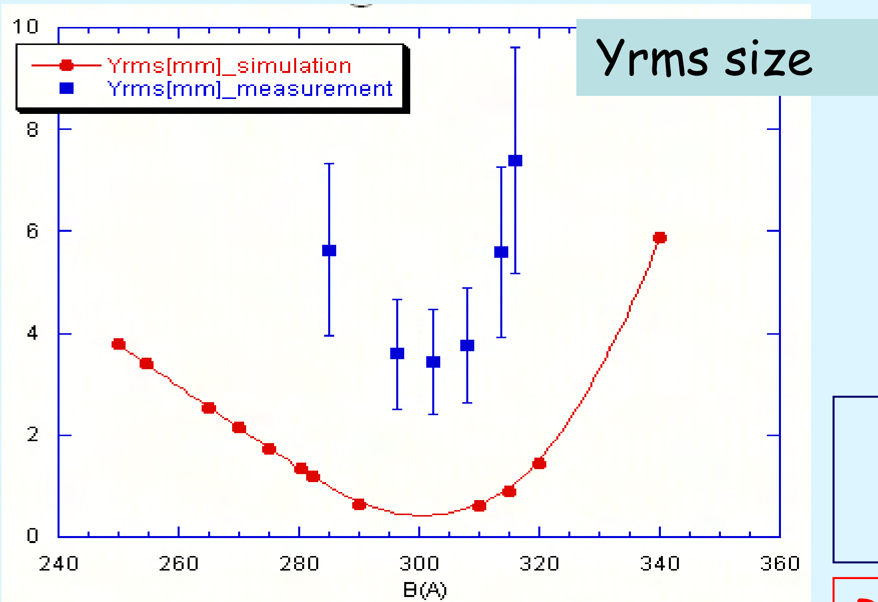






Measurement and simulations @e-meter z=7.7m

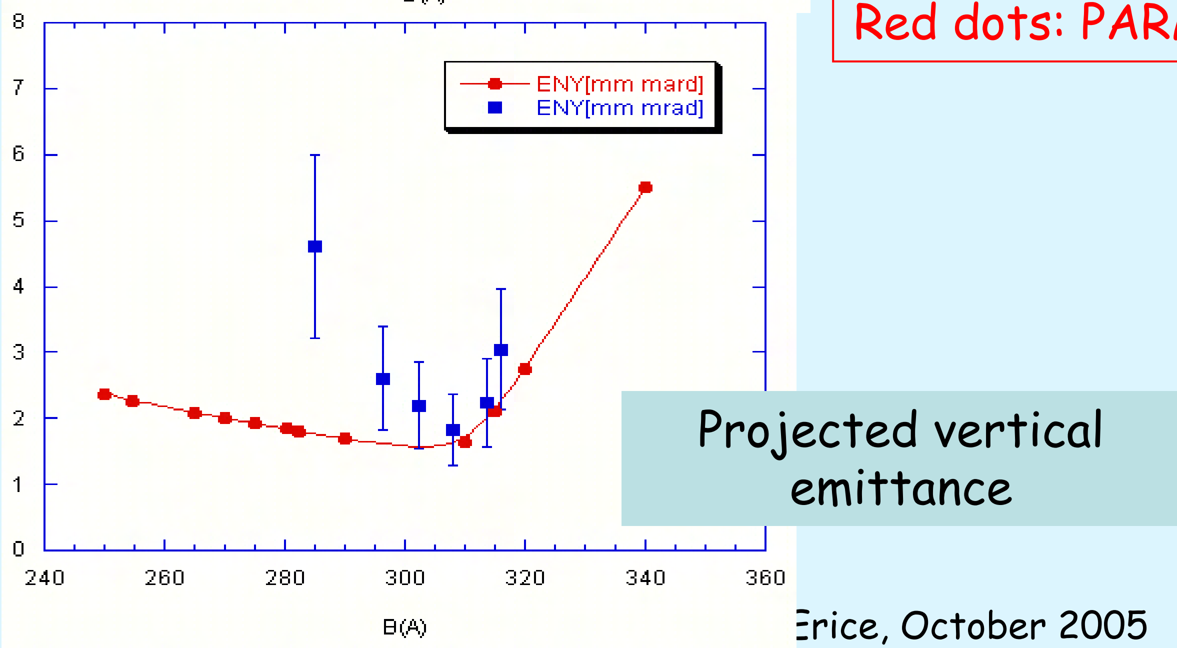
If we consider a 10% mismatch between the solenoid current and strength



Blue dots: Measurements

including a shift in B(I)

Red dots: PARMELA Simulations



Conclusions

- First simulations have been performed for the PITZ1.5 facility
- There are still some problems due to the limited knowledge of machine parameters, but
- an overall good agreement has been found.