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Istituto Nazionale di Fisica Nucleare
Sezione di Milano

UNIVERSITÀ DEGLI STUDI DI MILANO

PhD thesis proposals @ INFN-Milan and University of Milan

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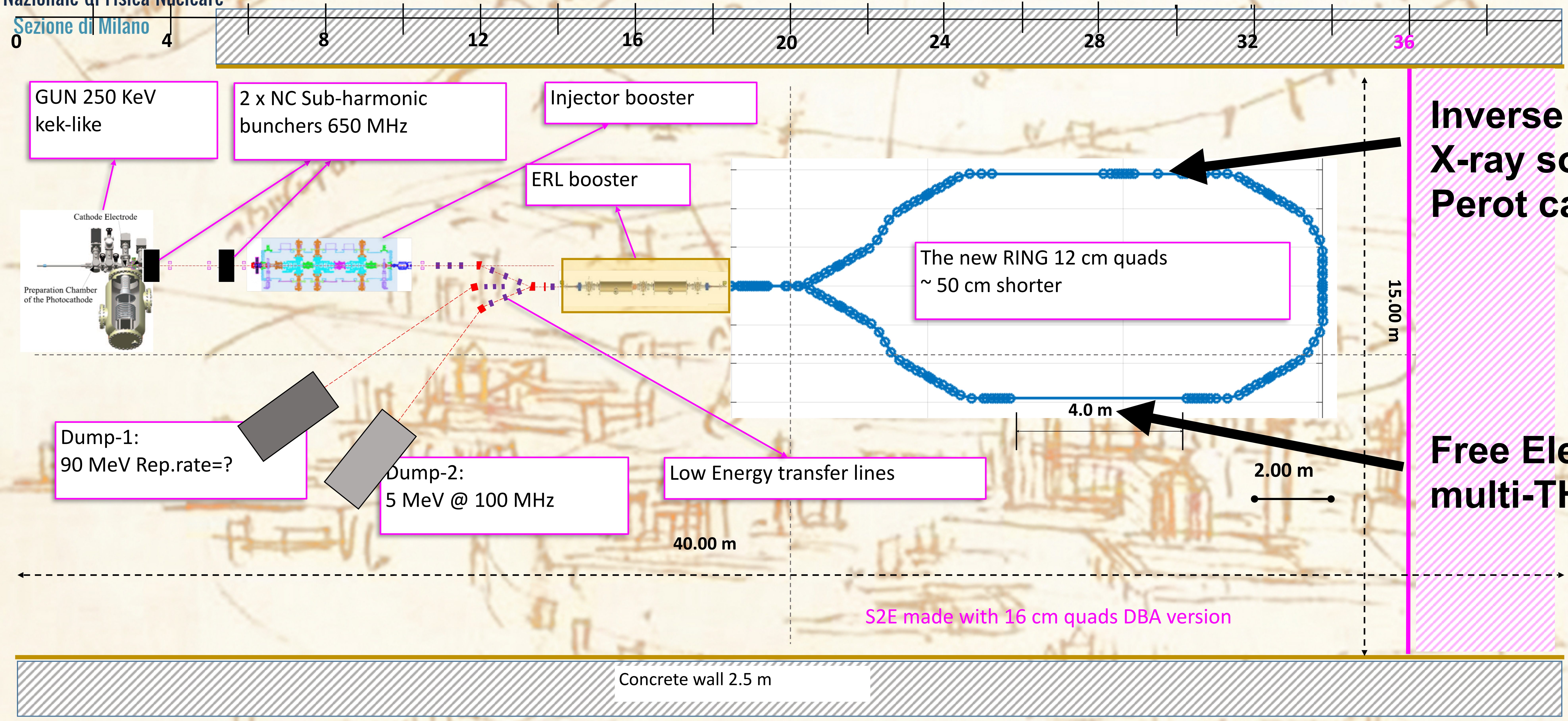
The BriXSino project



Inverse Compton Scattering X-ray source and Fabry-Perot cavity

Free Electron Laser multi-THz source

e-beam parameters:

Energy (*MeV*)	20 - 45
Bunch charge (*pC*)	50 - 200
Repetition rate (*MHz*) (CW operation, ca. 93 – *0.9286 MHz*)	1300./14, down to 0.9286
Average Current (*mA*)	< 5
Nominal beam power (*kW*)	< 225

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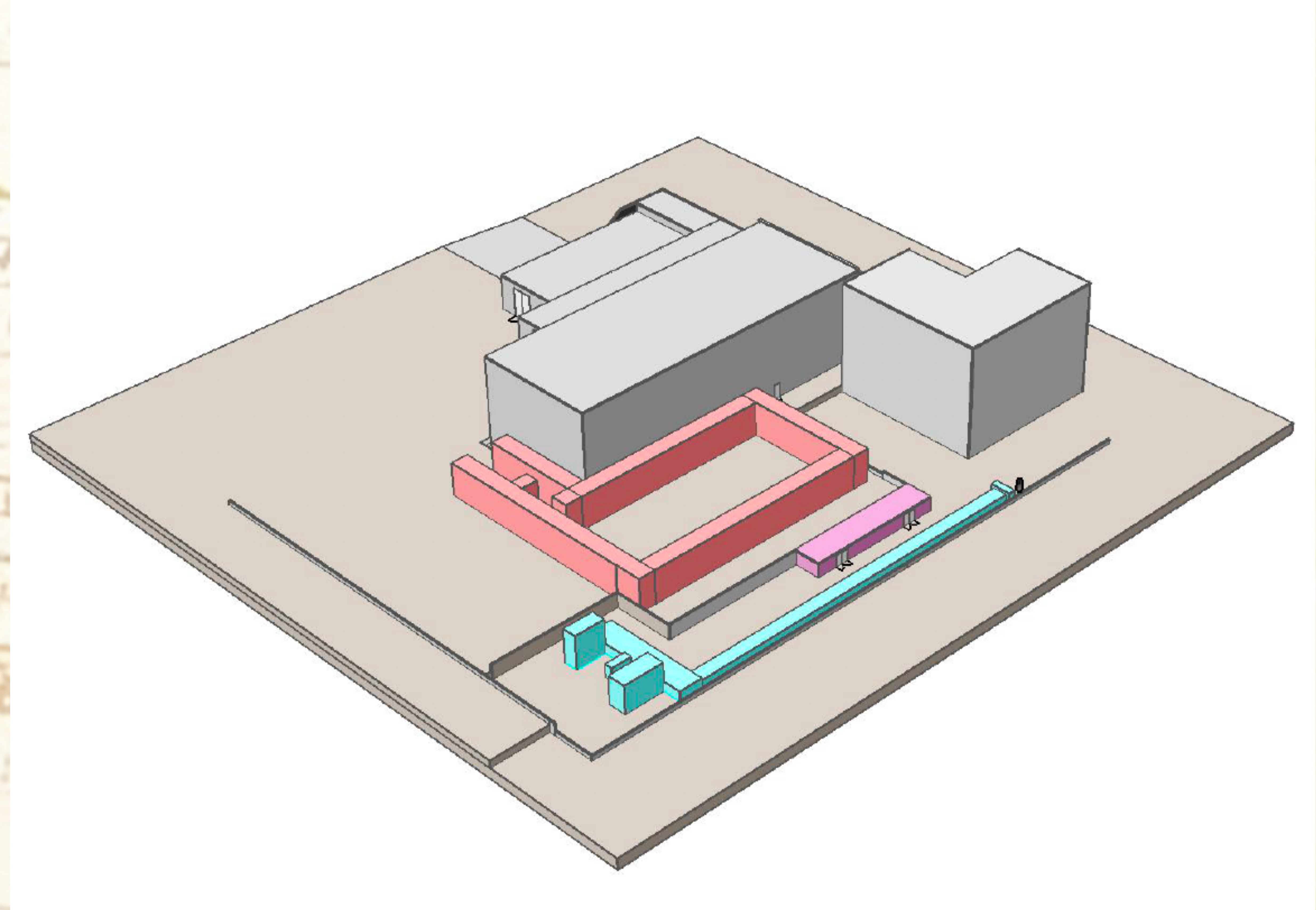
The BriXSino project

BriXSino is the demonstrator for MariX (FEL) and BriXS (Compton source)

See www.marix.eu for further details.

