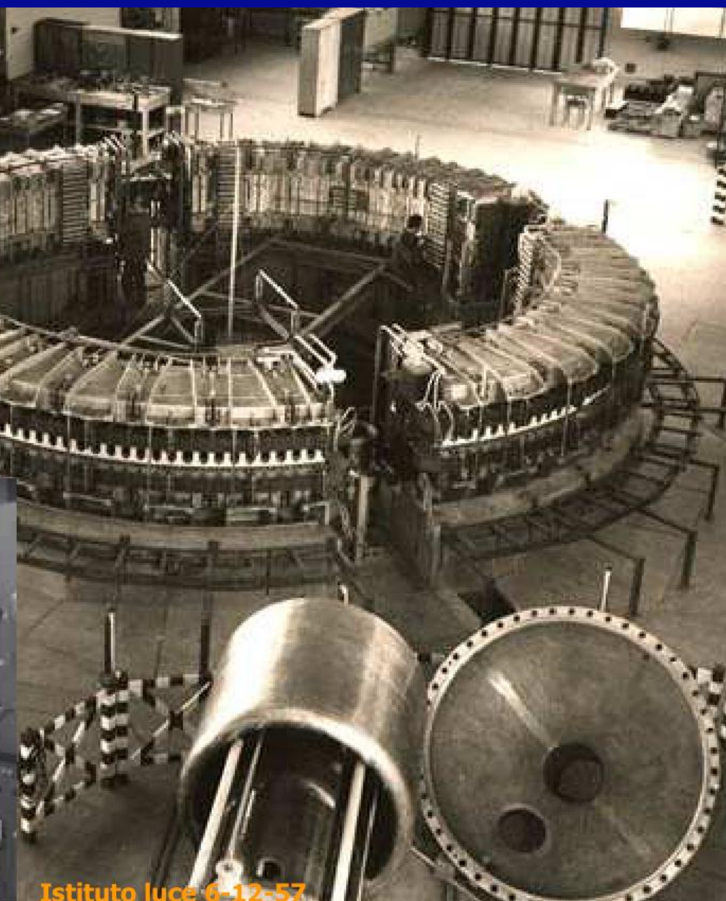
INFN - LNF perspective for accelerators

Andrea Ghigo

Electron Synchrotron (1959-1975)

The Frascati Synchrotron was the *first high energy accelerator* realized in Italy.
E = 1 GeV



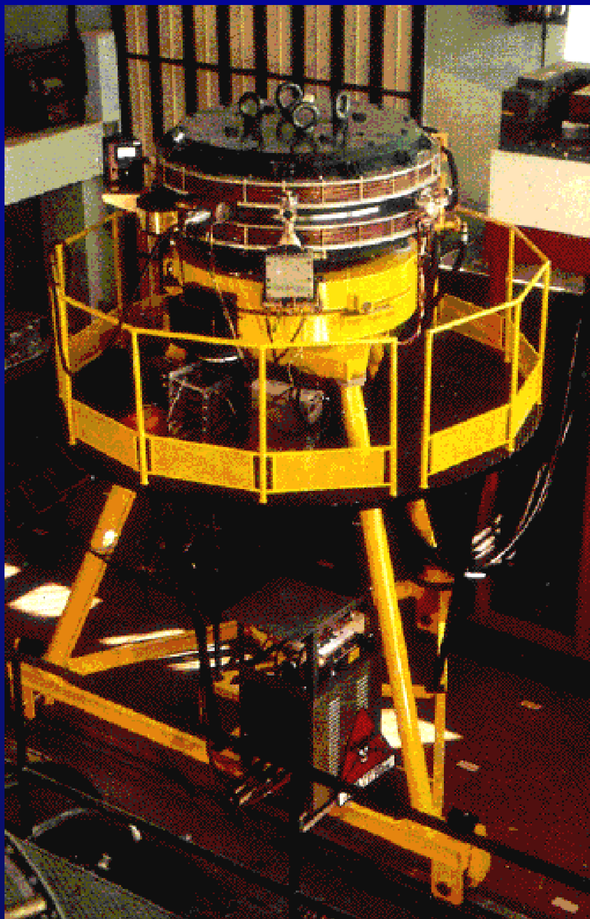
LNF-54/48 (1954)

Il progetto italiano di un elettrosincrotone.

G. SALVINI

Istituto di Fisica dell'Università - Pisa
Istituto Nazionale di Fisica Nucleare - Sezione Acceleratore

AdA (Anello di Accumulazione) 1960-1965



AdA was the first matter antimatter storage ring with a single magnet (weak focusing) in which e+/e- were stored at *250 MeV*

IL NUOVO CIMENTO

The Frascati Storage Ring.

C. Bernardini, G. F. Corazza, G. Ghigo
Laboratori Nazionali del CNEN - Frascati

B. Touschek
Istituto di Fisica dell'Università - Roma
Istituto Nazionale di Fisica Nucleare - Sezione di Roma

(ricevuto il 7 Novembre 1960)

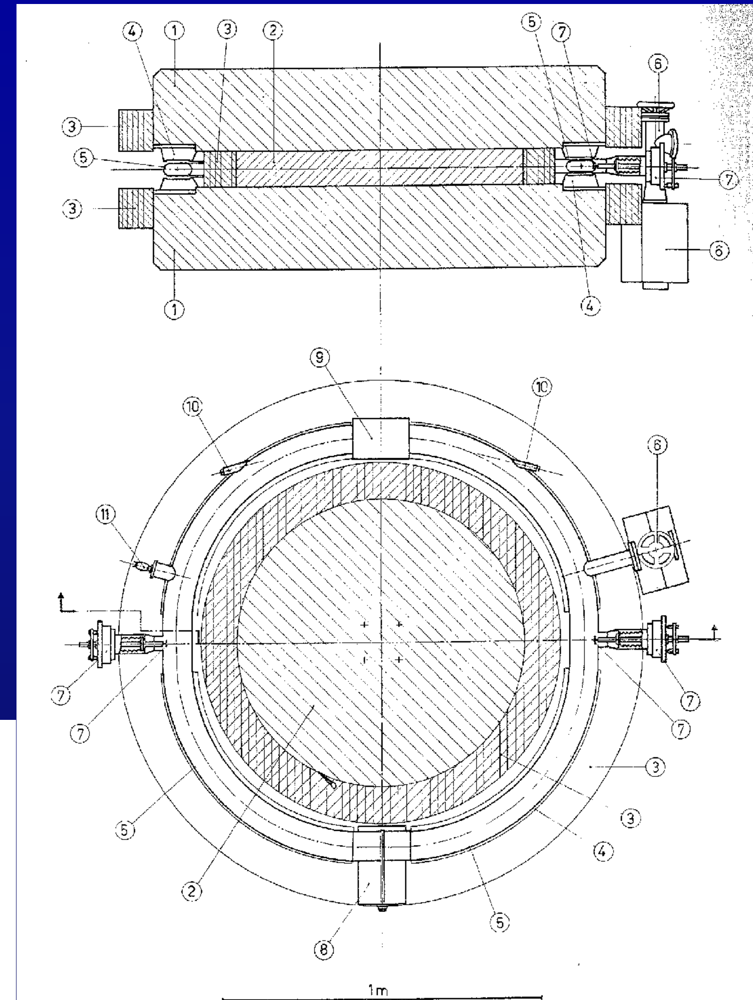
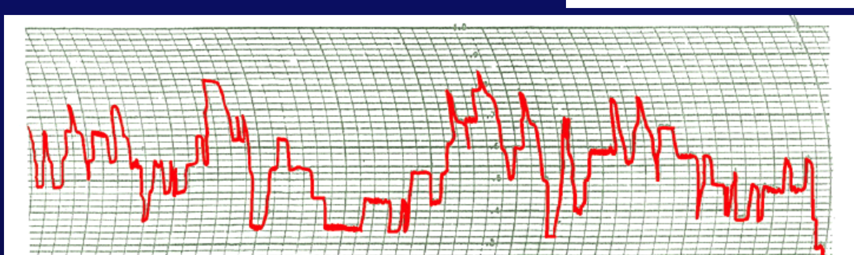


Fig. 1. – Elevation and plan section of the Frascati Storage Ring (anello di accumulazione = AdA): 1) magnet yoke; 2) magnet core; 3) coils; 4) polepieces; 5) doughnut; 6) titanium pump; 7) injection ports; 8) RF cavity; 9) experimental section; 10) windows for the observation of the synchrotron radiation; 11) vacuum gauge.

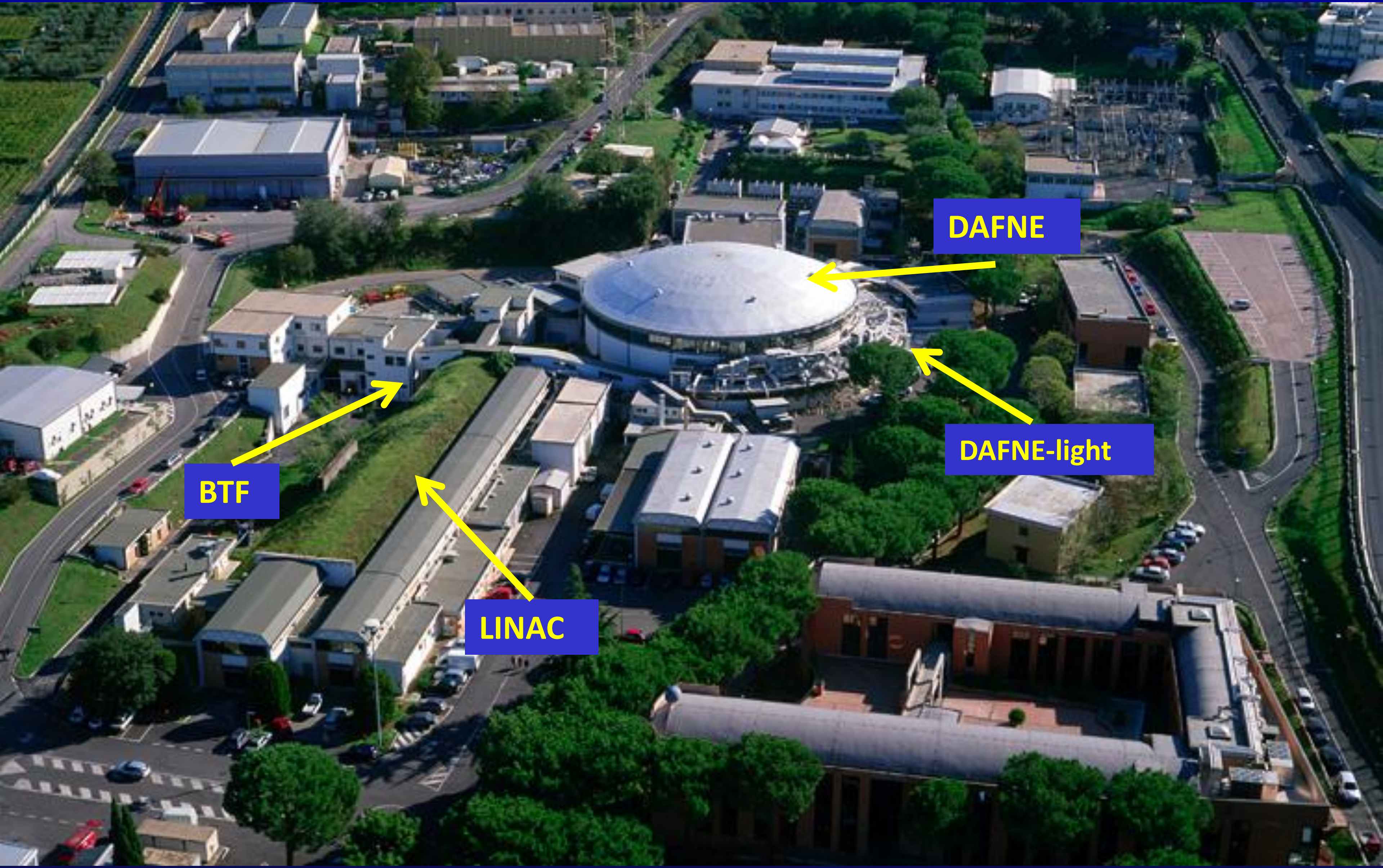


First electrons stored in AdA. Lifetime 21 sec, average e- number 2.3.

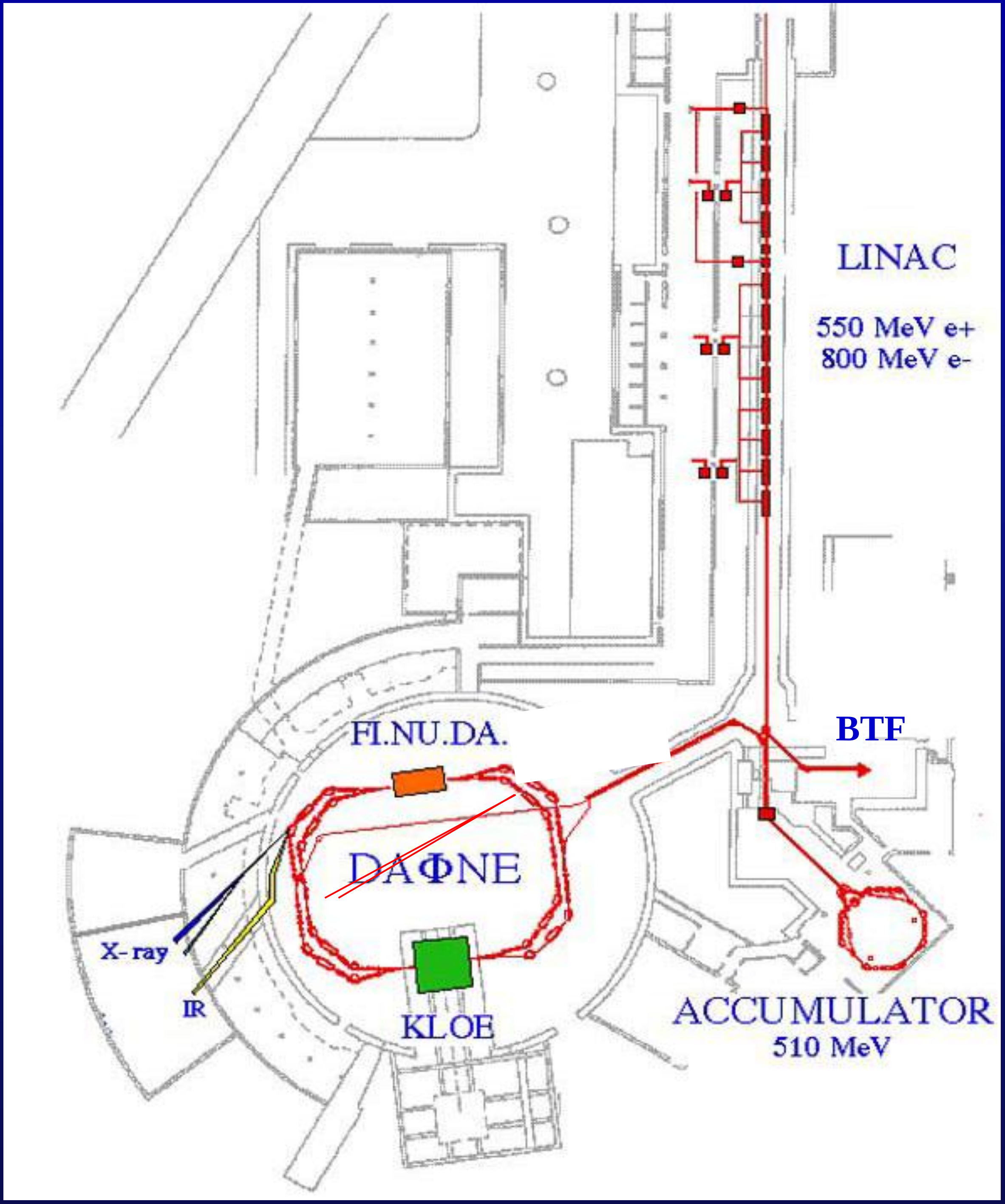
ADONE (1968- 1993)

