START TO END SIMULATIONS AND MACHINE SENSITIVITY STUDY FOR THE ELI-NP γ-SOURCE

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on behalf of the
SPARC_LAB and ELI-NP team

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Start to end simulations and machine sensitivity study for the ELI-NP γ-source

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Abstract

The ELI-NP Gamma Beam System is an advanced gamma ray source up to 20 MeV based on Compton back-scattering effect, presently under construction in Magurele-Bucharest (RO). Here the head-on collision is foreseen between an intense high power laser beam and a high brightness electron beam with a maximum kinetic energy of 740 MeV. Start to end simulations of the ELI-NP Gamma Source are here presented regarding the machine sensitivity to the possible jitters and misalignments. The effects on the beam quality are illustrated providing the basis for the alignment procedure and jitters tolerances.

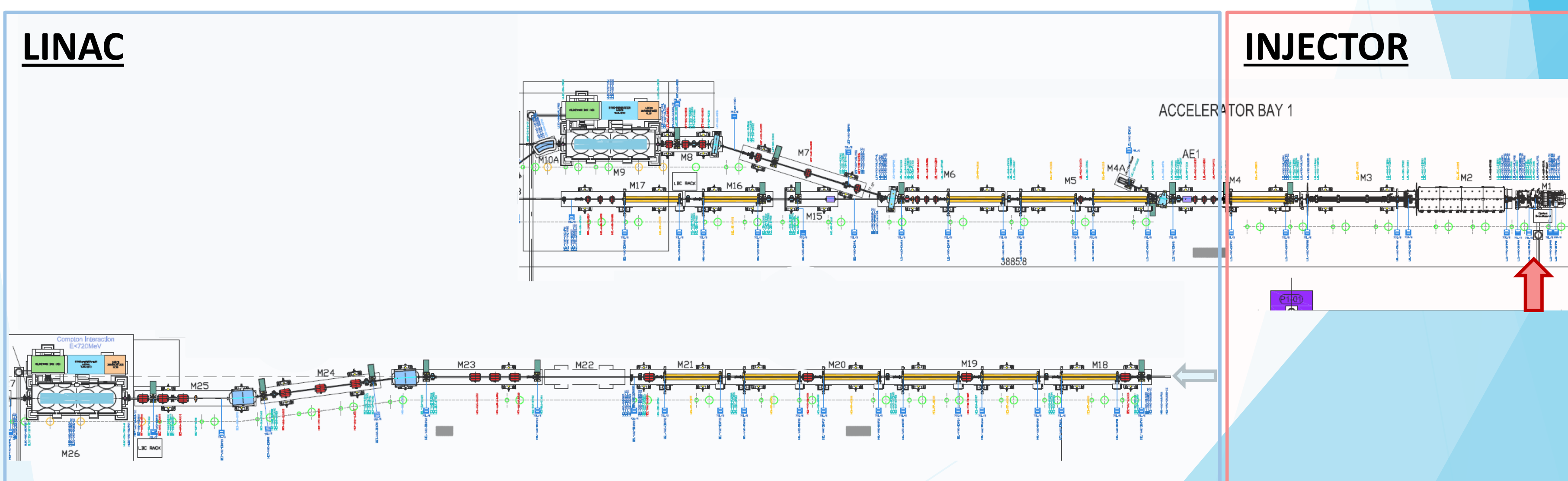
The ELI-NP γ-source

Peculiarities of the γ-source are:

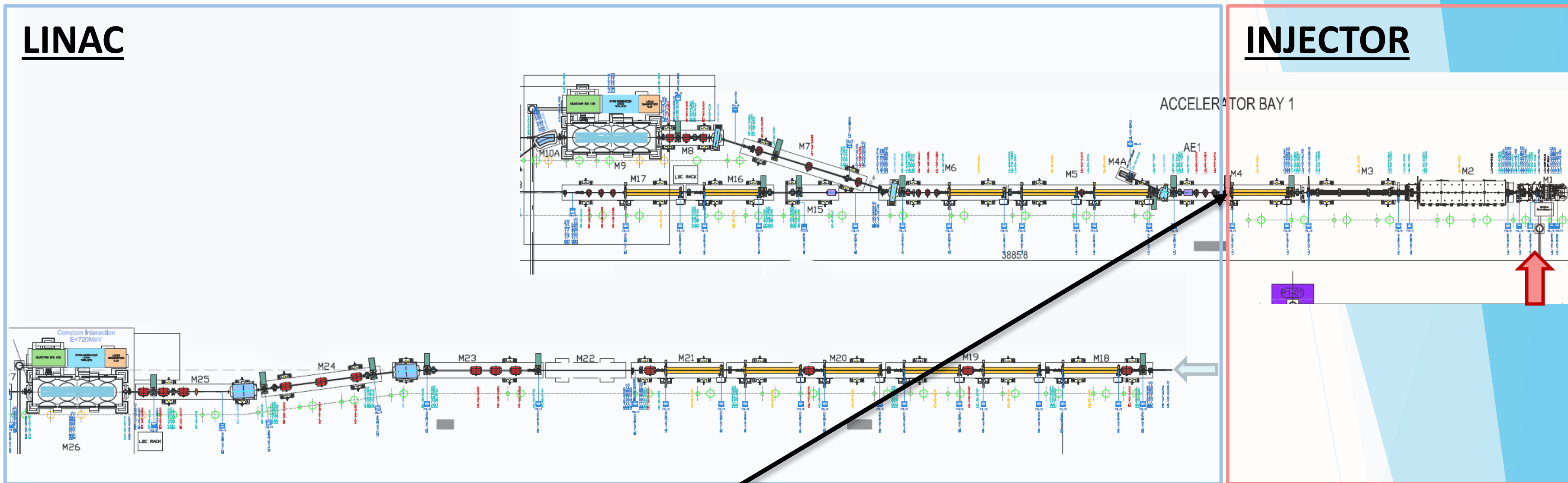
1. Energy tunability of the γ-source in the range [0.2 – 20.0] MeV