- TDR founded by the INFN
- Demonstrate energy recovery in two-way operation
- Demonstrate two way acceleration of a FEL graded, high power beam
- Bonus: deliver a high flux ($\approx 10^{12}$ ph/s), < 40 keV, X-ray beam for medical imaging (mammography) by Inverse Compton Scattering (ICS).
- Bonus: deliver a high power ($\approx$ 3 kW) beam of up to 30 THz radiation by Free Electron Laser (FEL)
- Bonus: employ spent electron beam for flash therapy
- Bonus: TBD.

BriXSino wil be built in LASA: Laboratorio Acceleratori e Superconduttività Applicata



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BriXSino side experiment: ACTIS

ACTIS
Arc Compressor Test In a Synchrotron

Istituto Nazionale di Fisica Nucleare

ACTIS will take place at SOLARIS in Kraków

Experimental demonstration of sub-picosecond e-bunch compression in a storage ring.

M. Rossetti Conti

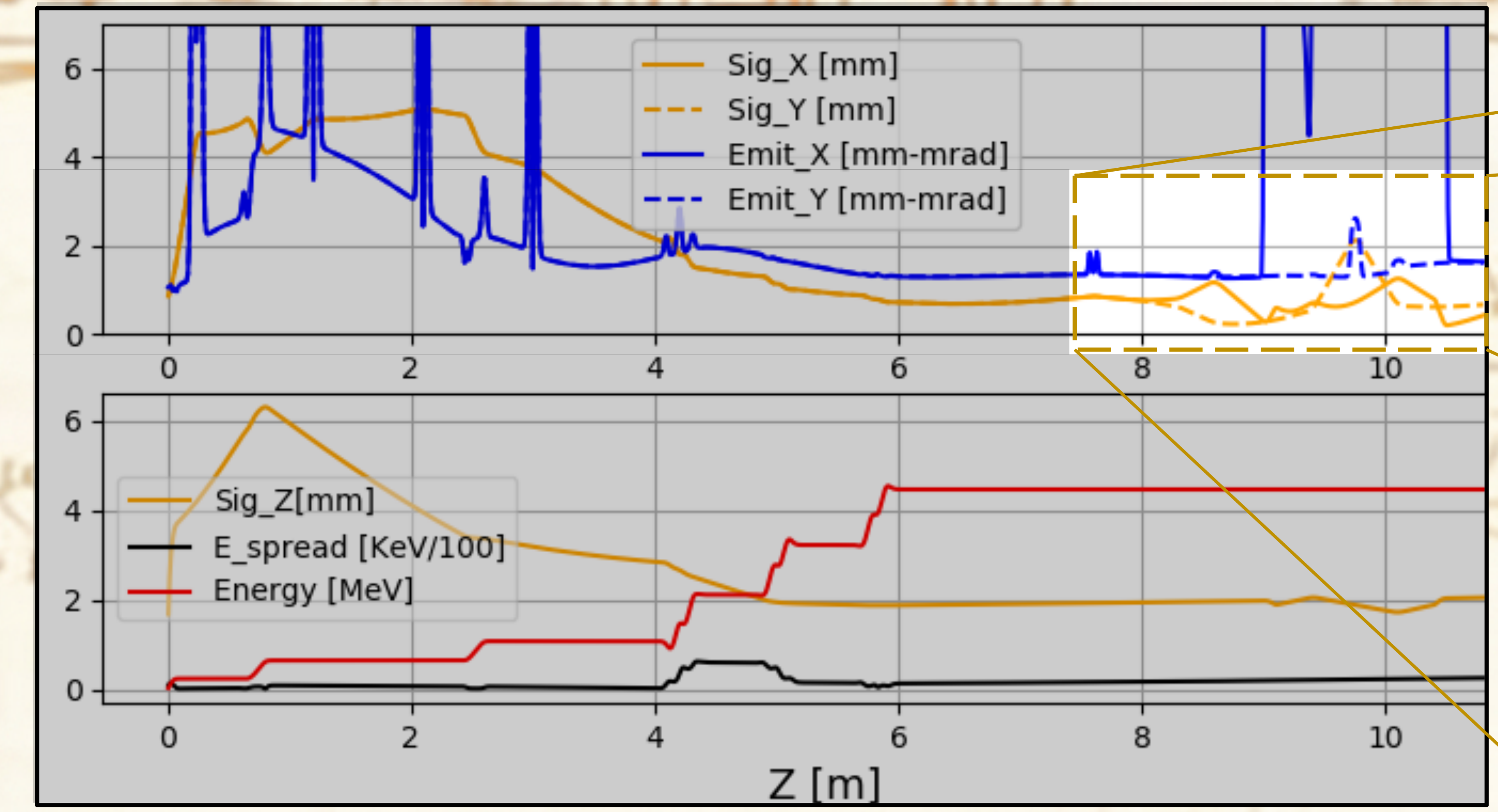
CSN5 – *Call 21188/2019 to award funding to 6 projects presented by young researchers.*