- c.m. Energy 3 GeV
- circonference 100 m

The Φ-Factory complex



DAΦNE



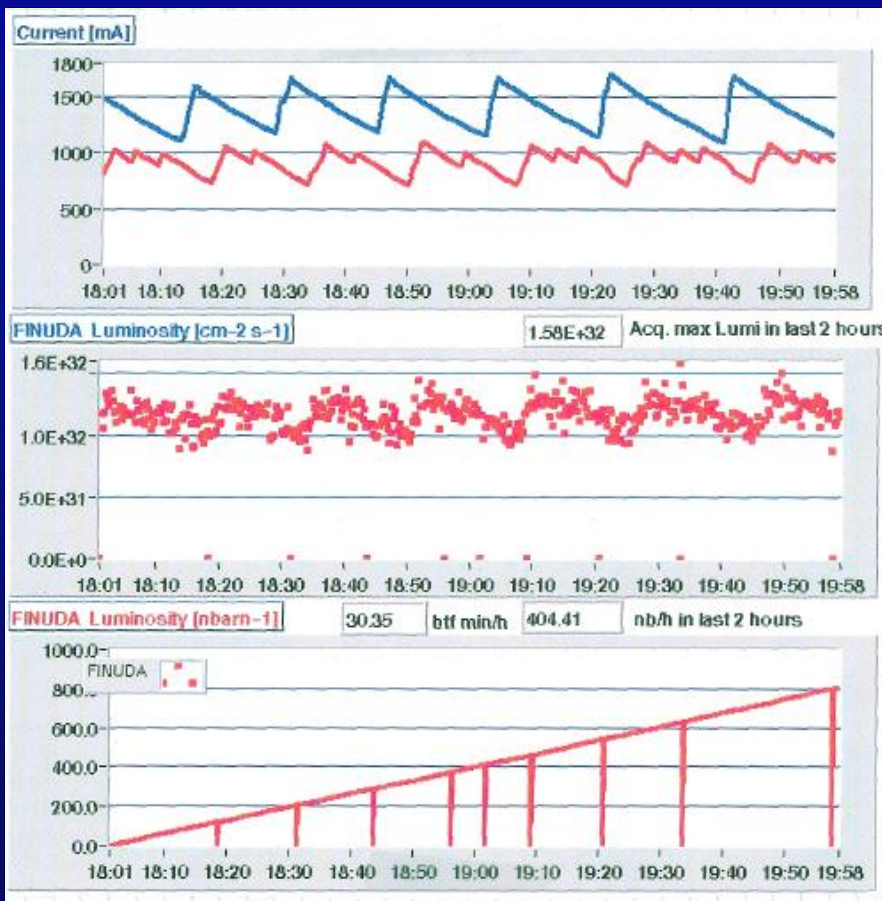
LINAC
550 MeV e+
800 MeV e-
BTF
FI.NU.DA.
DAΦNE
X-ray
IR
KLOE
ACCUMULATOR
510 MeV

DAΦNE

e+ e- collider
E c.m. = 1.02 GeV
L = 4.5 10^{32} cm^{-2} sec

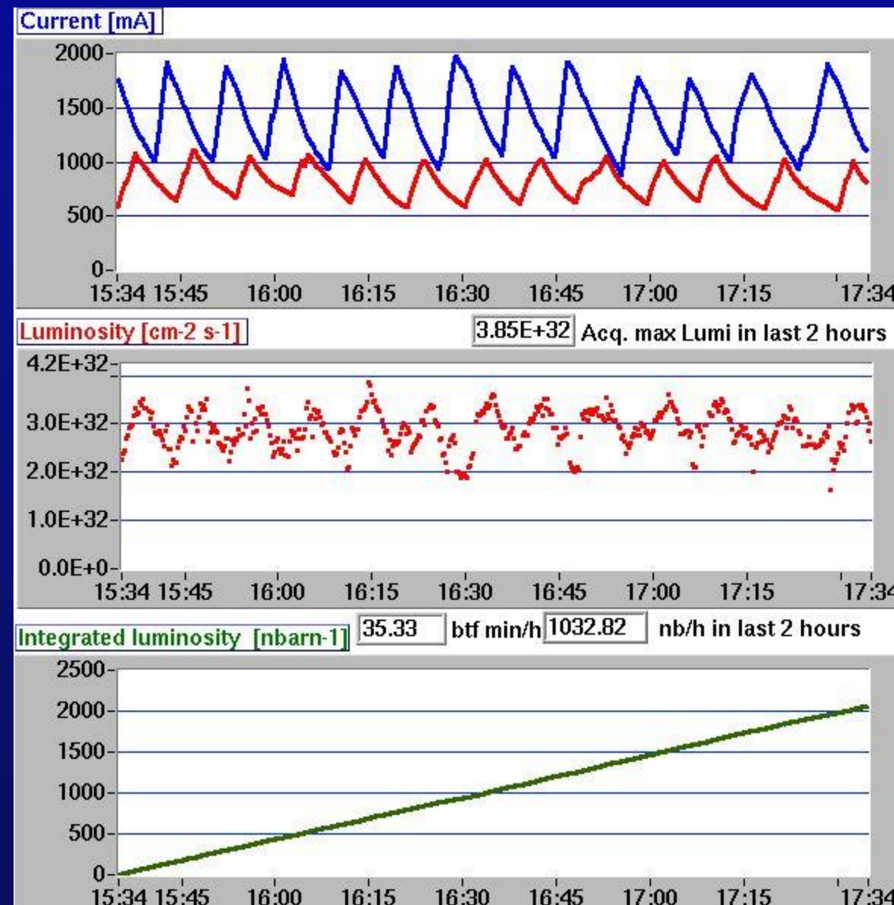
DAFNE gain in luminosity
with micro-beam, large crossing angle and crab waist

KLOE classical with
apparatus solenoidal field

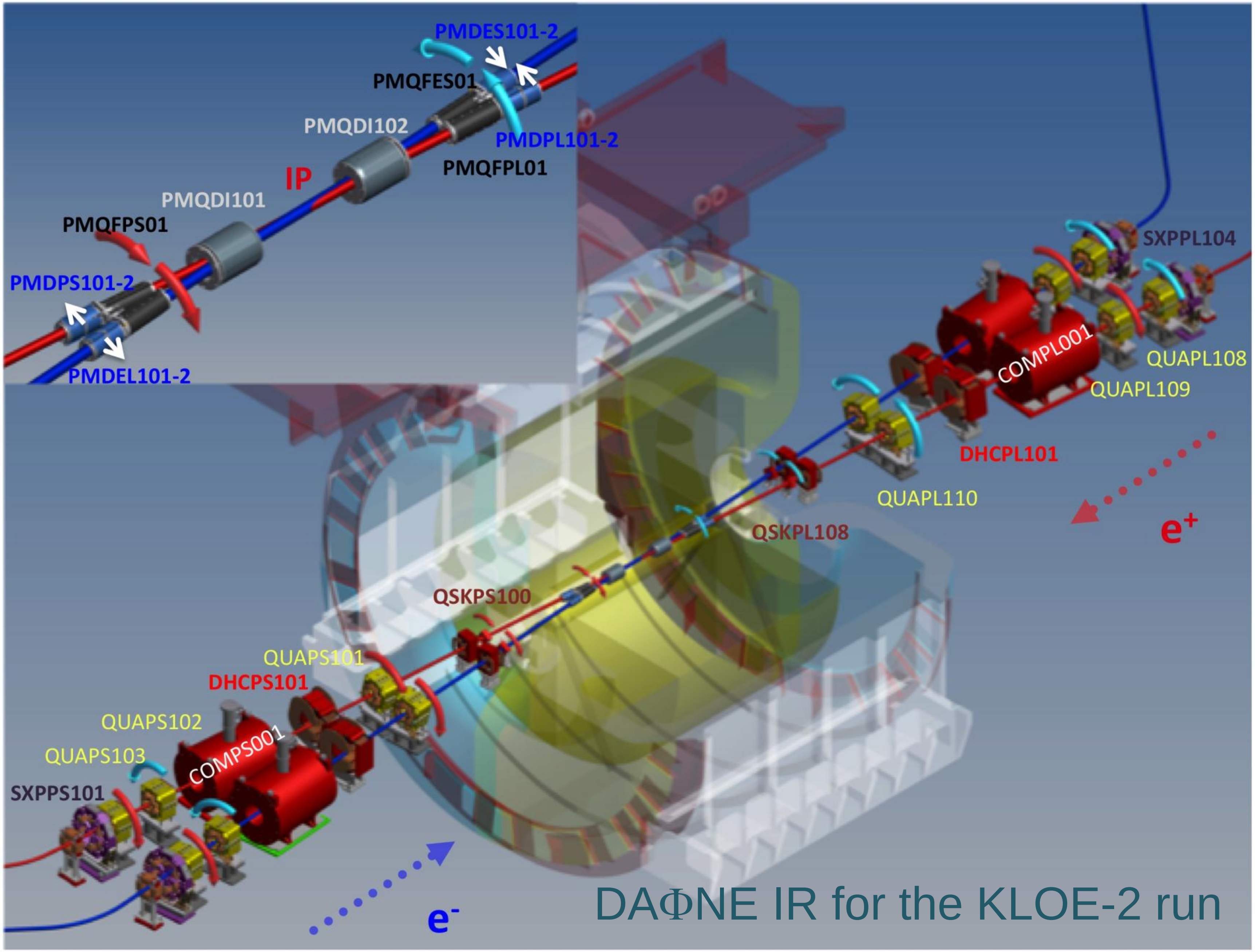


L_{max} =1.7 10^{32} cm^{-2} sec^{-1}
0.4 $pbarn^{-1}$ / hour

Siddharta CRAB waist
without solenoidal field

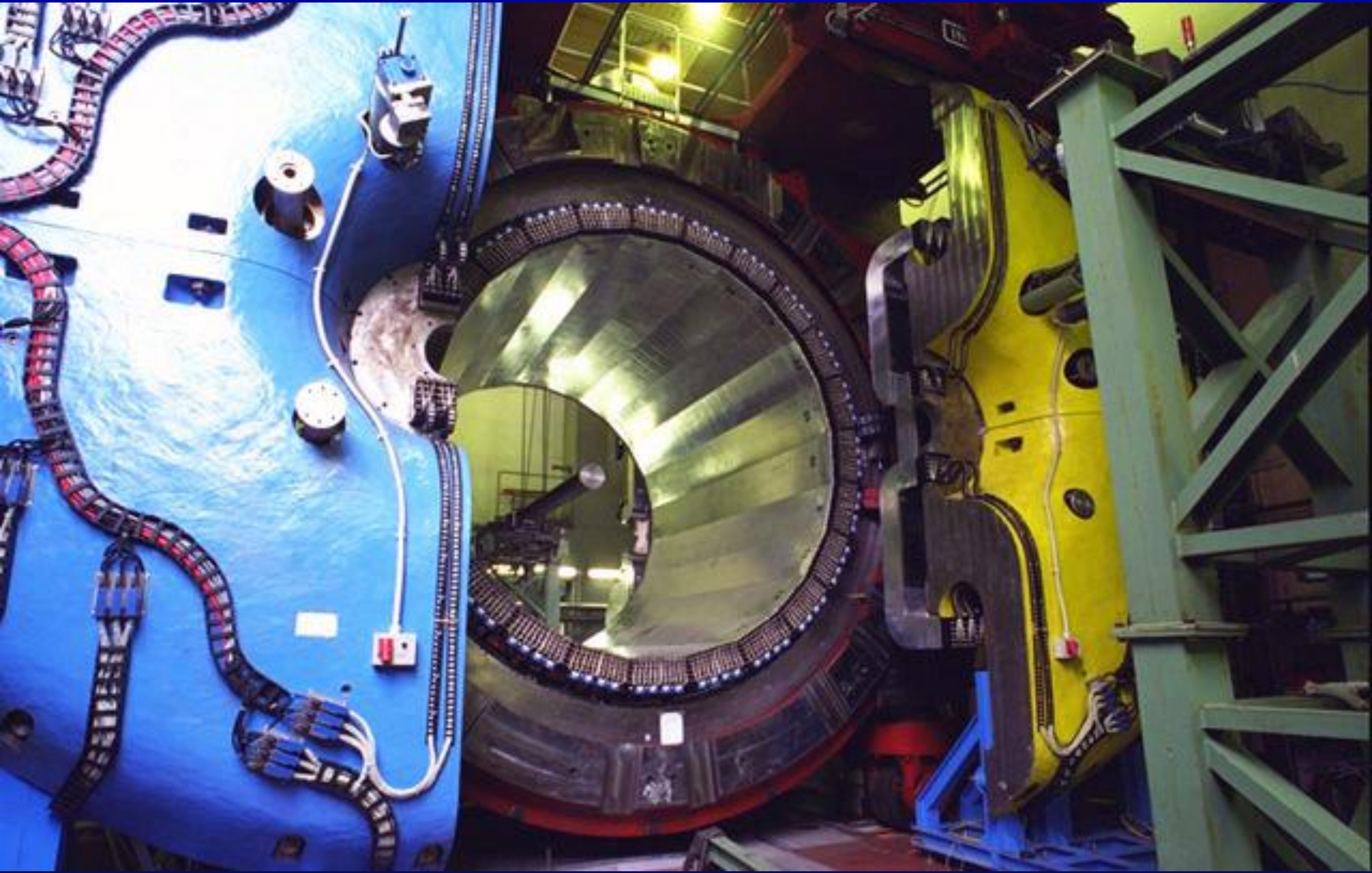


L_{max} = 4.5 10^{32} cm^{-2} sec^{-1}
1.0 $pbarn^{-1}$ / hour

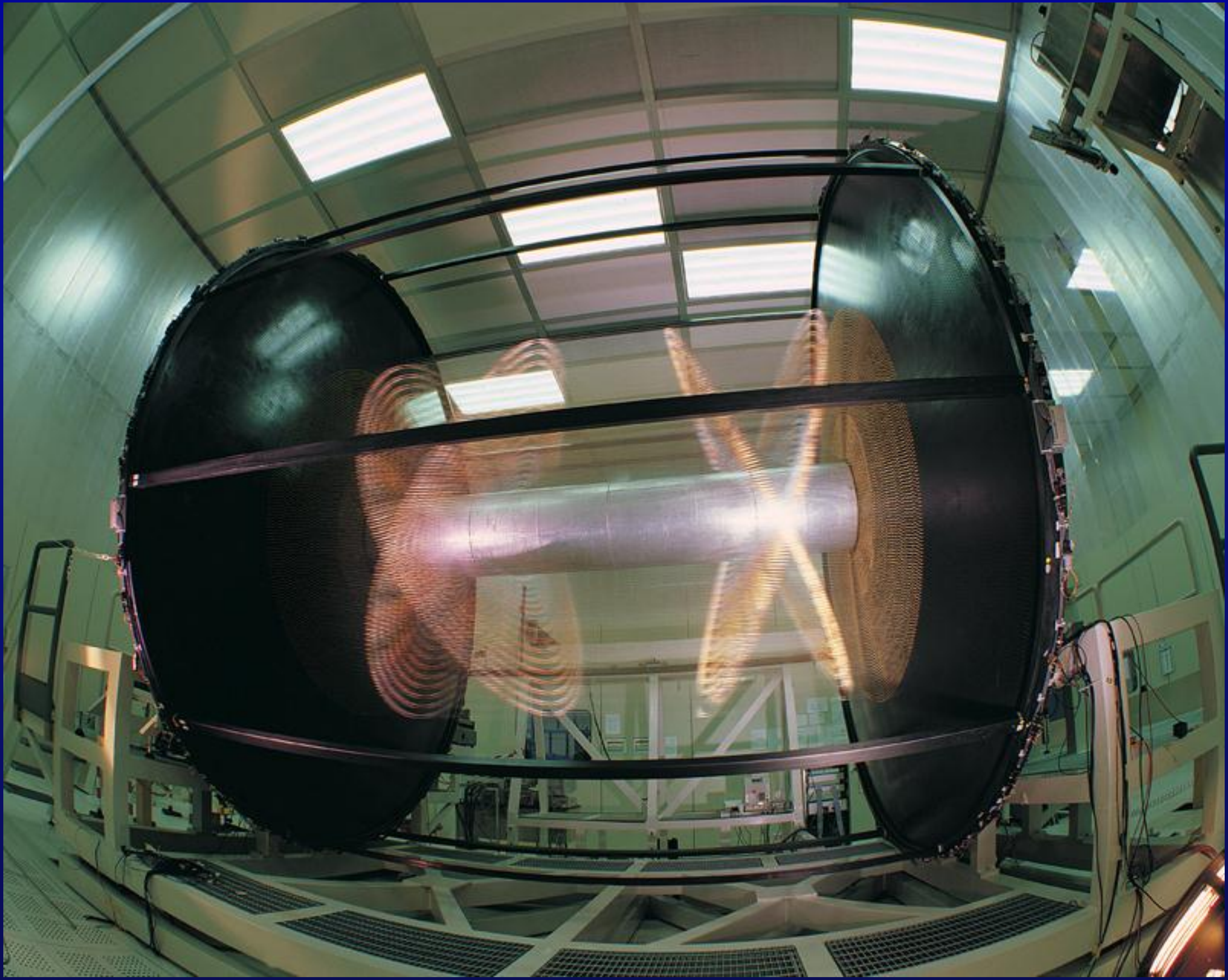


DAΦNE IR for the KLOE-2 run

KLOE Experiment Detector: magnet and calorimeter



KLOE Experiment Detector: wire chamber



KLOE-2 Physics Program

“Natural” extension of the KLOE program in the field of flavour and hadronic physics, with some additions, such as $\gamma\gamma$ interactions, or searches for new light gauge bosons.