2. Mono-chromaticity of the γ-source with a BW (rms) ≤ 0.5%

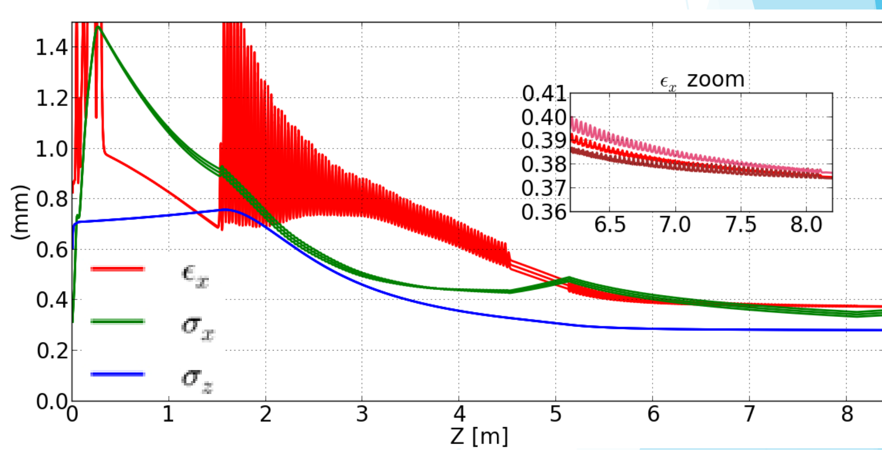
1. Energy Tunability of Electron Beam
2. 0.04% ≤ Energy Spread of Electron Beam (%) ≤ 0.1%



The ELI-NP γ-source



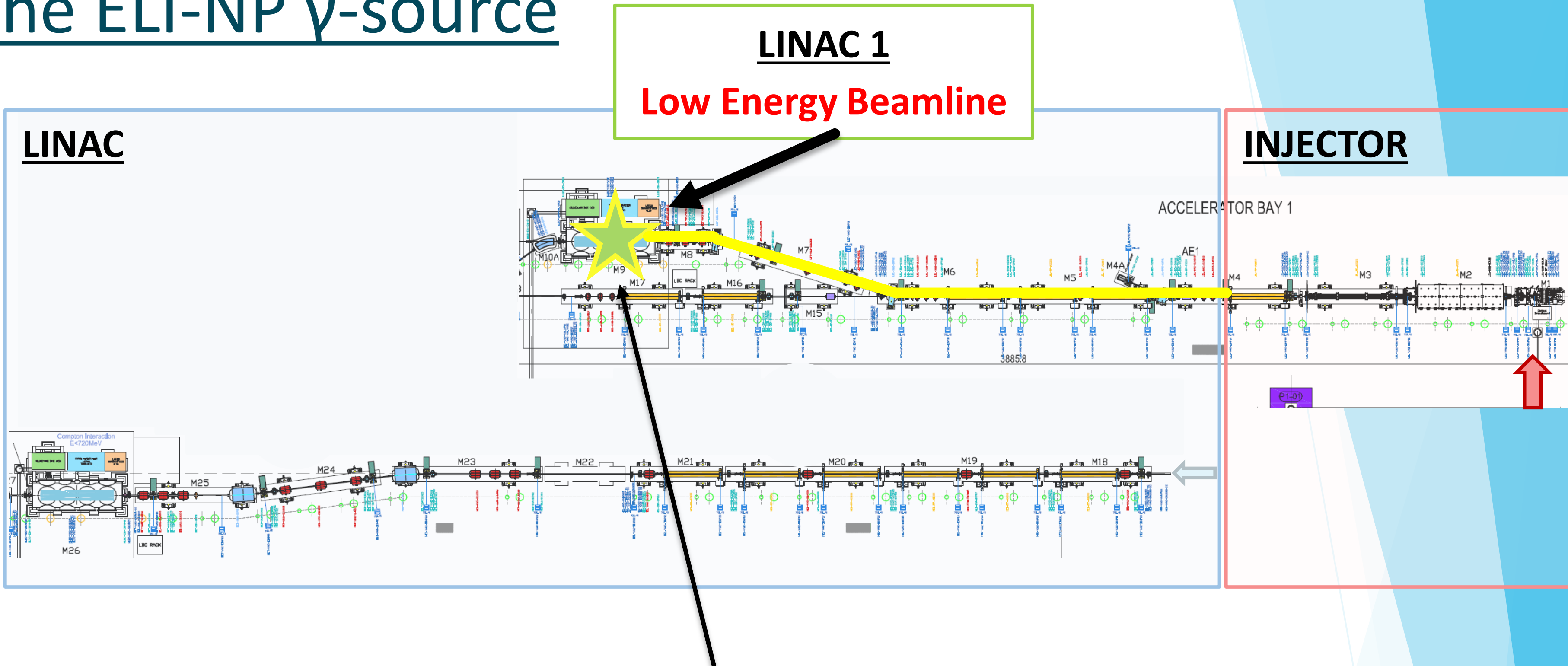
81 MeV @Injector Exit		
Bunch charge	250	pC
Energy spread	0.161	%
Bunch length	282	µm
$\varepsilon_{n_{x,y}}$	0.4	mm mrad
Spot Size	390	µm