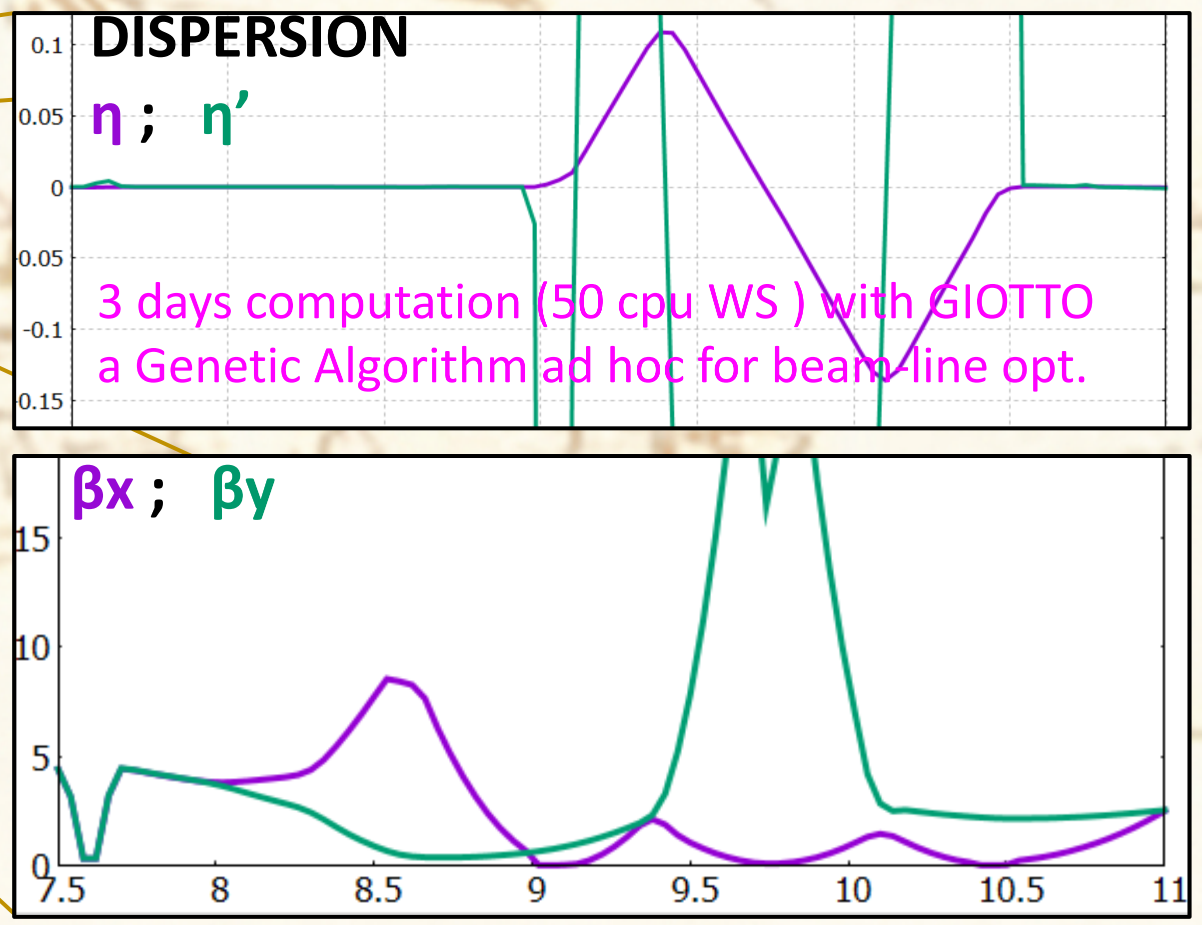
BriXSino beam dynamics

Highly non trivial beam dynamics due to high power, relatively low energy and unique machine layout