- Studies on CPT and QM violation with neutral kaons interferometry
- Tests of Lepton Flavor Violation with K_{e2} decays
- Studies on C, P, CP violation using rare η and K_S decays
- Tests of Chiral Perturbation Theory with η, η', and K_S decays
- Searches for signals of a Secluded Gauge Symmetry

Most of them involve decay processes at or very close the interaction point ⇨

- *Charged vertex efficiency near the IP*
- *Acceptance for photons emitted at low polar angles*

KLOE-2

Inner Tracker : cylindrical GEM (C-GEM)

Taggers for $\gamma\gamma$ reactions installed.

Low and high energy Tagger installations

Beamlines @ DAΦNE-Light

SINBAD - *IR beamline*

DXR1 - *Soft x-ray beamline*

DXR2 - *UV setup*

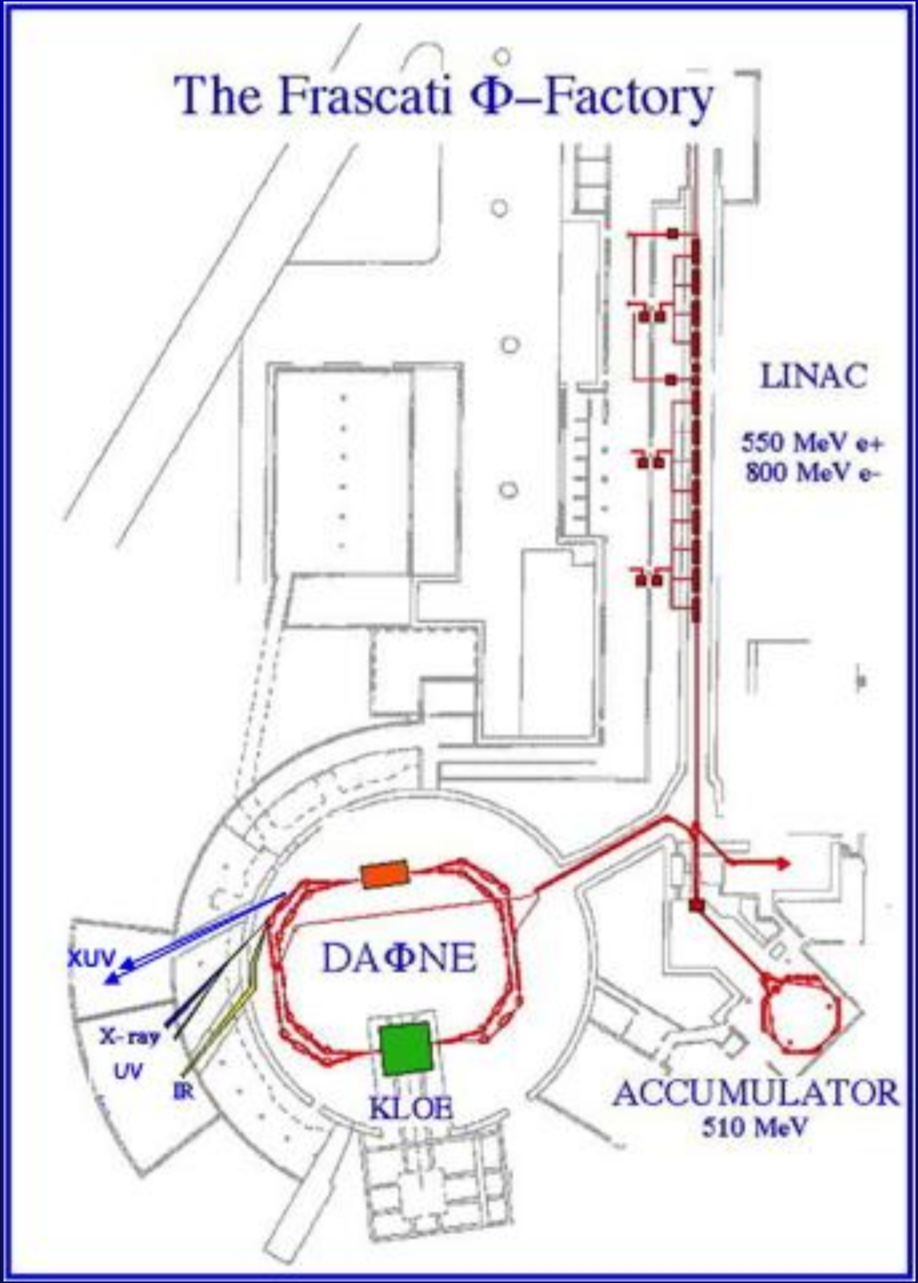
Open to Italian and EU users

DXR2 - New VUV setup ready in 2012

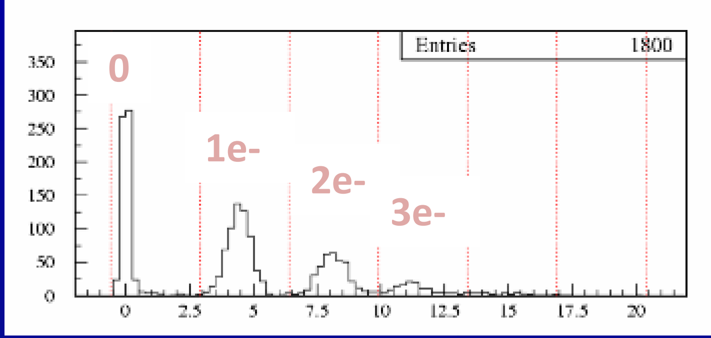
2 new XUV beamlines

Low Energy Beamline (35-200 eV) commissioning in 2012;

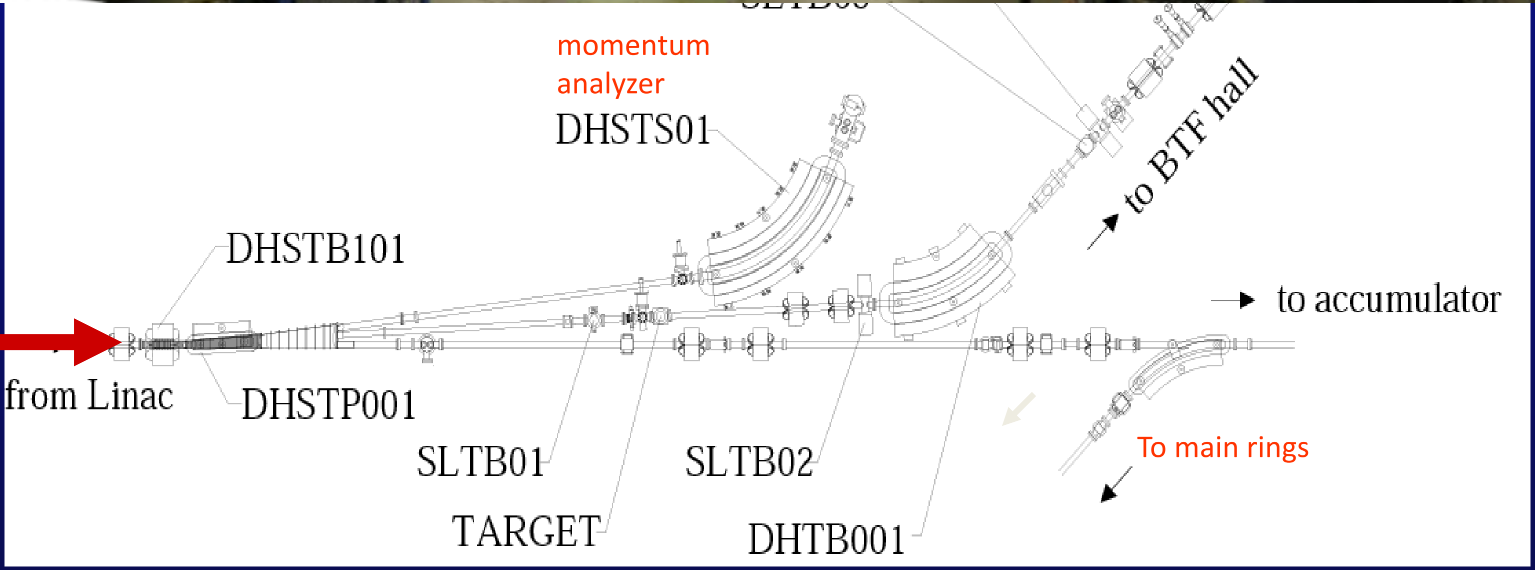
High Energy Beamline (60-1000 eV) commissioning in 2012



Beam Test Facility (BTF) Infrastructure
@DAFNE Linac



LINAC tunnel



Beam Test Facility e^+/e^- characteristic

The Frascati **Beam Test Facility** infrastructure is a beam extraction line optimized to produce **electrons**, **positrons**, **photons** and **neutrons** mainly for HEP detector **calibration** purposes

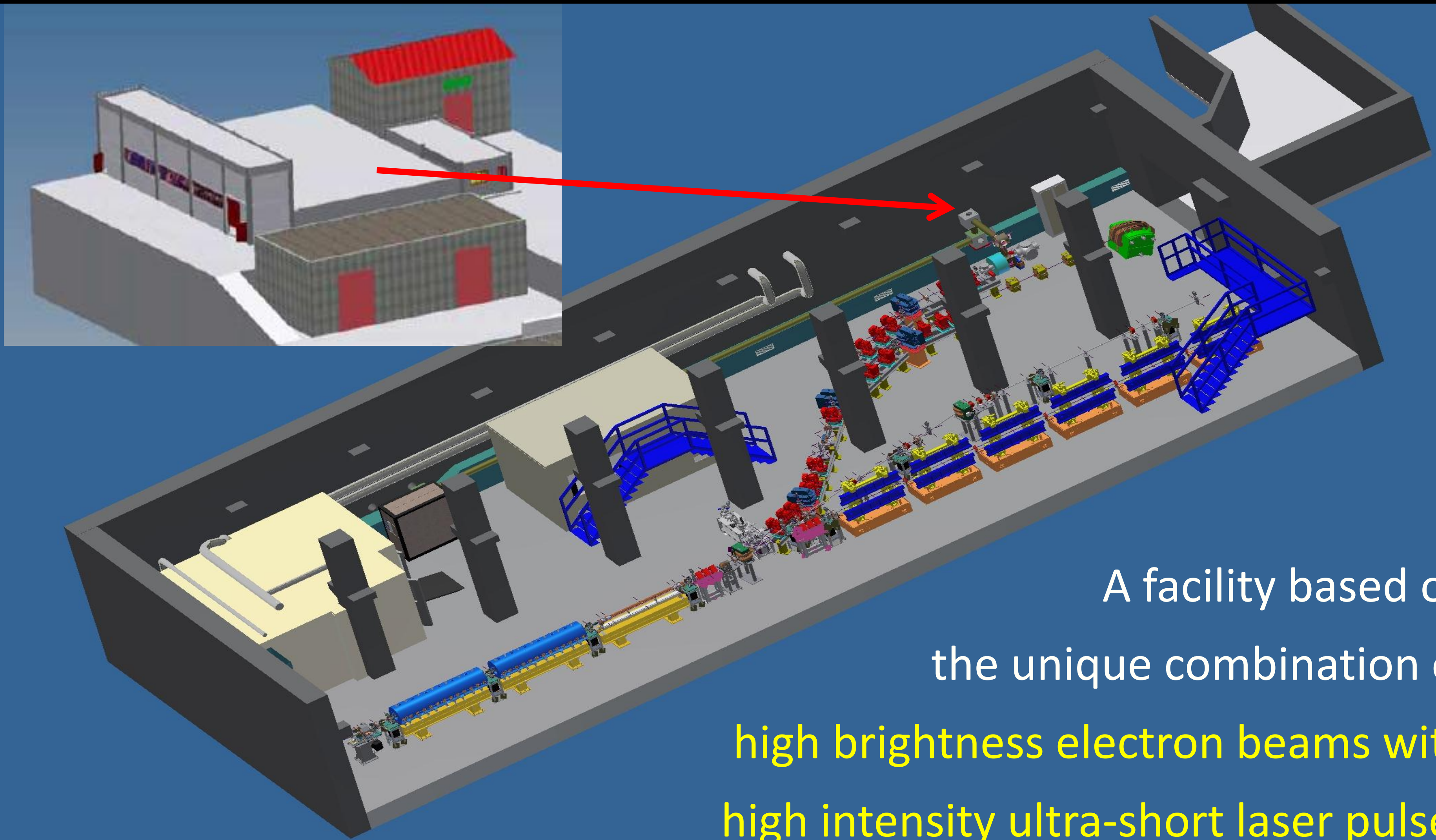
	parasitic	dedicated
Number (particles/pulse)	$1 \div 10^5$	$1 \div 10^{10}$
Energy (MeV)	25-500	25÷750
Repetition rate (Hz)	20-50	50
Pulse Duration (ns)	10	1 or 10
p resolution	1%	
Spot size (mm)	$s_{x,y} \approx 2$ (single particle)	
Divergence (mmrad)	$s'_{x,y} \approx 2$ (single particle)	

Main applications

- HEP detector calibration and setup
- Low energy calorimetry & resolution
- Low energy electromagnetic interaction studies
- High multiplicity efficiency
- Detectors aging and efficiency
- Beam diagnostics