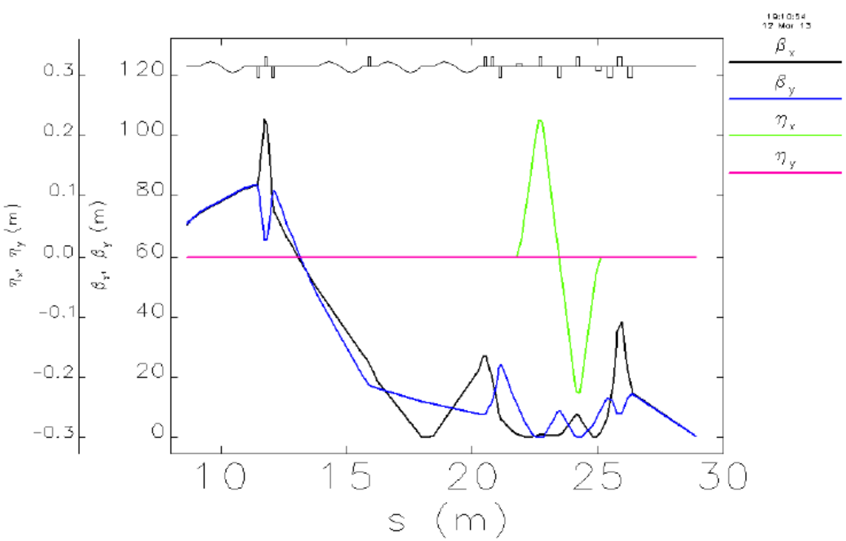


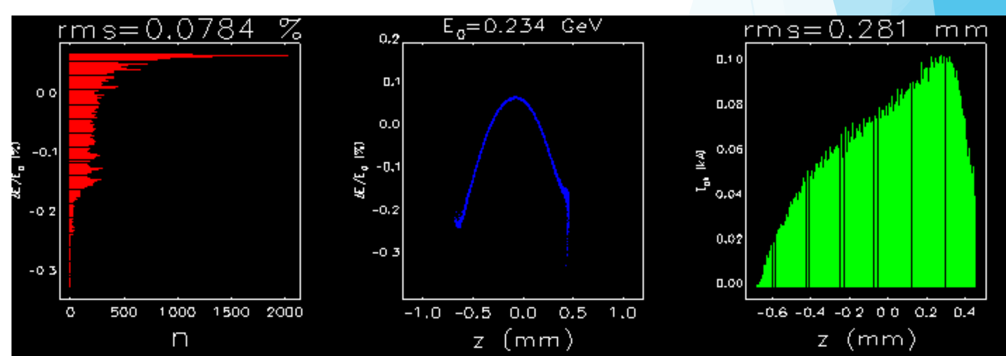
Rms normalized transverse emittance, rms transverse envelope and rms bunch length at the injector exit