SPARC_LAB

Sources for Plasma Accelerators and Radiation Compton with Lasers And Beams



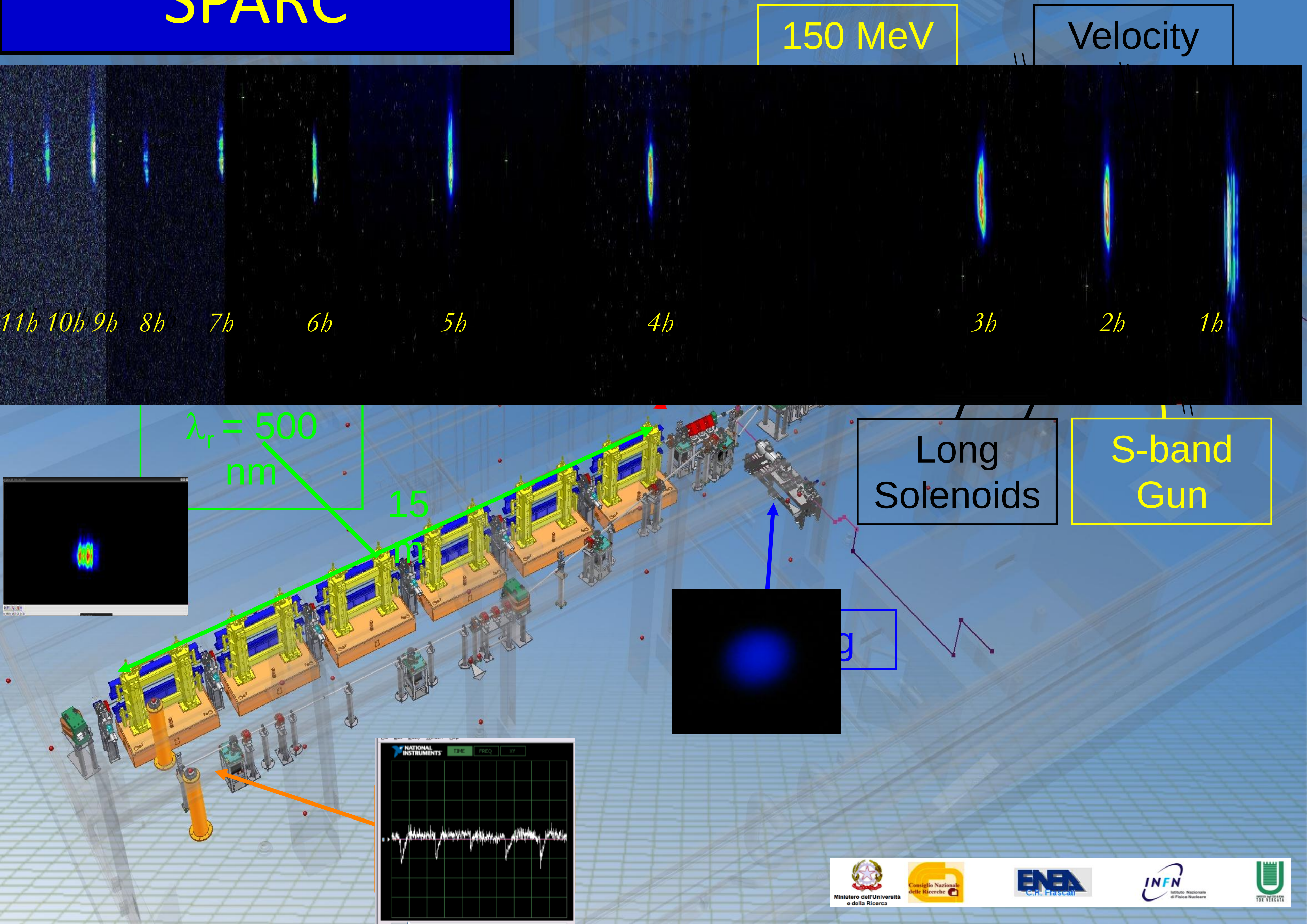
A facility based on

the unique combination of

high brightness electron beams with

high intensity ultra-short laser pulses

SPARC

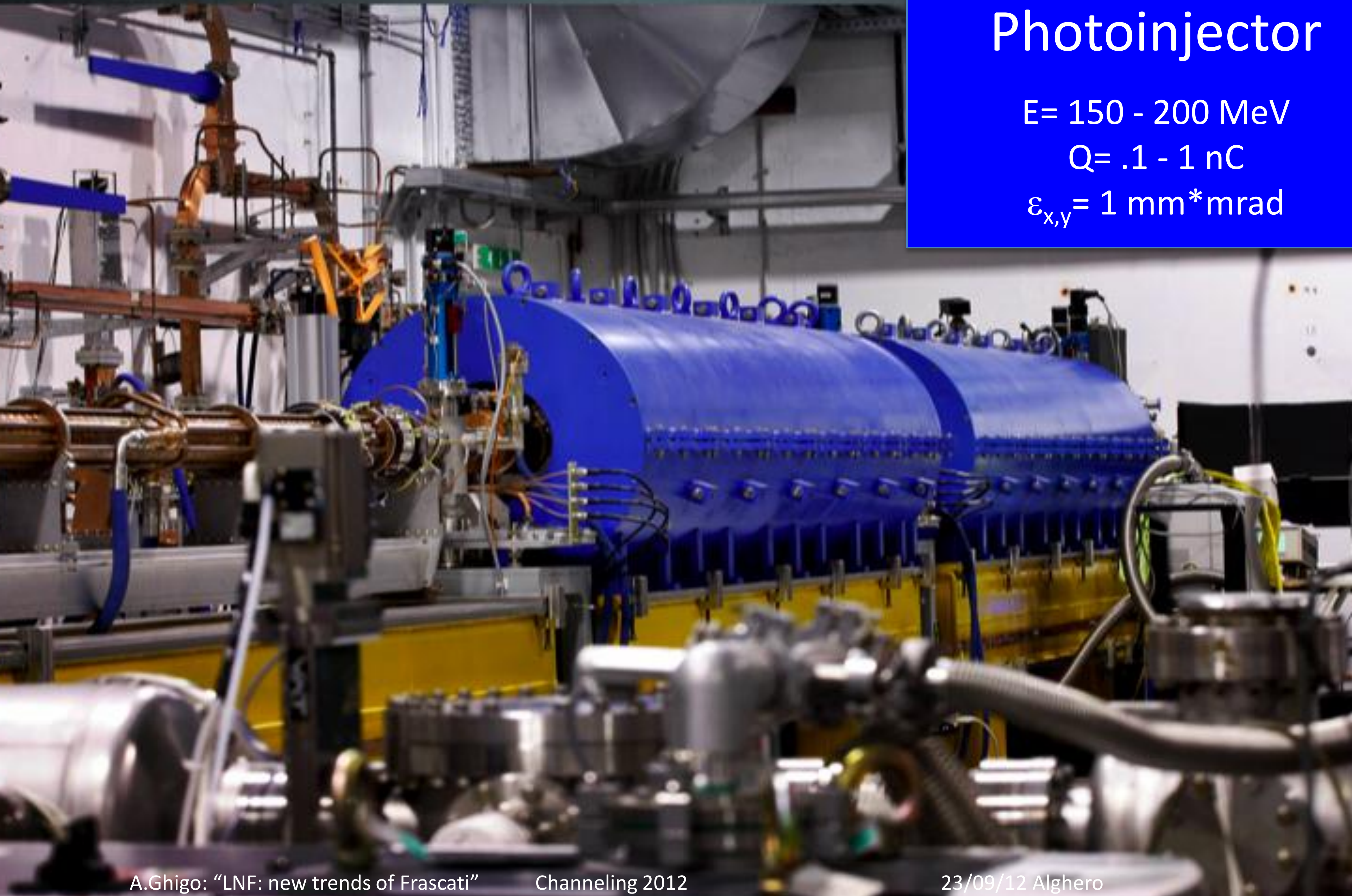

150 MeV
Velocity
11h 10h 9h 8h 7h 6h 5h 4h 3h 2h 1h
λr = 500 nm
15
Long Solenoids
S-band Gun

SPARC Photoinjector

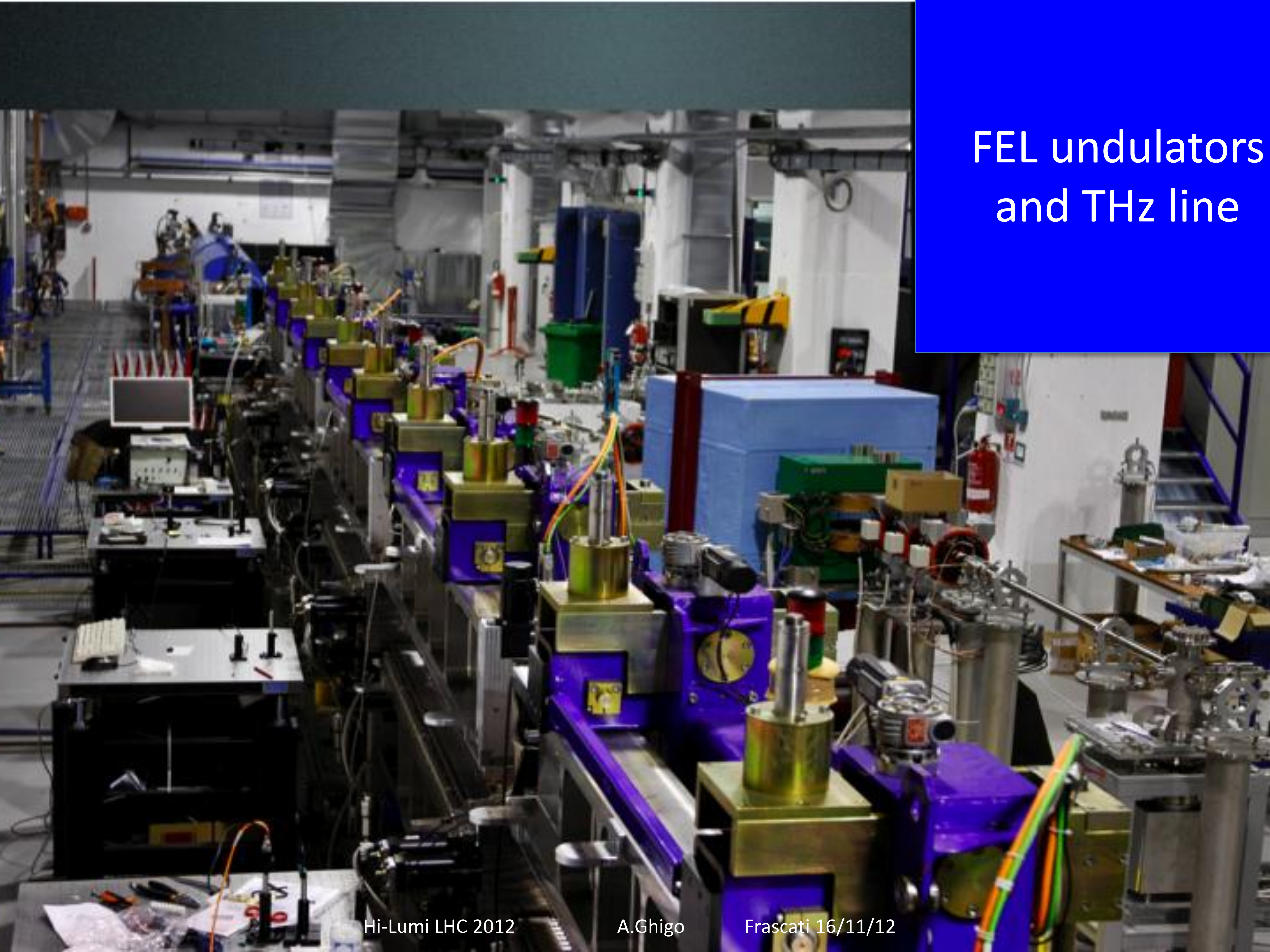
$E = 150 - 200$ MeV

$Q = .1 - 1$ nC

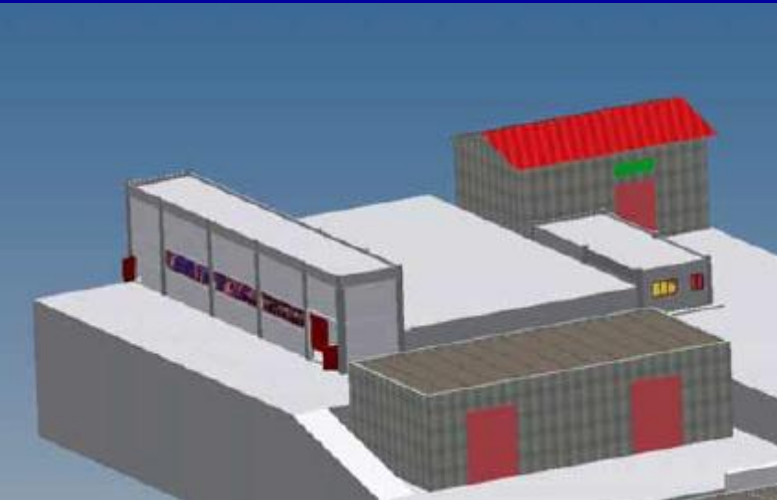
$\varepsilon_{x,y} = 1$ mm*mrad

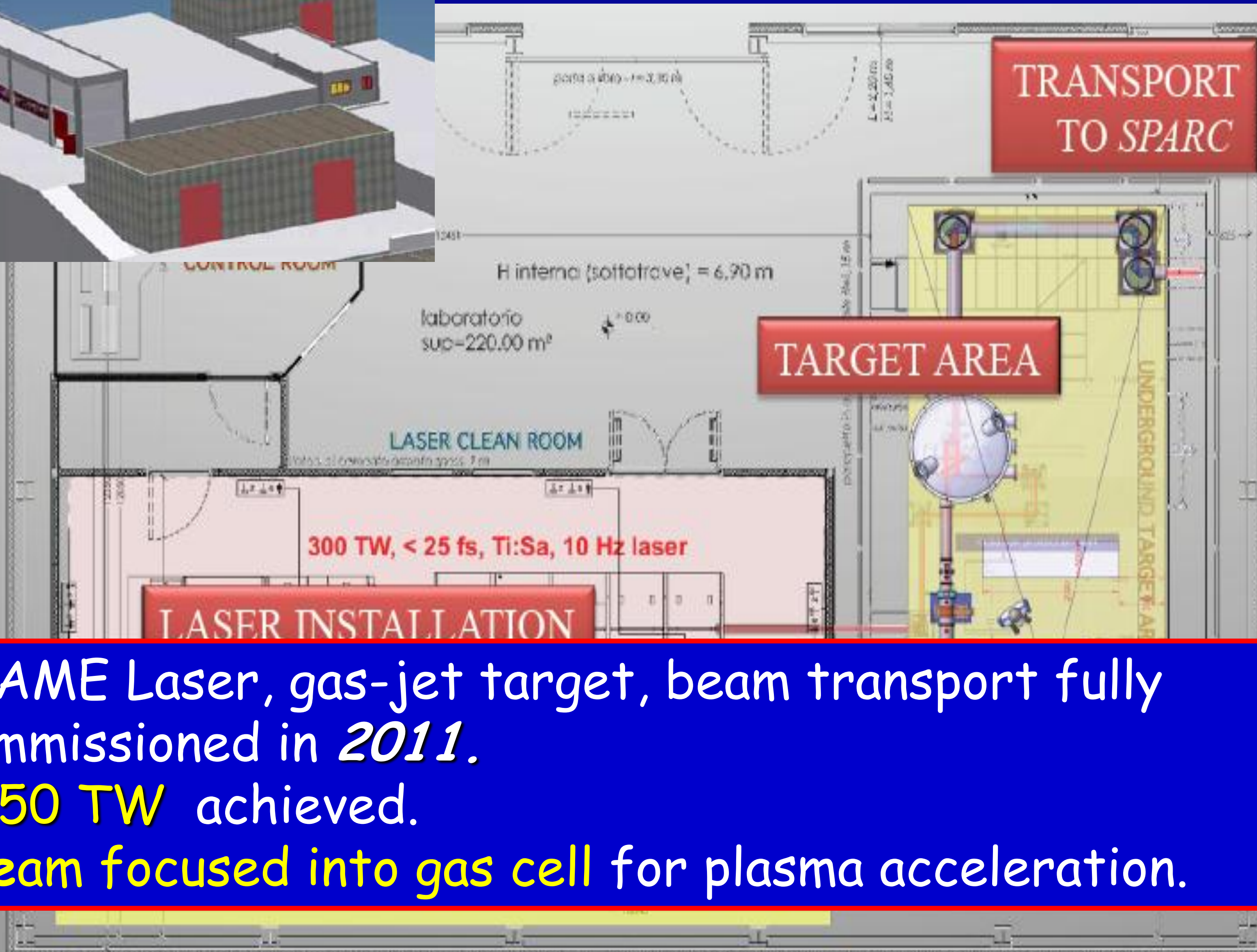


FEL undulators and THz line



FLAME: Frascati Laser for Acceleration and Multidisciplinary Experiments



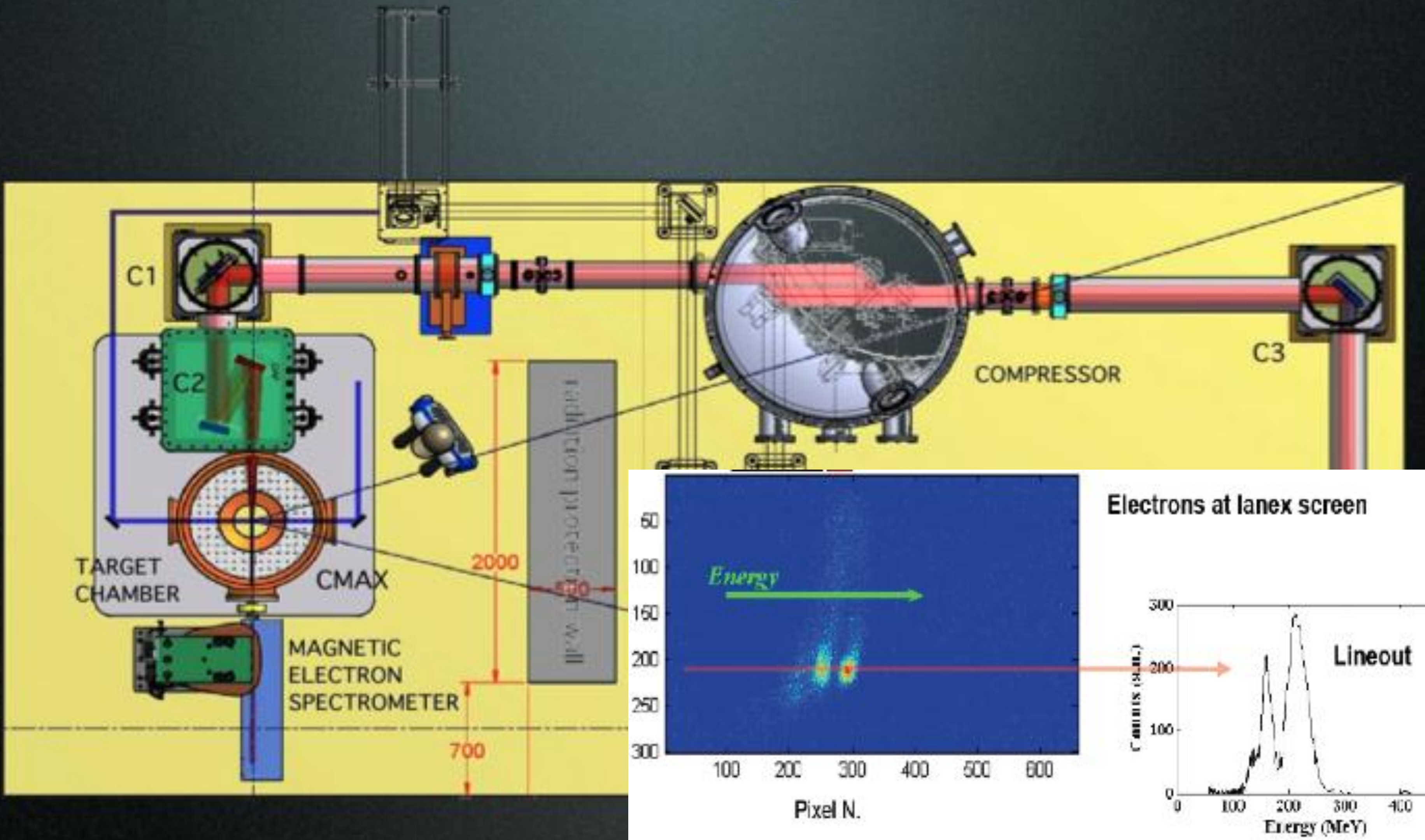


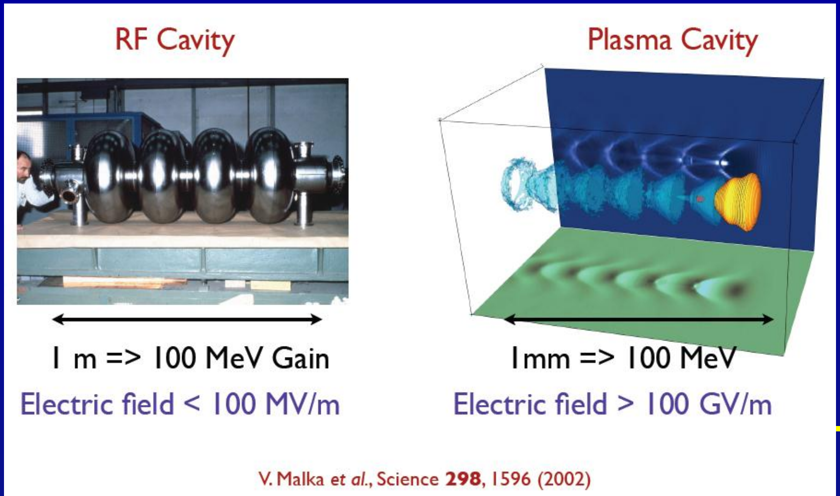
FLAME Laser, gas-jet target, beam transport fully commissioned in ***2011.***

-**250 TW** achieved.

-**Beam focused into gas cell** for plasma acceleration.

FLAME Target Area





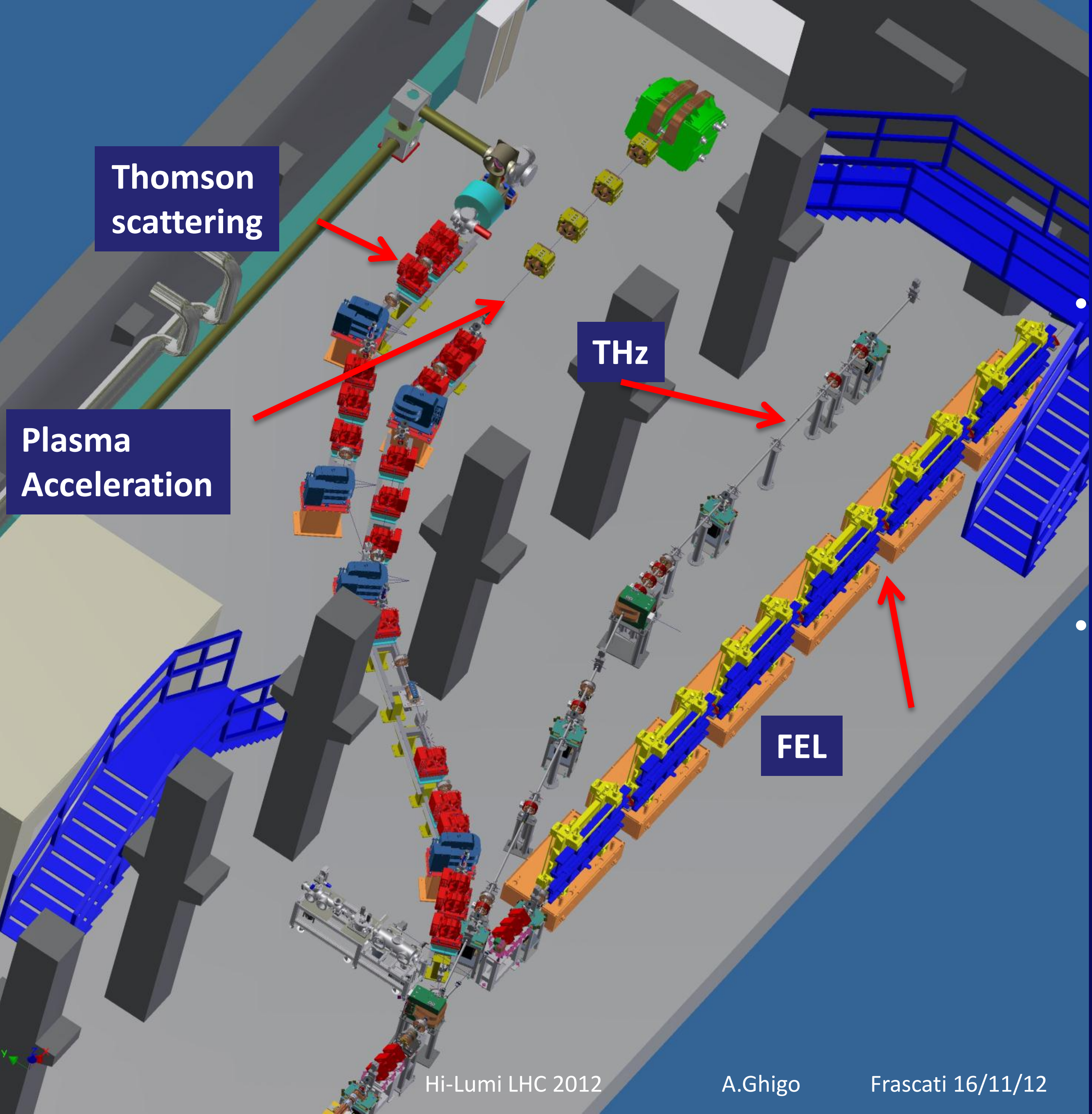
Plasma accelerators:

Transform transverse fields into longitudinal fields

Test @ SPARC_LAB

- **Laser driven**
  - Self-injection
  - External injection
- **e- driven**
- **p driven**
- **Dielectric wakefields**

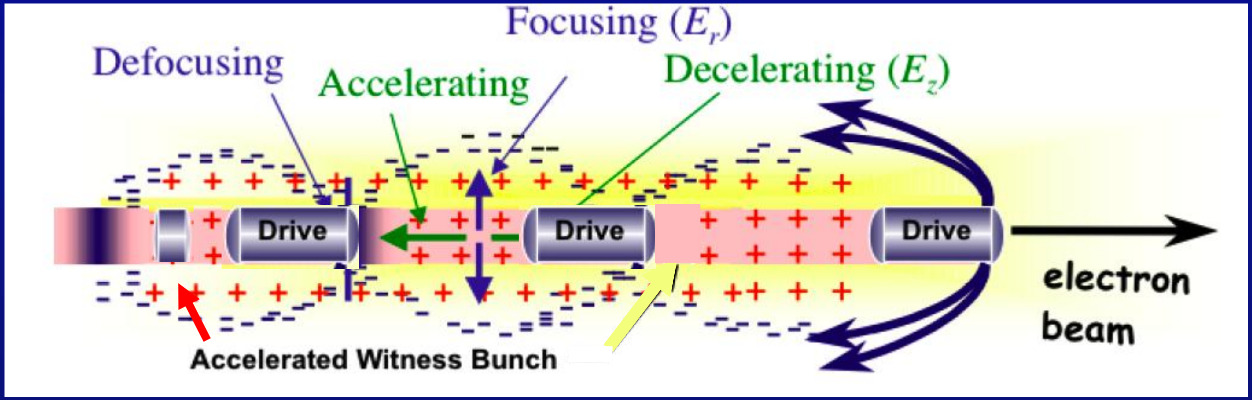
Demonstrated accelerating Gradients up to 3 orders of magnitudes beyond presently used RF technologies.



- Investigation of different configurations of plasma accelerator.
- Production of monochromatic ultra-fast X-rays by Thomson b-s driven by high-quality electron beam.

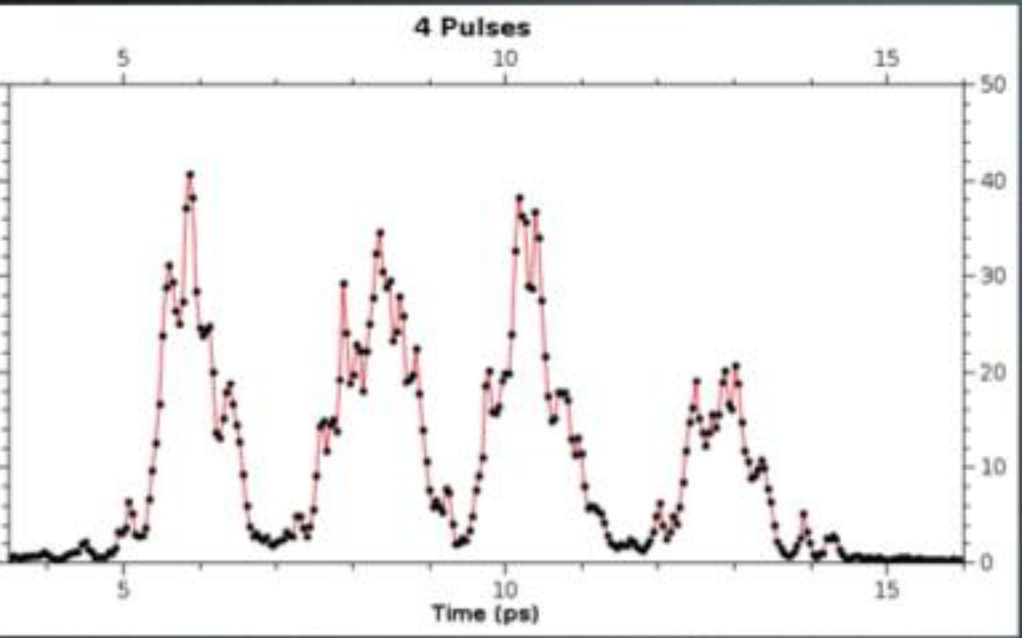
Using a high charge driving bunch to accelerate a low charge witness bunch

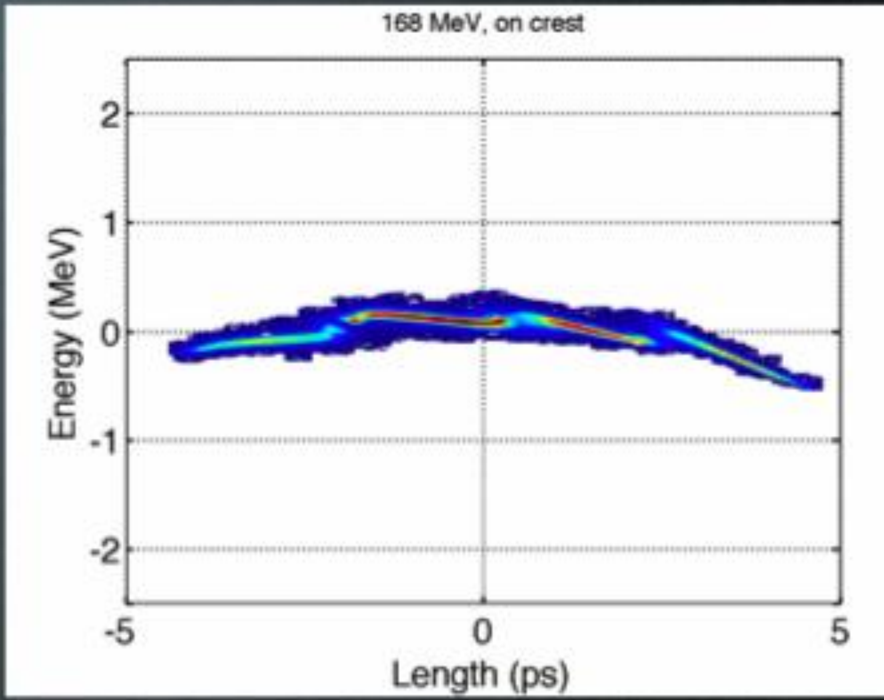
Resonant plasma Oscillations by Multiple electron Bunches

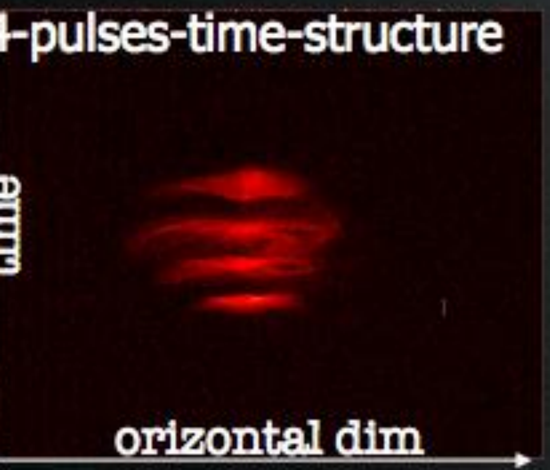


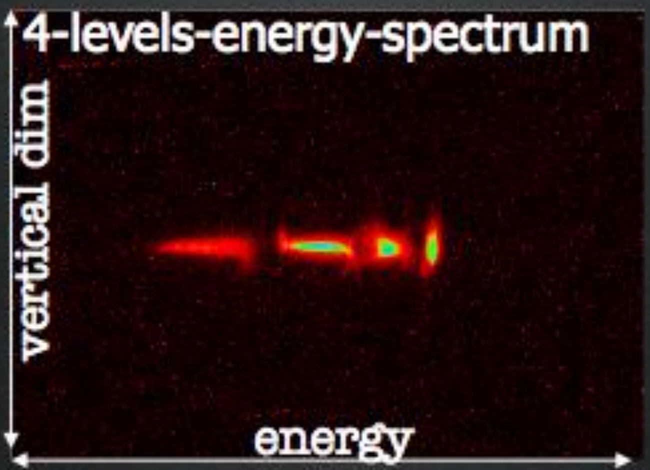
- Weak blowout regime with resonant amplification of plasma wave by a train of high Brightness electron bunches produced by Laser Comb technique ==> 5 GV/m with a train of 3 bunches, 100 pC/bunch, 50 μm long, 20 μm spot size, in a plasma of density 10^{22} e^-/m^3 at λ_p=300 μm ?
- Ramped bunch train configuration to enhance tranformer ratio?
- Strong blowout regime with pC/fs bunches ==> TV/m regime ?