Courtesy of A. Bacci – INFN-MI

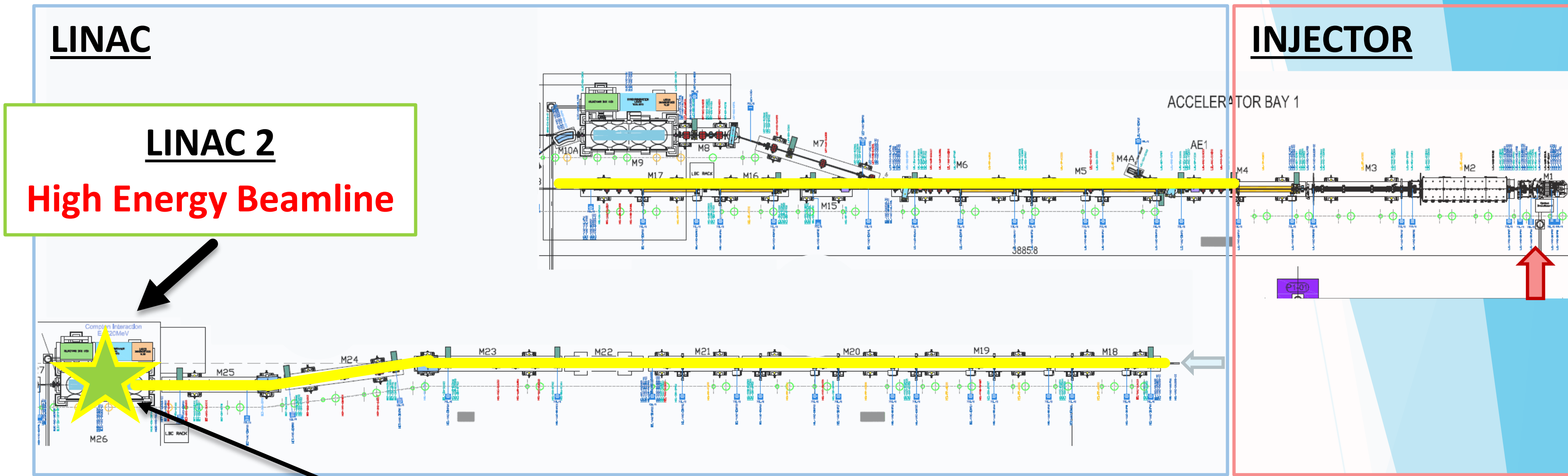
The ELI-NP γ-source

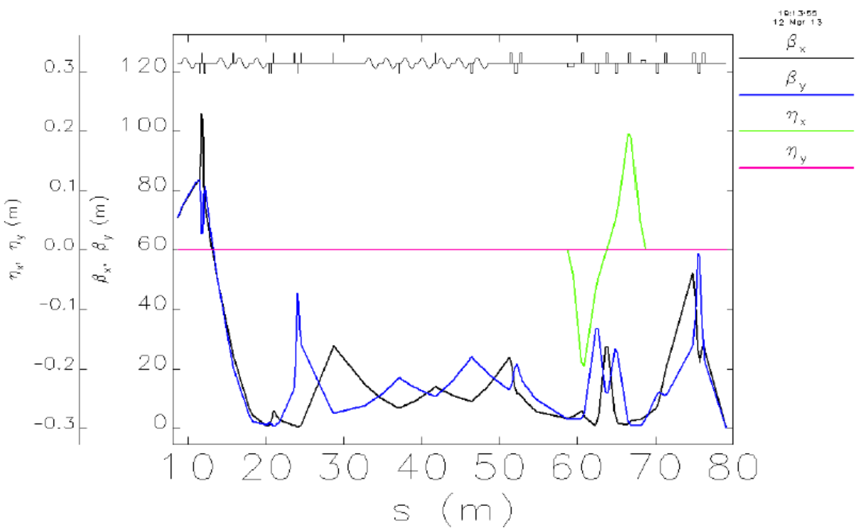


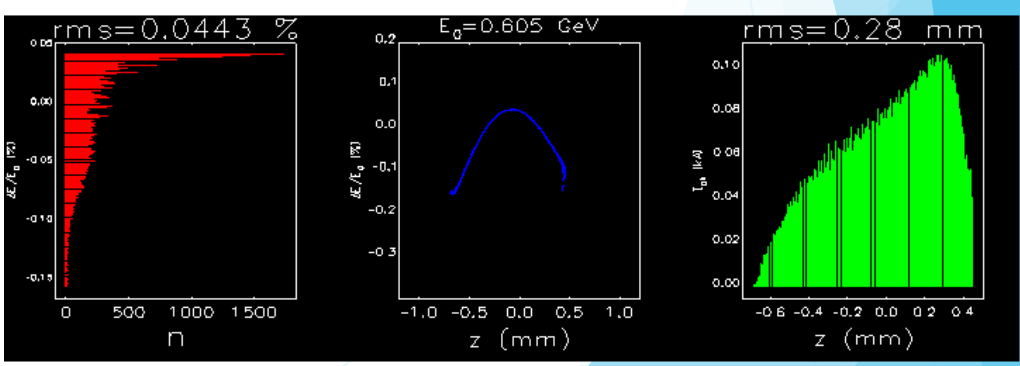




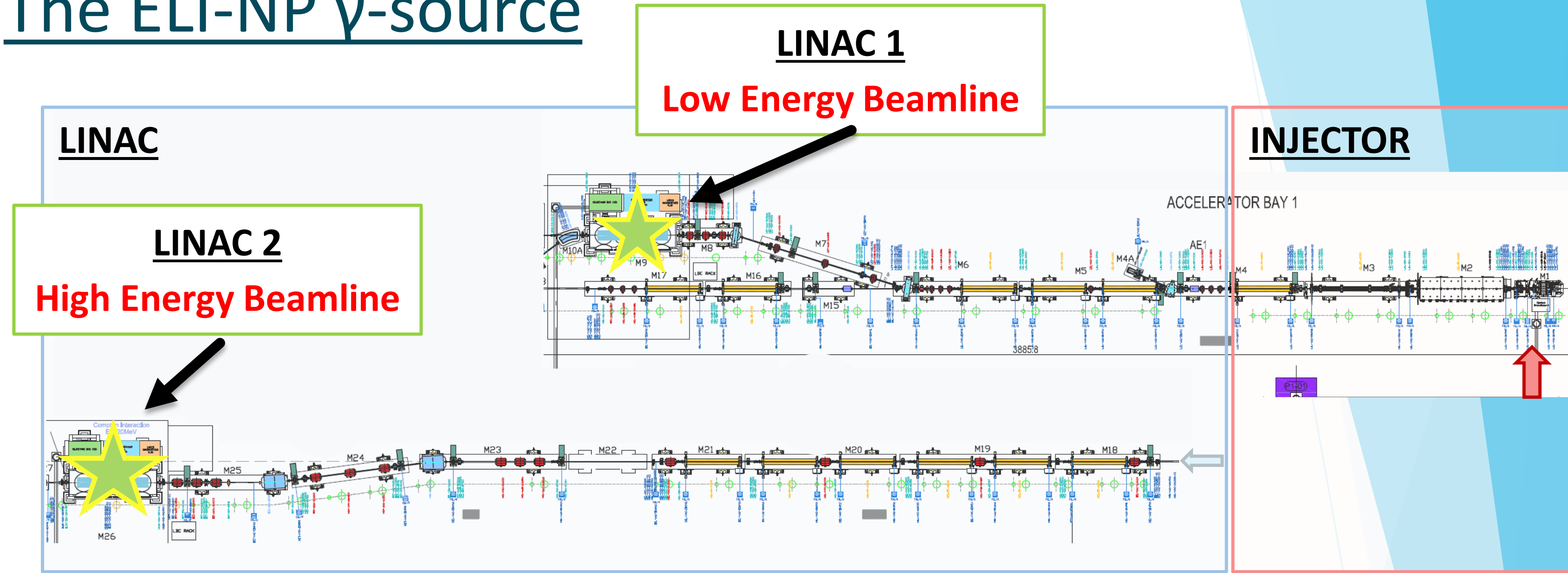
The ELI-NP γ-source







The ELI-NP γ-source



Beams Parameters @IP		
Electron Beam Q = 25 - 400 pC		
Energy	80 - 740	MeV
Energy spread	0.04 - 0.1	%
Bunch length	100 - 400	μm
$\varepsilon_{n_{x,y}}$	0.2 – 0.6	mm mrad
Focal Spot Size	> 15	μm
Laser Beam λ = 515 nm		
Energy	0.2 – 0.4	J
Focal Spot Size	> 28	μm

GBS - Beam Specifications		
Energy	0.2 – 20.0	MeV
Flux within FWHM BW	≤ $2.6 \cdot 10^5$	N_{ph}/pulse
Peak brilliance	10^{20} - 10^{23}	$N_{ph}/s \cdot mm^2 \cdot mrad^2 \cdot 0.1\%$
BW (rms)	≤ 0.5	%
Source Size	10 - 30	μm

Technical Design Report

E-Gammas proposal for the ELI-NP Gamma beam System

With 79 tables and 252 figures

O. Adriani, S. Albergo, D. Alesini, M. Anania, D. Angal-Kalinin, P. Antici, A. Bacci, R. Bedogni, M. Bellaveglia, C. Biscari, N. Bliss, R. Boni, M. Boscolo, F. Broggi, P. Cardarelli, K. Cassou, M. Castellano, L. Catani, I. Chaikovska, E. Chiadroni, R. Chiche, A. Cianchi, J. Clarke, A. Clozza, M. Coppola, A. Courjaud, C. Curatolo, O. Dadoun, N. Delerue, C. De Martinis, G. Di Domenico, E. Di Pasquale, G. Di Pirro, A. Drago, F. Druon, K. Dupraz, F. Egal, A. Esposito, F. Falcoz, B. Fell, M. Ferrario, L. Ficcadenti, P. Fichot, A. Gallo, M. Gambaccini, G. Gatti, P. Georges, A. Ghigo, A. Goulden, G. Graziani, D. Guibout, O. Guilbaud, M. Hanna, J. Herbert, T. Hovsepian, E. Iarocci, P. Iorio, S. Jamison, S. Kazamias, F. Labaye, L. Lancia, F. Marcellini, A. Martens, C. Maroli, B. Martlew, M. Marziani, G. Mazzitelli, P. McIntosh, M. Migliorati, A. Mostacci, A. Mueller, V. Nardone, E. Pace, L. Palumbo, A. Pelorosso, F.X. Perin, G. Passaleva, L. Pellegrino, V. Petrillo, M. Pittman, G. Riboulet, R. Ricci, C. Ronsivalle, D. Ros, A. Rossi, L. Serafini, M. Serio, F. Sgamma, R. Smith, S. Smith, V. Soskov, B. Spataro, M. Statera, A. Stecchi, A. Stella, A. Stocchi, S. Tocci, P. Tomassini, S. Tomassini, A. Tricomi, C. Vaccarezza, A. Variola, M. Veltri, S. Vescovi, F. Villa, F. Wang, E. Yildiz, F. Zomer

SAPIENZA UNIVERSITÀ DI ROMA
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UNIVERSITE PARIS SUD Comprendre le monde, construire l'avenir

Machine Error Sensitivity Studies

The Method:

- The beamline has been preliminary matched for the ideal electron beam.
- Misalignments and jitters have been introduced both in the injector and all along the linac with the aim to provide specifications for jitters and alignments of accelerating structures and magnets.
- Error matrices from injector and linac have been coupled one with each other randomly.
- Error value distributions are calculated according to the latin hypercube scheme (as reported in the TDR) by using a matrix of the latin hypercube randomly factorizes in the range [-100 : +100]% of error values.
- Data analysis has been done on 100 bunches, each composed of 30k macro particles.