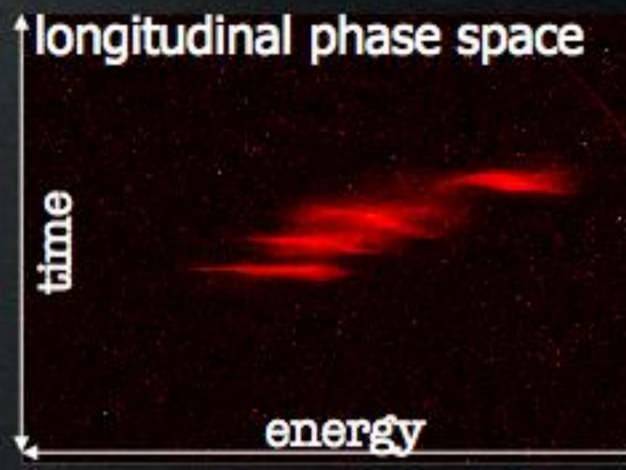
Laser COMB technique











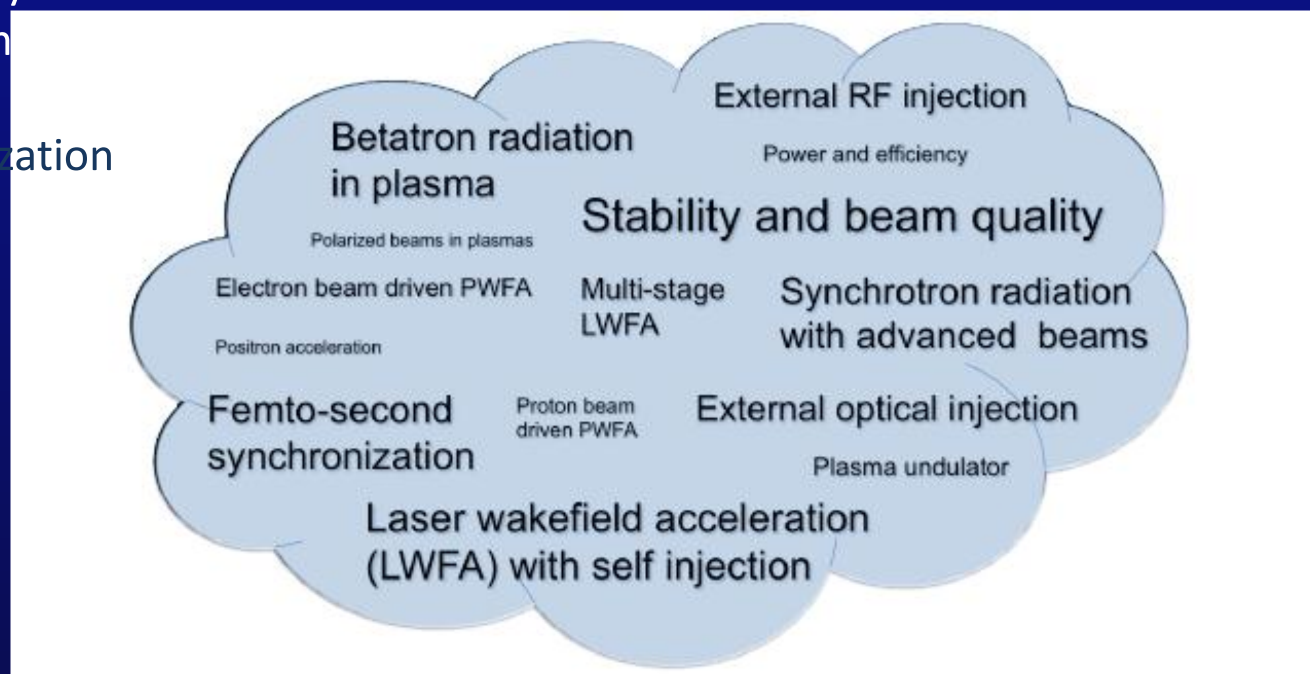
EURONACC: most important Technical Goals

1. External Optical injection
2. External RF injection
3. LWFA with self injection
4. Multi-stage LWFA
5. Synchrotron radiation with advanced beams
6. Electron beam driven PWFA
7. Proton beam driven PWFA
8. Betatron radiation in plasma
9. Plasma undulator
10. Stability and beam quality
11. Polarized beams in plasm
12. Positron acceleration
13. Femto-second synchronization
14. Power and efficiency

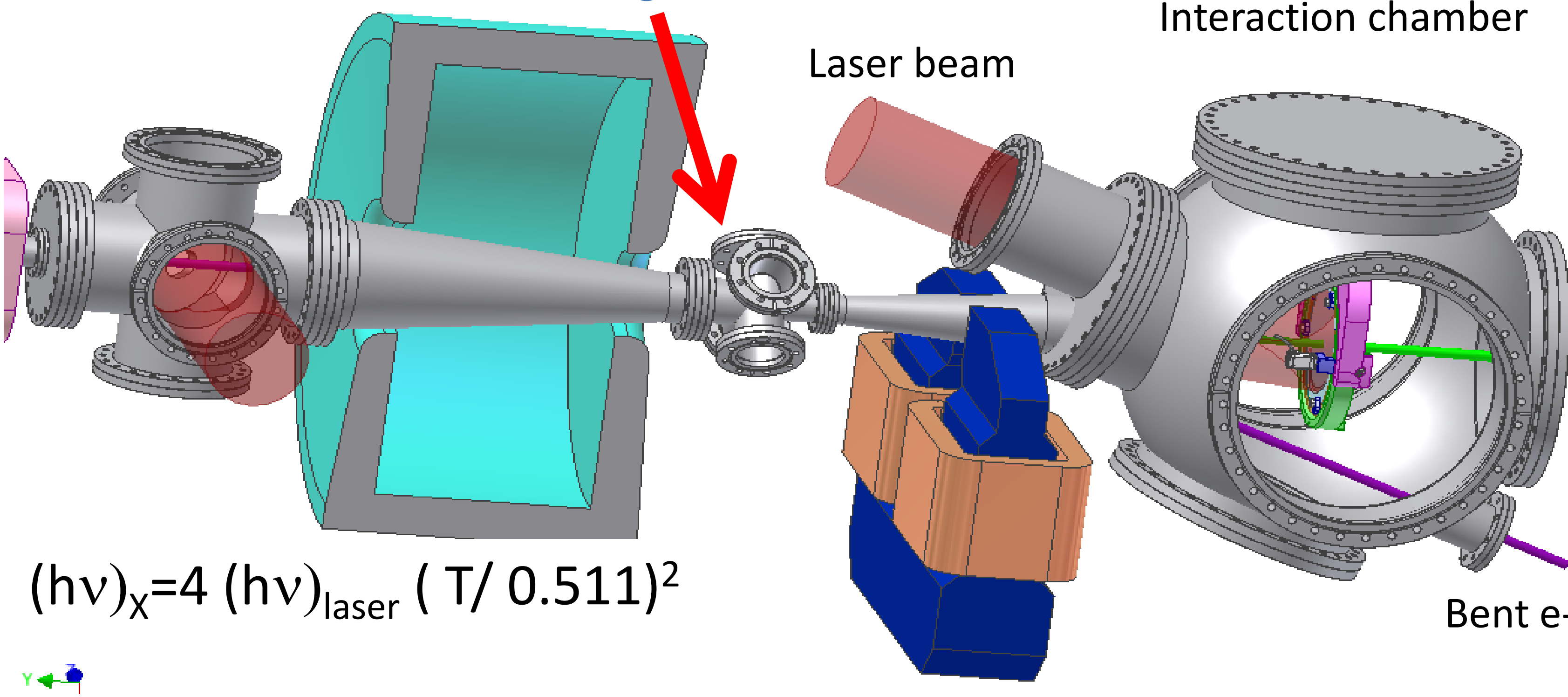
Investments :

1 billlion Euro over 10 year horizon

EuroNNAc : 52 institutes



Thomson Interaction region
(20-550 keV)

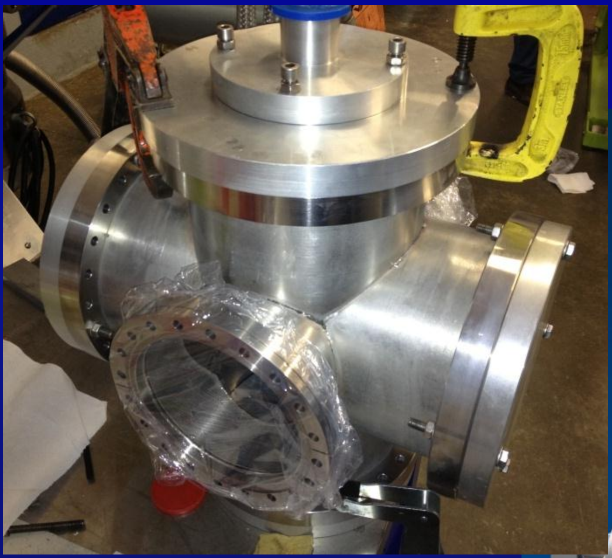


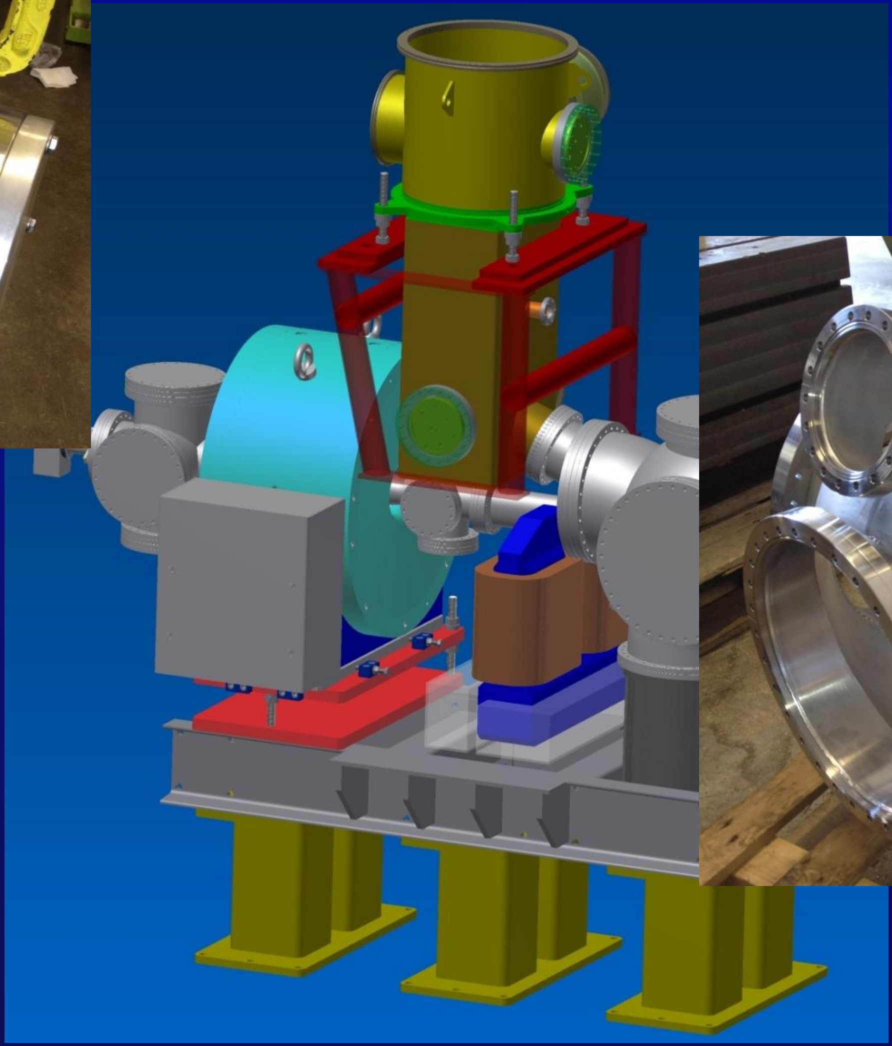
$(h\nu)_X = 4\,(h\nu)_{laser}\,(T/\,0.511)^2$

$(h\nu)_{laser}$ = 1.2 eV
T = 30.28 MeV

laser: pulse 6 ps, 5 J
e^- bunch: 1 nC , l: 2 mm (rms)
X ray pulse: 10 ps, 10^9 fotoni per interactionj
α emission: 12 mrad

Thomson Interaction Chamber





Courtesy of A. Zolla

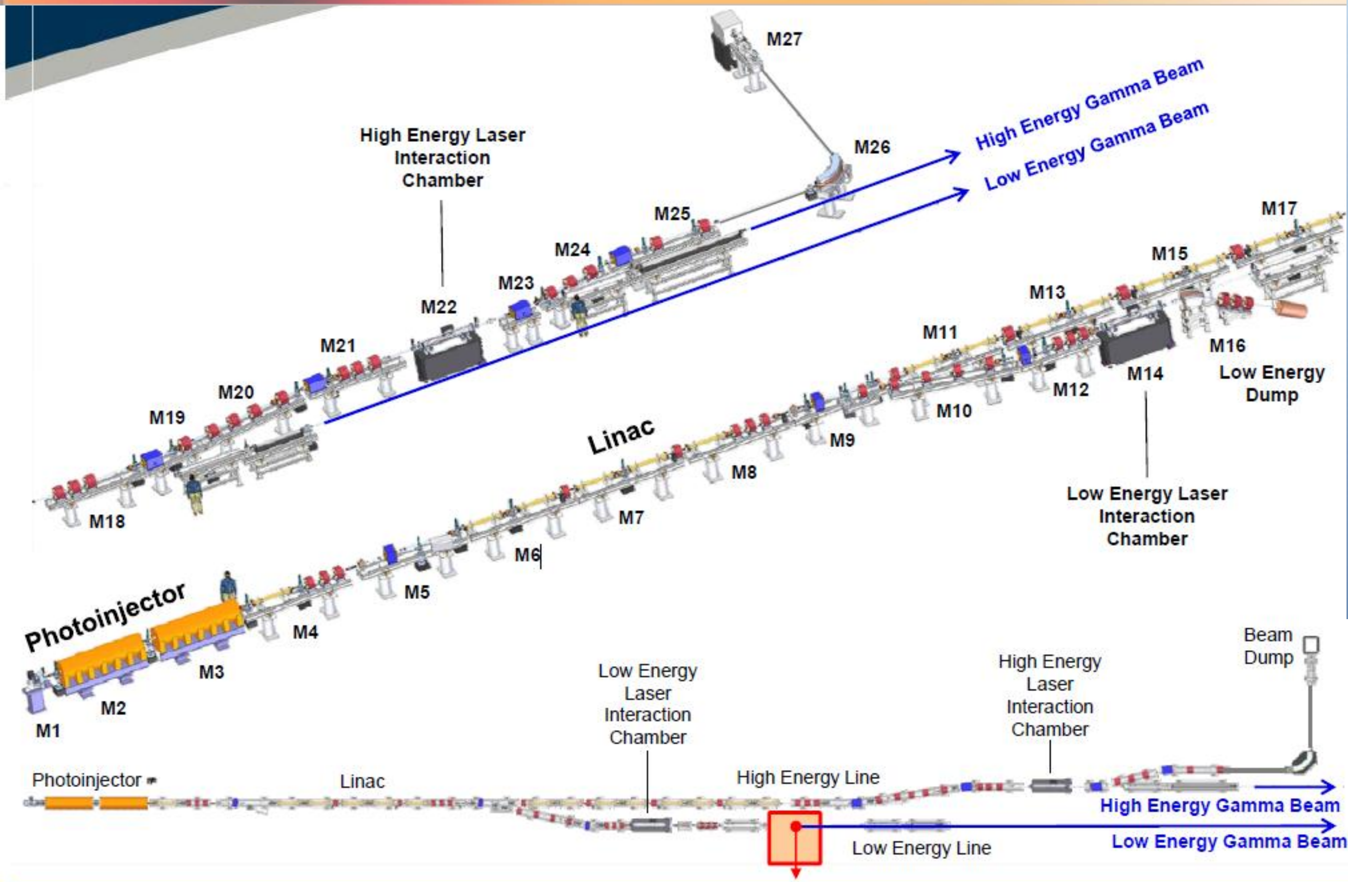
SAPIENZA UNIVERSITÀ DI ROMA · INFN Istituto Nazionale di Fisica Nucleare · Science & Technology Facilities Council · CNRS IN2P3 Les deux infinis · UNIVERSITÉ PARIS SUD Comprendre le monde, construire l'avenir

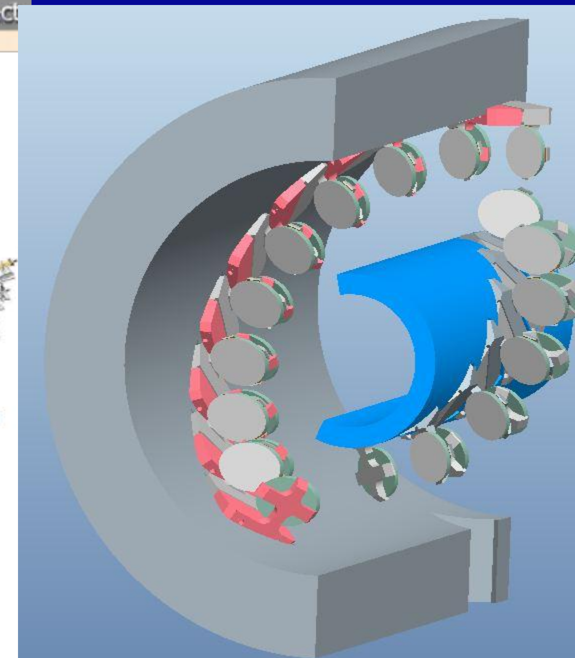
ELI-NP

Nuclear Physics

European Collaboration for the proposal of a Gamma-Beam System to the ELI-NP Project

TDR ready in Oct. 2012
To be built in 4 years





E beam energy : 720 MeV
Photon energy : 20 MeV
Laser pulse energy : 0.5 J

Laser wavelength: 2.4 eV
Rep rate : 100 Hz
# of recirculations: up to 40

LNF Participation in HL-LHC Project

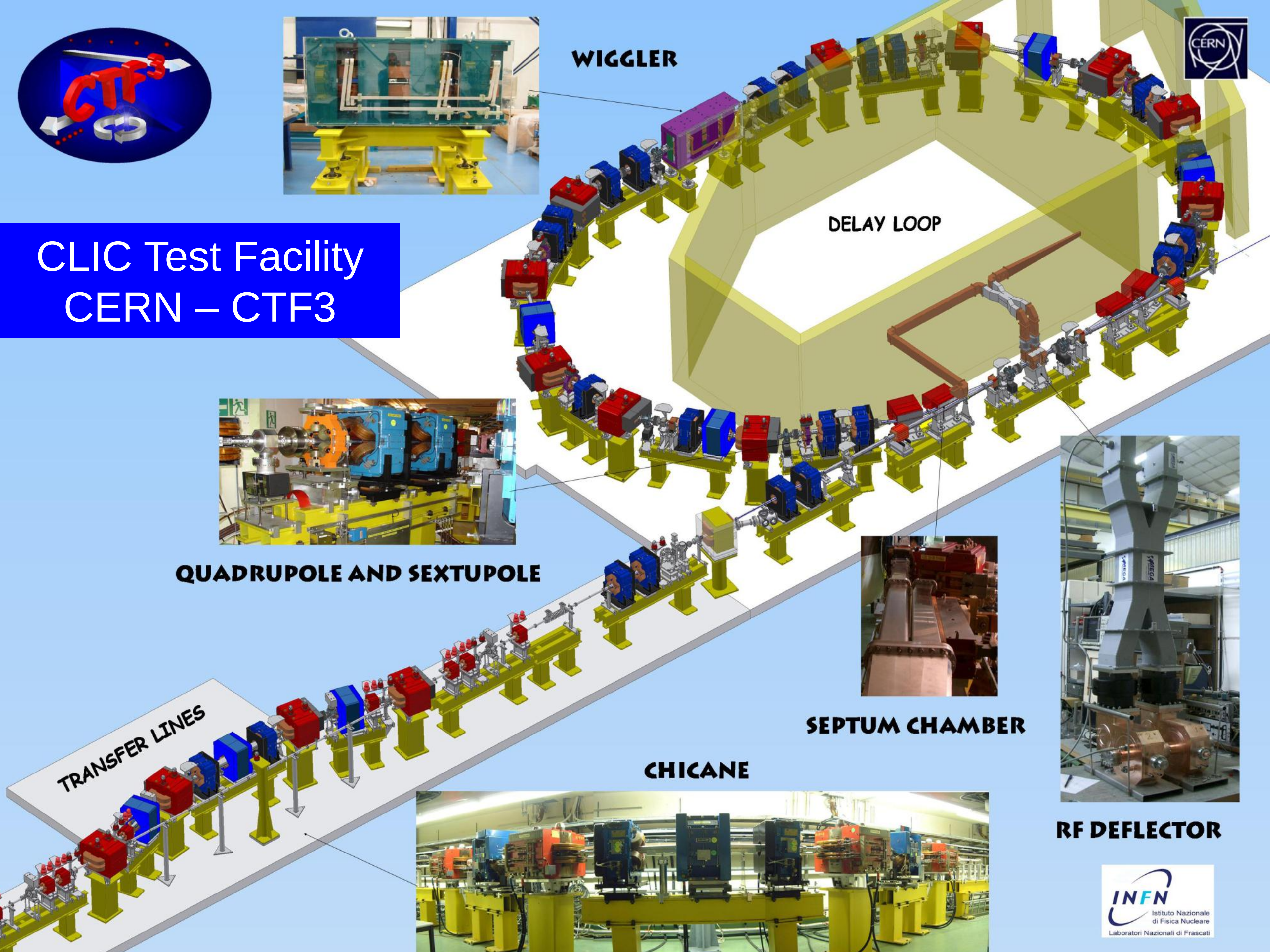
Participants (Accelerator Division)

1. Zobov Mikhail - Local Coordinator
2. Alesini David
3. Drago Alessandro
4. Gallo Alessandro
5. Marcellini Fabio
6. Milardi Catia
7. Bruno Spataro

Subjects to Study for LHC Upgrade (WP2)

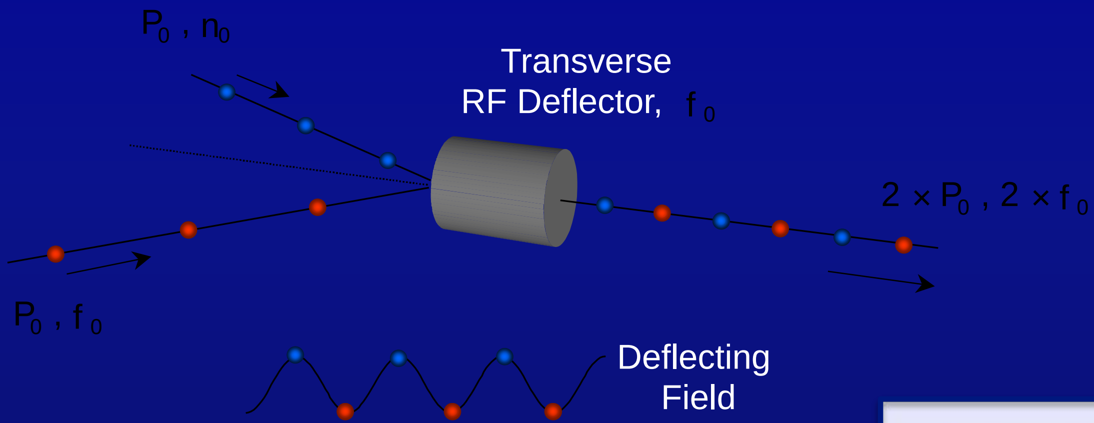
1. Linear and Nonlinear Optics
2. Vacuum Chamber Design and Beam Impedance Evaluation
3. Collective Effects and Beam Instabilities (including e-Cloud)
4. Beam-Beam Effects

CLIC Test Facility
CERN – CTF3



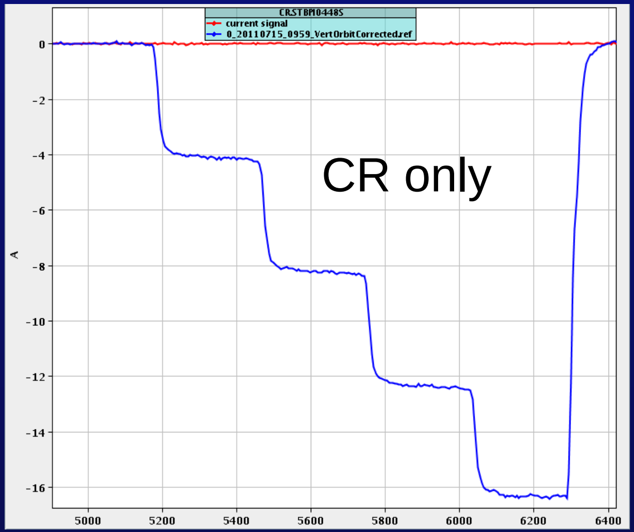
CLIC

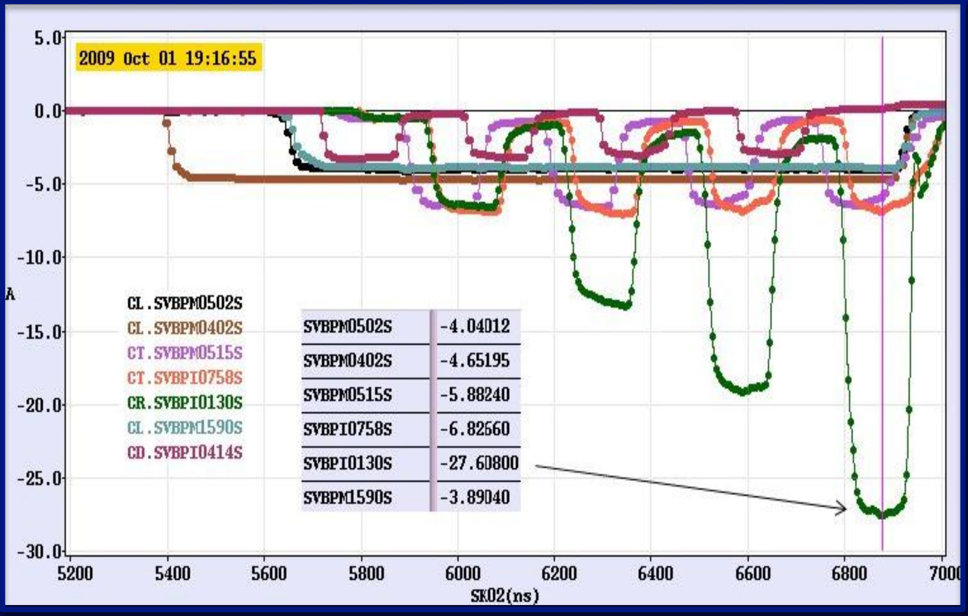
CTF3 Achievements – Drive Beam Generation



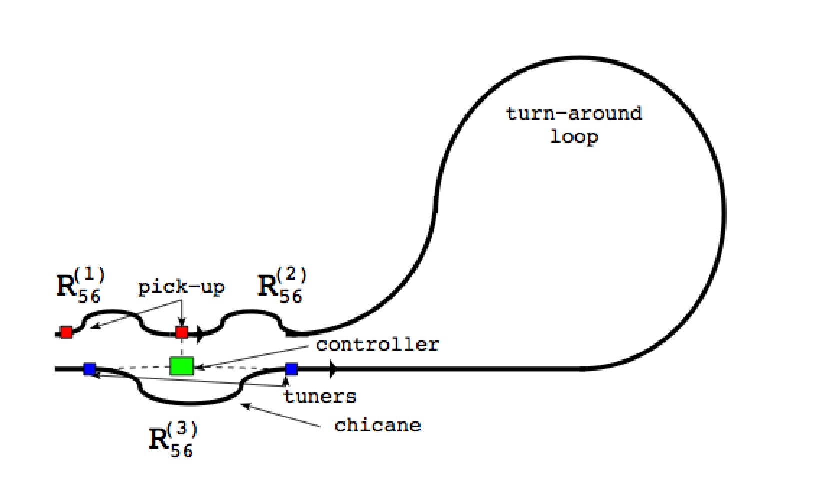
Beam recombination

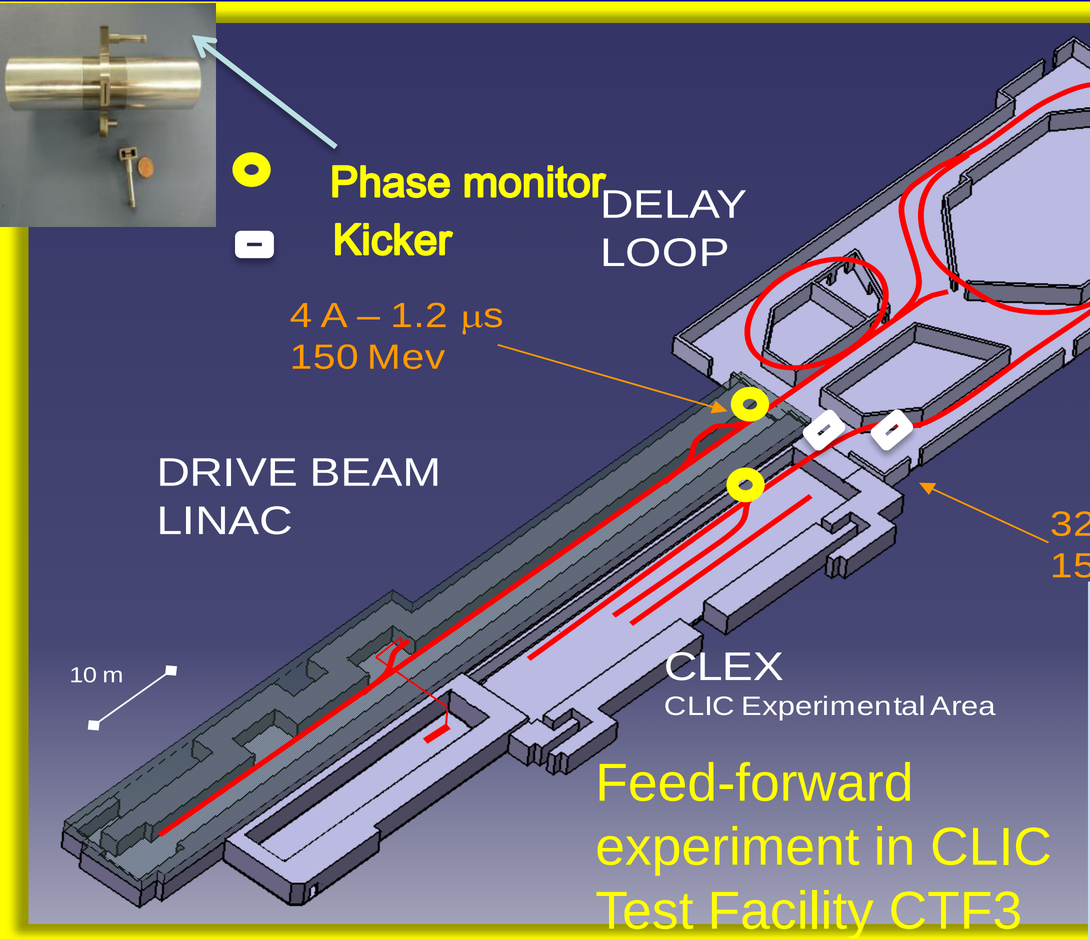
- Factor 8 recombination by RF deflector injection