Injector Error Sensitivity Studies

Specifications for cathode laser system, power supplies and solenoids

- Injector sensitivity analysis has been performed over a random sampling of 100 runs, by using the codes Giotto and Astra.

- In table the considered errors on all devices

Errors on GUN		
RF Voltage [ΔV]	0.2	%
RF Phase [Δϕ]	200	fs
Errors on S-band Accelerating Sections		
RF Voltage [ΔV]	0.2	%
RF Phase [Δϕ]	200	fs
Alignment on transverse plane [Δxy]	70	μm
Errors on Solenoids (GUN & TW cavities)		
Alignment on transverse plane [Δxy]	70	μm
Errors on Cathode Laser System		
Arrival time [Δt]	200	fs
Pointing Instabilities [Δs]	20	μm
Energy Fluctuation	5	%

Courtesy of A. Bacci – INFN-MI

Linac Error Sensitivity Studies

Specifications for power supplies and magnetic elements

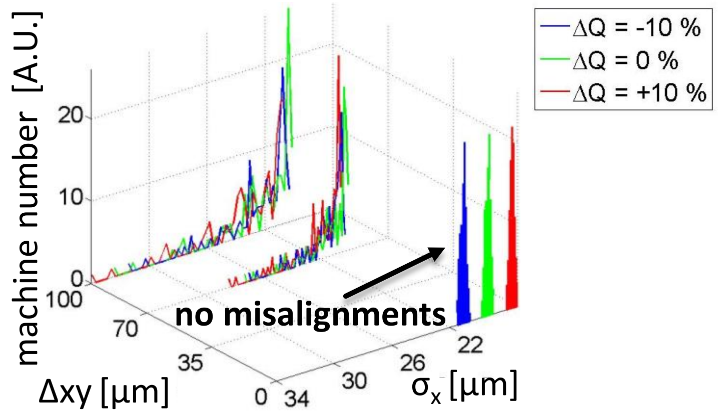
- Linac sensitivity analysis has been performed over a recursive sampling of 100 runs, by using the Elegant code.
- In table the considered errors on all devices

Errors on C-band Accelerating Sections		
RF Voltage [ΔV]	0.2	%
RF Phase [Δϕ]	1	Deg
Alignment on transverse plane [Δxy]	0,70,100	µm
Errors on Quadrupoles		
Geometric strength [Δk]	0.3	%
Alignment on transverse plane [Δxy]	0,70,100	µm
Rotation about incoming longitudinal axis [ΔΘ]	1	mrad
Errors on Dipoles		
Bend angle [ΔB]	0.1	%
Rotation about incoming longitudinal axis [ΔΘ]	1	mrad
Errors on Steerers		
Strenght Jitters [ΔB]	0.2	µrad
Errors on BPMs		
Noise	20	µm

Linac Error Sensitivity Studies

Specifications for power supplies and magnetic elements

- Machine sensitivity analysis suggests that the most critical parameters are the RF phase jitter on accelerating structures and misalignments on magnetic elements



Electron beam spot size at low energy IP in case of Δxy=70-100µm, jitters on RF system and on magnetic elements

Linac Error Sensitivity Studies

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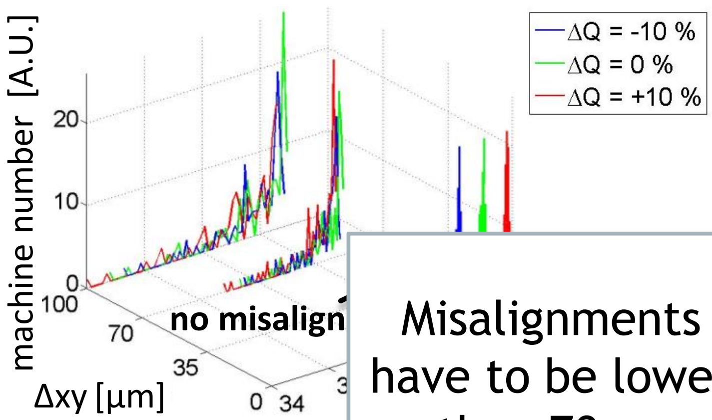