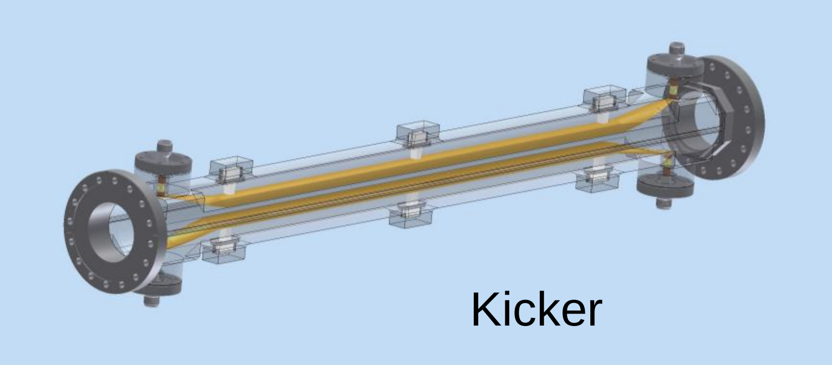
Drive Beam phase measurement and correction in CLIC turn around





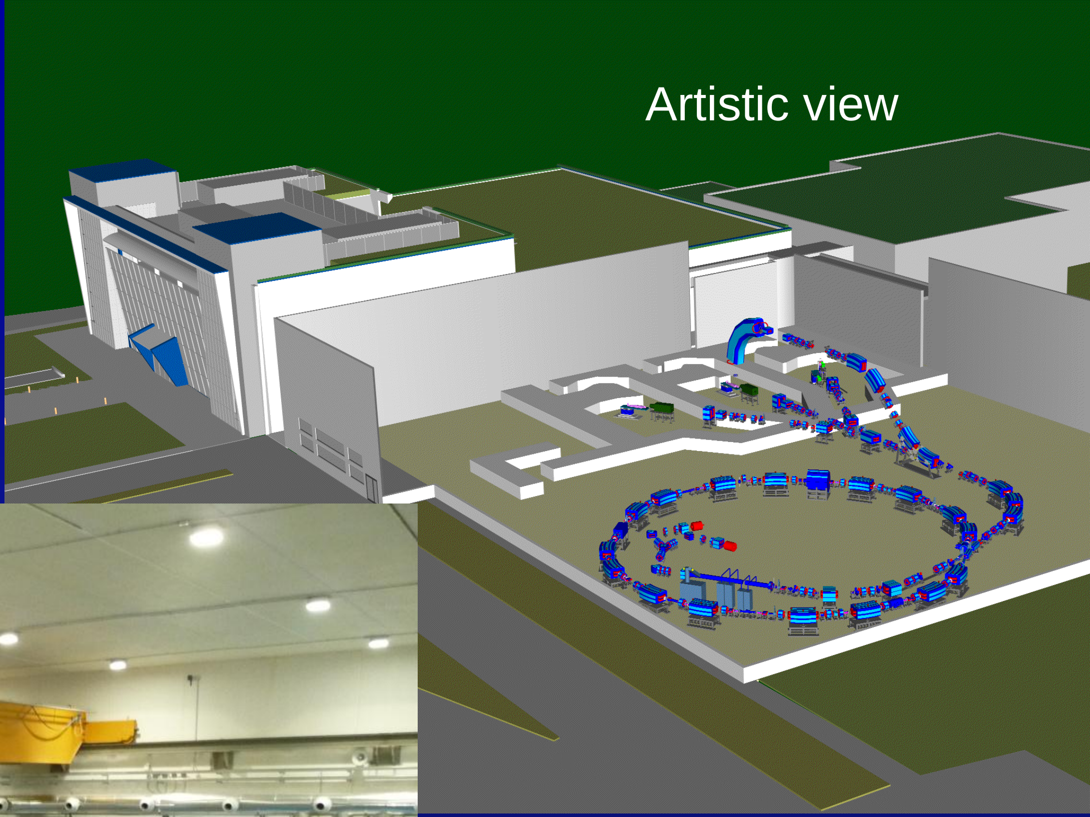
Feed-forward experiment in CLIC Test Facility CTF3

Transverse orbit distortion in the transfer line change the longitudinal path length -> the beam phase



CNAO – PAVIA

patients treated with protons
since september 2011.
Two days ago the first
carbon ion treatment !



Synchrotron hall
P – 200 MeV
C – 450 MeV

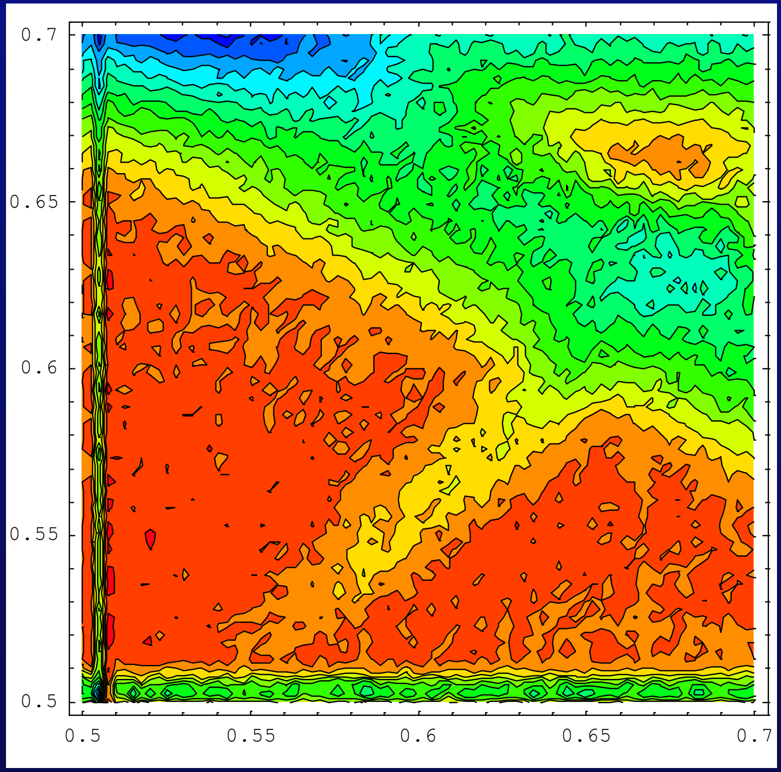
SuperB project

- High luminosity B-Factory → **10^{36} cm^{-2}s^{-1}**
- 2 rings: HER(e^+) @6.7 GeV, LER(e^-) @4.18 GeV
- Collision scheme: Large Piwinski Angle & Crab Waist sextupoles (LPA&CW) → large crossing angle, small beam sizes, very small emittances, $\beta_y^* << \sigma_l$
- Twin SC IP doublets of «new» design
- Low emittances comparable to latest generation SL sources and Damping Rings
- Unique feature: polarization of e^- beam in LER
- Possibility to use Linac for SASE-FEL in parassitic mode
- Site: Tor Vergata University campus (5 Km from LNF)
- Consortium «Nicola Cabibbo Laboratory» in charge

SuperB parameters

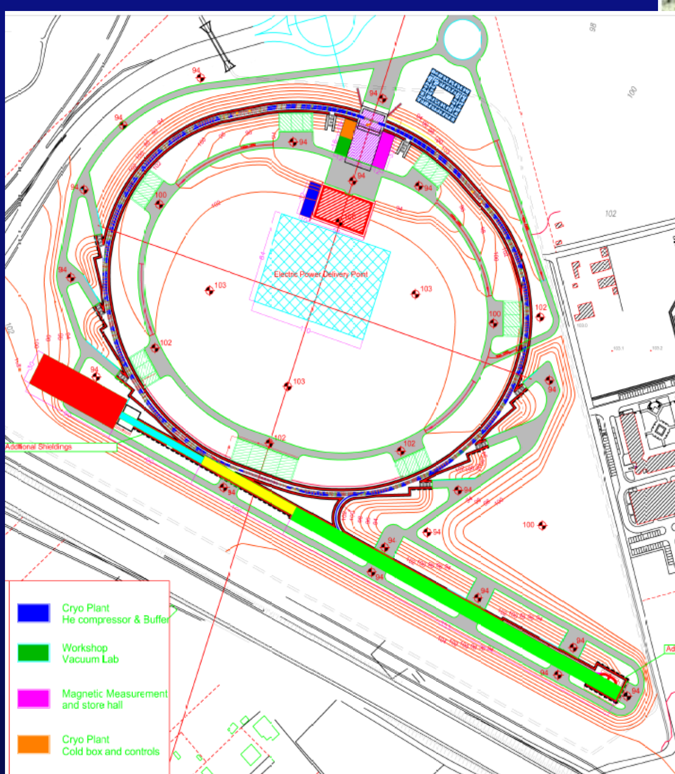
- Low emittances → tuning procedure developed and tested at DIAMOND and SLS
- Beam currents similar to previous B-factories but Luminosity 100 times larger
- BB simulations show large operational area in tune space
- Flexibility to achieve the design Luminosity with different beam parameters

Parameter	HER (e^+)	LER (e^-)
Luminosity ($cm^{-2}s^{-1}$)	10^{36}	
E (GeV)	6.7	4.18
C (m)	1205	
Crossing angle (mrad)	60	
Piwinski angle	19.6	17. 5
BB tune shift (x/y)	0.0026/0.11	0.004/0.105
N. bunches	937	
I (mA)	1976	2446
Part/bunch ($x10^{10}$)	5.30	6.56
IP $\beta_{x/y}$ (cm/mm)	2.6/0.253	3.2/0.205
$\varepsilon_{x/y}$ (nm/pm) (with IBS)	2.26/5.7	2.29/5.7
IP $\sigma_{x/y}$ (mm/nm)	7.7/38	8.6/34
σ_l (mm)	5	5
Polarization (%)	0	80

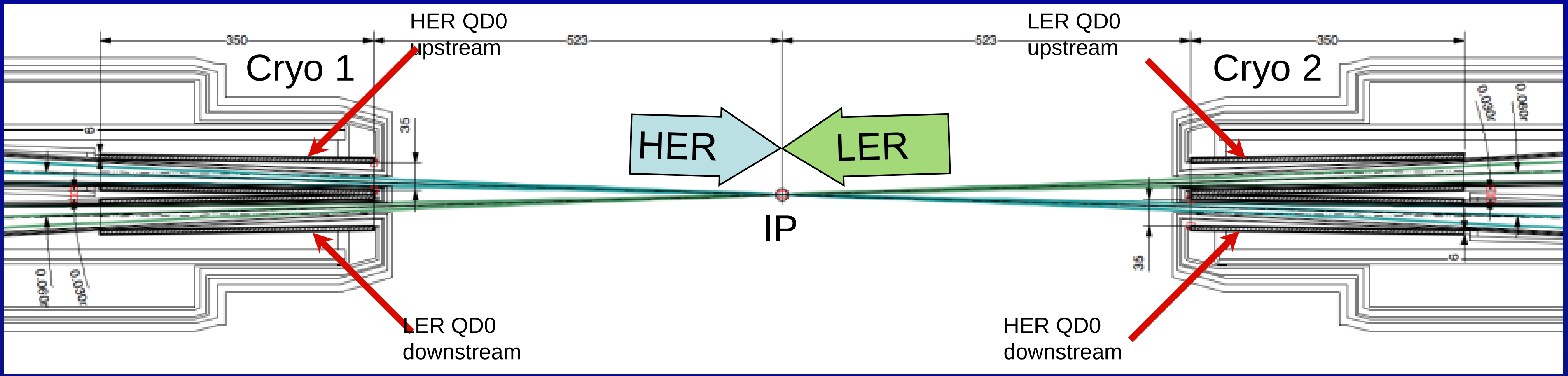


SuperB progresses

- Layout optimized to fit Tor Vergata site, ground motion measurements showed that vibrations are very well absorbed
- LER dipoles changed to increase polarization degree to 80%, Final Focus geometry changed for better spin dynamics
- Coupling correction with and without detector solenoid implemented
- Beam pipe radius increased, evaluation of beam power ready for final vacuum design
- Injection system optimized to incorporate SASE-FEL option
- Lattice ready for engineering stage

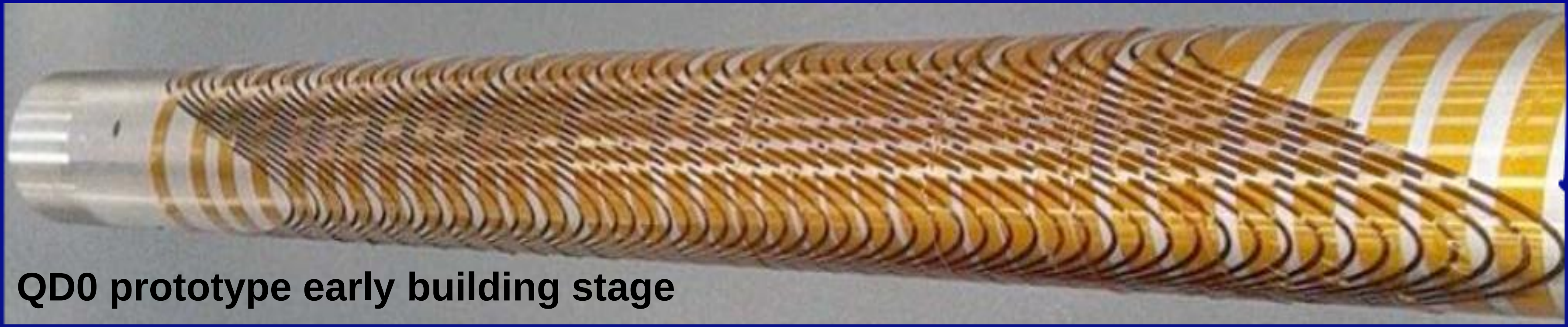


IP doublets design



- With large crossing angle a shared quadrupole layout is not viable, since displacement of magnetic axis with respect to nominal trajectories will generate unmanageable backgrounds by steering off-energy particles in the detector
- New design of the first doublet with «twin» SC quadrupoles developed
- Must generate a large field gradient (100 T/m) to obtain β_y^*~0.2 mm
- Thermal load on QD0 beam pipe must be evacuated at room temperature hence a cold pipe design is not feasible

QD0 prototype



- Magnetic design based on the double helical concept
  - Excellent field quality on almost the whole mechanical aperture
  - Possibility to produce arbitrary combinations of multipolar fields by clever design of the winding shape
- NbTi SC wire for a nominal current of 2650 A
- 50 mm inner bore diameter to accommodate rotating coil device to measure field quality
- Prototype successfully tested. Magnet quickly restores from quench even at currents exceeding its design current (2750 A)

Thanks for your attention