Misalignments have to be lower than 70μm

Electron beam spot size a
of Δxy=70-100μm, jitters
magnetic elements

Linac Error Sensitivity Studies

Specifications for power supplies and magnetic elements

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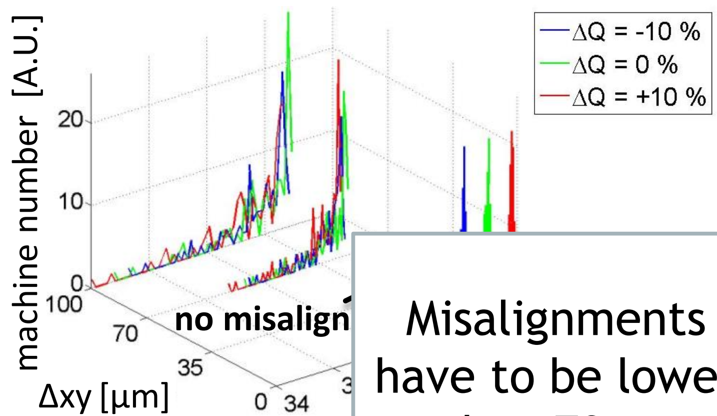
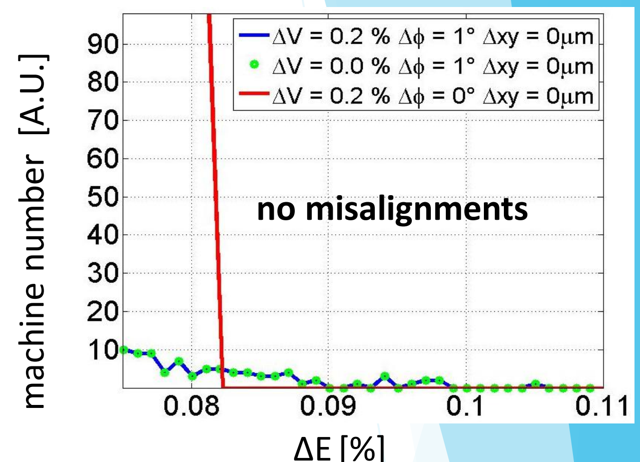


Misalignments have to be lower than 70µm

Electron beam spot size a [illegible] of Δxy=70-100µm, jitters [illegible] magnetic elements



Energy spread [%] for the nominal 250pC electron beam in case of RF jitters

Linac Error Sensitivity Studies

Specifications for power supplies and magnetic elements

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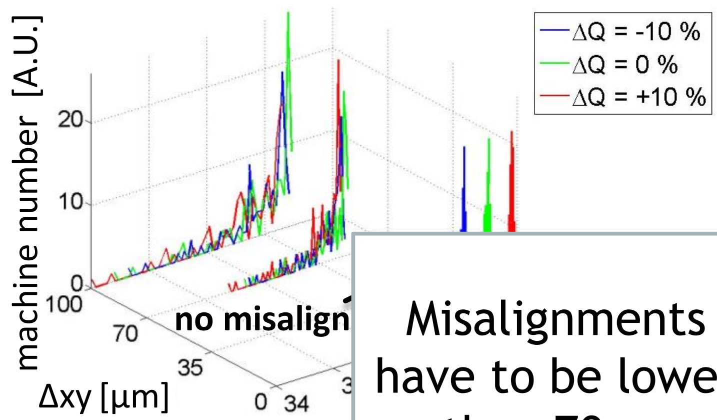
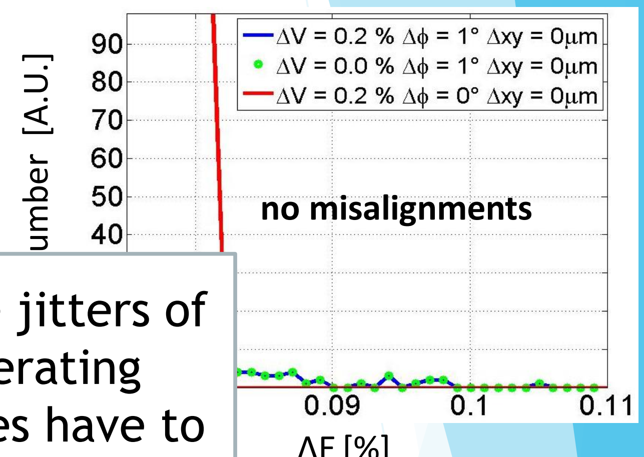


Misalignments have to be lower than 70μm

Electron beam spot size a
of Δxy=70-100μm, jitters
magnetic elements



RF phase jitters of accelerating structures have to be lower than 1°

ad [%] for the nominal 250pC
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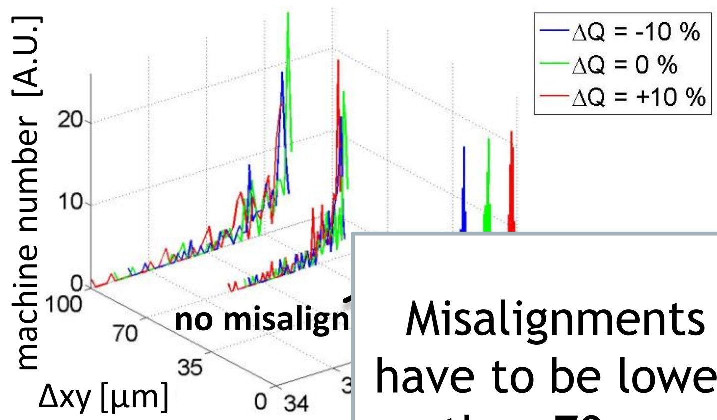
Linac Error Sensitivity Studies

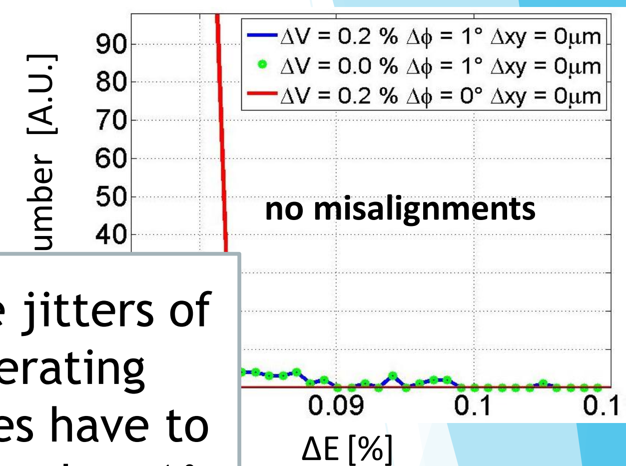
Specifications for power supplies and magnetic elements

- Machine sensitivity analysis suggests that the most critical parameters are the RF phase jitter on accelerating structures and misalignments on magnetic elements



Misalignments have to be lower than 70μm

Electron beam spot size a… of Δxy=70-100μm, jitters on RF system and on magnetic elements



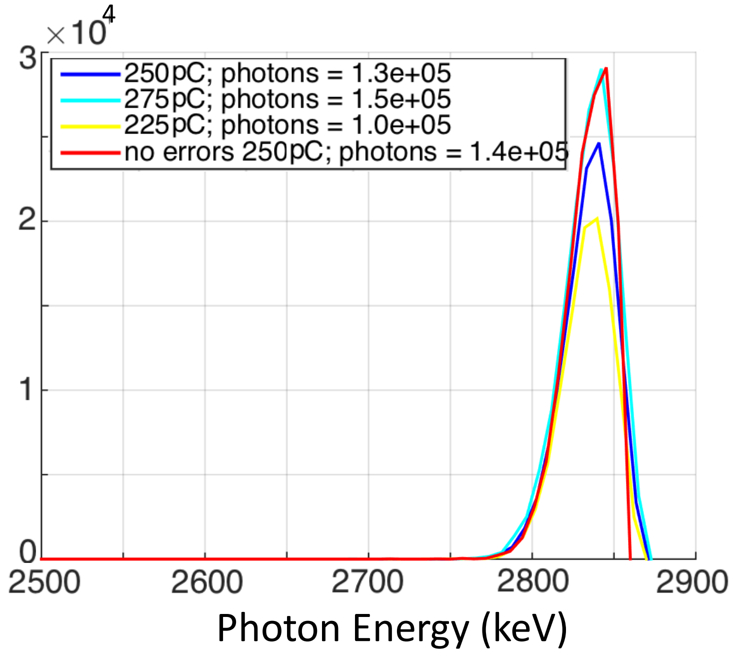
RF phase jitters of accelerating structures have to be lower than 1°

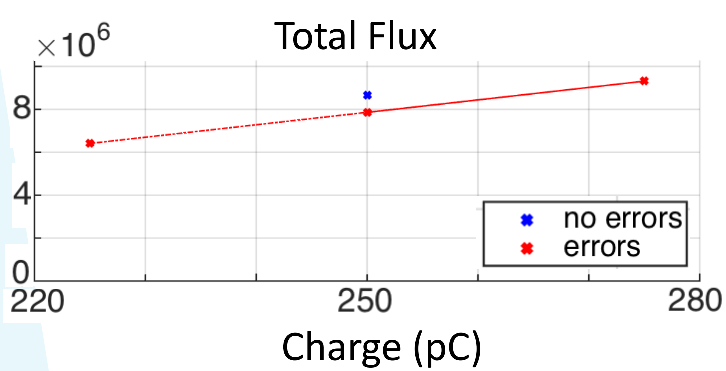
…ad [%] for the nominal 250pC electron beam in case of RF jitters

280 MeV @IP	Without errors	With errors	
Bunch charge	250	250 ± 25	pC
Energy spread	0.075	0.079 ± 0.039	%
Bunch length	280	273.3 ± 4.6	µm
$\varepsilon_{n_{x,y}}$	0.45	0.48 ± 0.03	mm mrad
Focal Spot Size	20.0	23.9 ± 1.5	µm
ΔC_{x-y}	0	8 ± 2	µm

ELI-NP γ-Source

- γ-source sensitivity analysis has been performed in order to investigate degradation of the bandwidth and flux due to misalignments and jitters in the linac.





2.85 MeV @IP	Without errors	With errors	
Electron bunch charge	250	250 ± 25	pC
Collimation Angle [Θ]	192.5	192.5	μrad
Total Flux	$8.7 \cdot 10^6$	$(8.0 \pm 1.7) \cdot 10^6$	N_{ph}/pulse
Flux within FWHM BW	$1.4 \cdot 10^5$	$(1.3 \pm 0.2) \cdot 10^5$	N_{ph}/pulse
BW	0.50	0.55 ± 0.02	%

Courtesy of I. Drebot– INFN-MI

Conclusions

- Start to end simulations has been presented for the ELI-NP Gamma Beam System
- Machine sensitivity analysis suggests that the machine is robust to errors in the specified range
- Tolerances regarding jitters and alignments of accelerating structures and magnets has been provided

Thank you!!!