We use a variety of simulation codes (Astra, Elegant,…) and in house developed genetic optimizer (Giotto) to improve performances

- Two way acceleration, bunch crossing
- Tight focusing for Compton source
- FEL graded beam for THz source
- Energy recovery
- CSR effects evaluation





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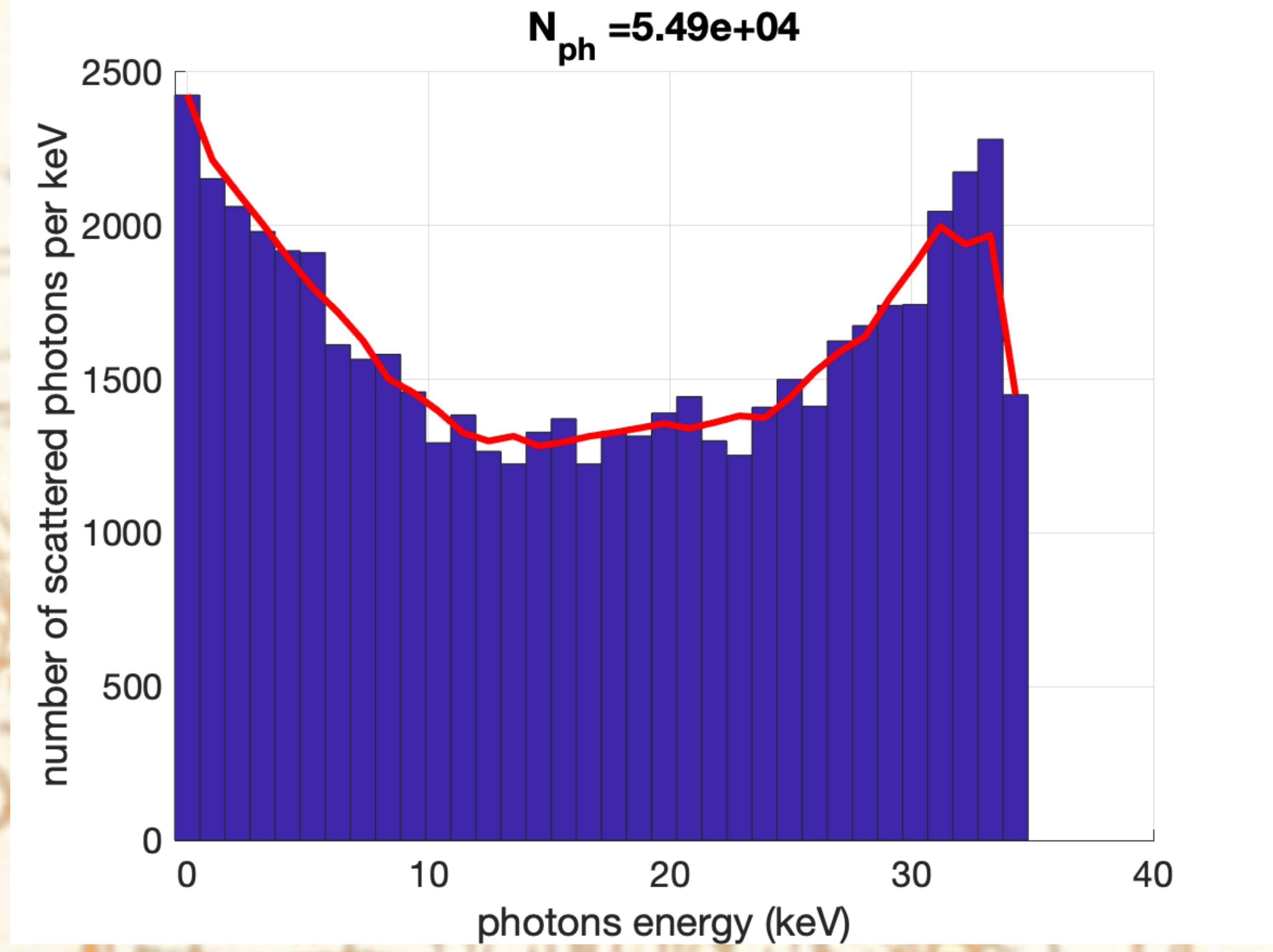
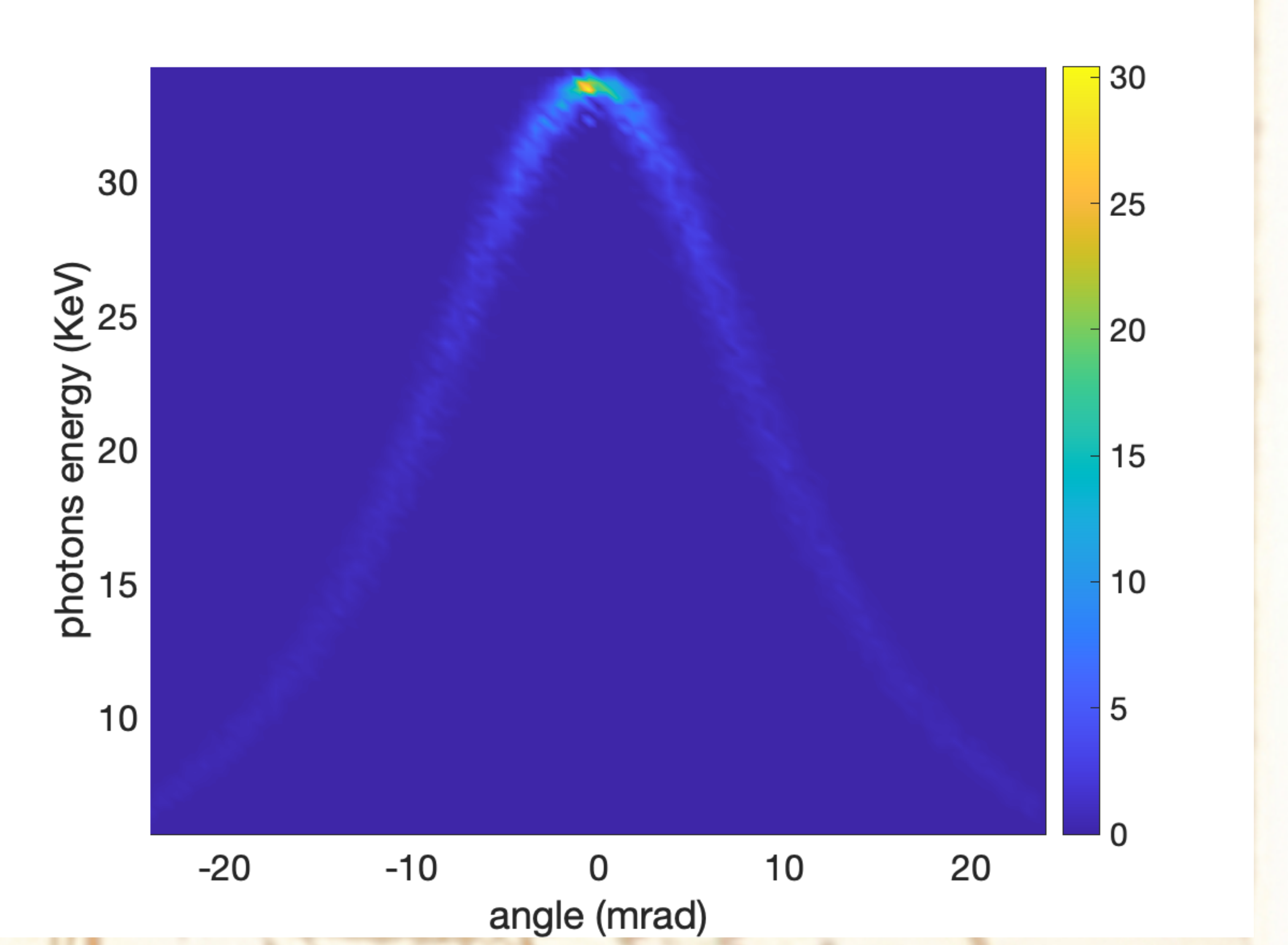
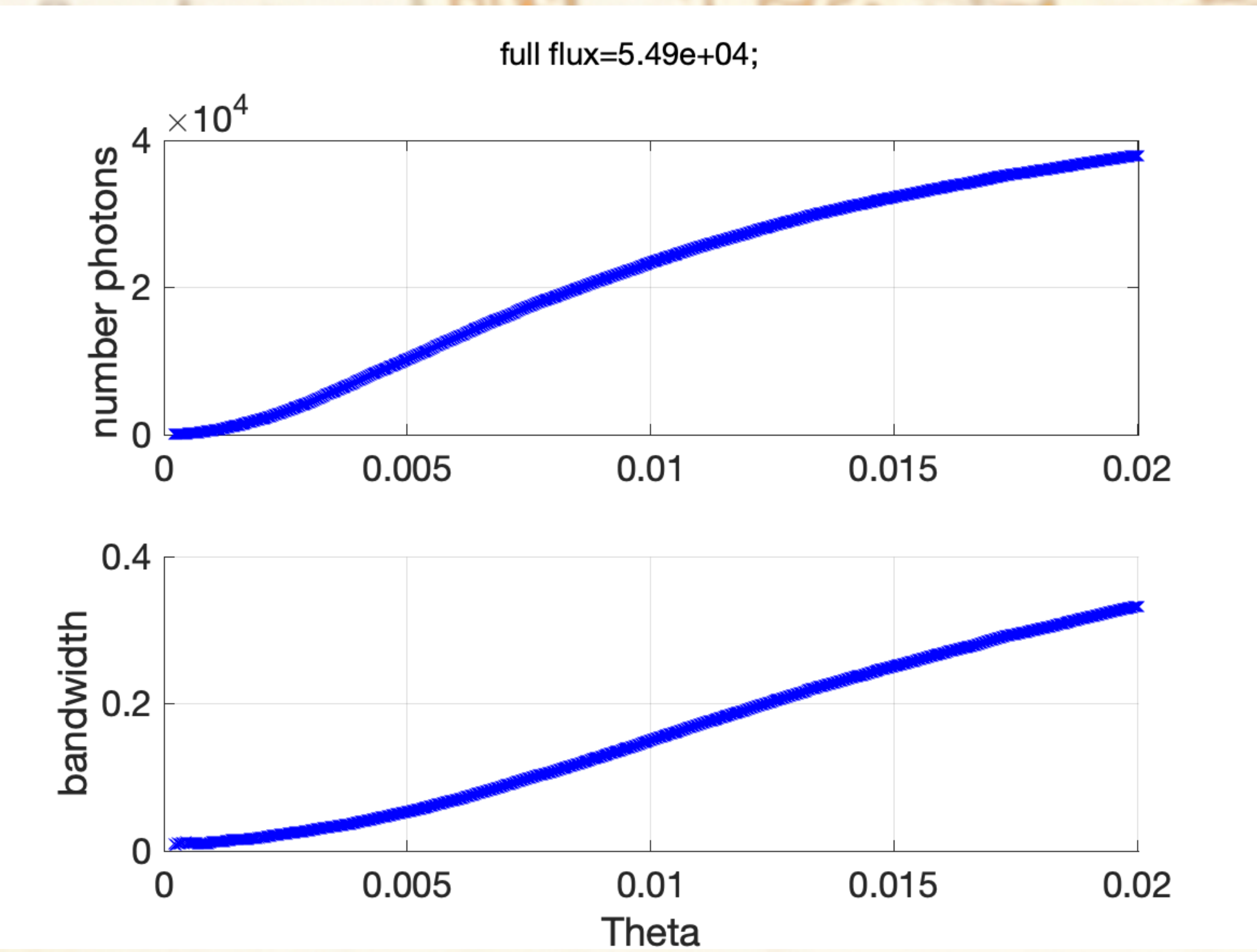
BriXSino ICS source

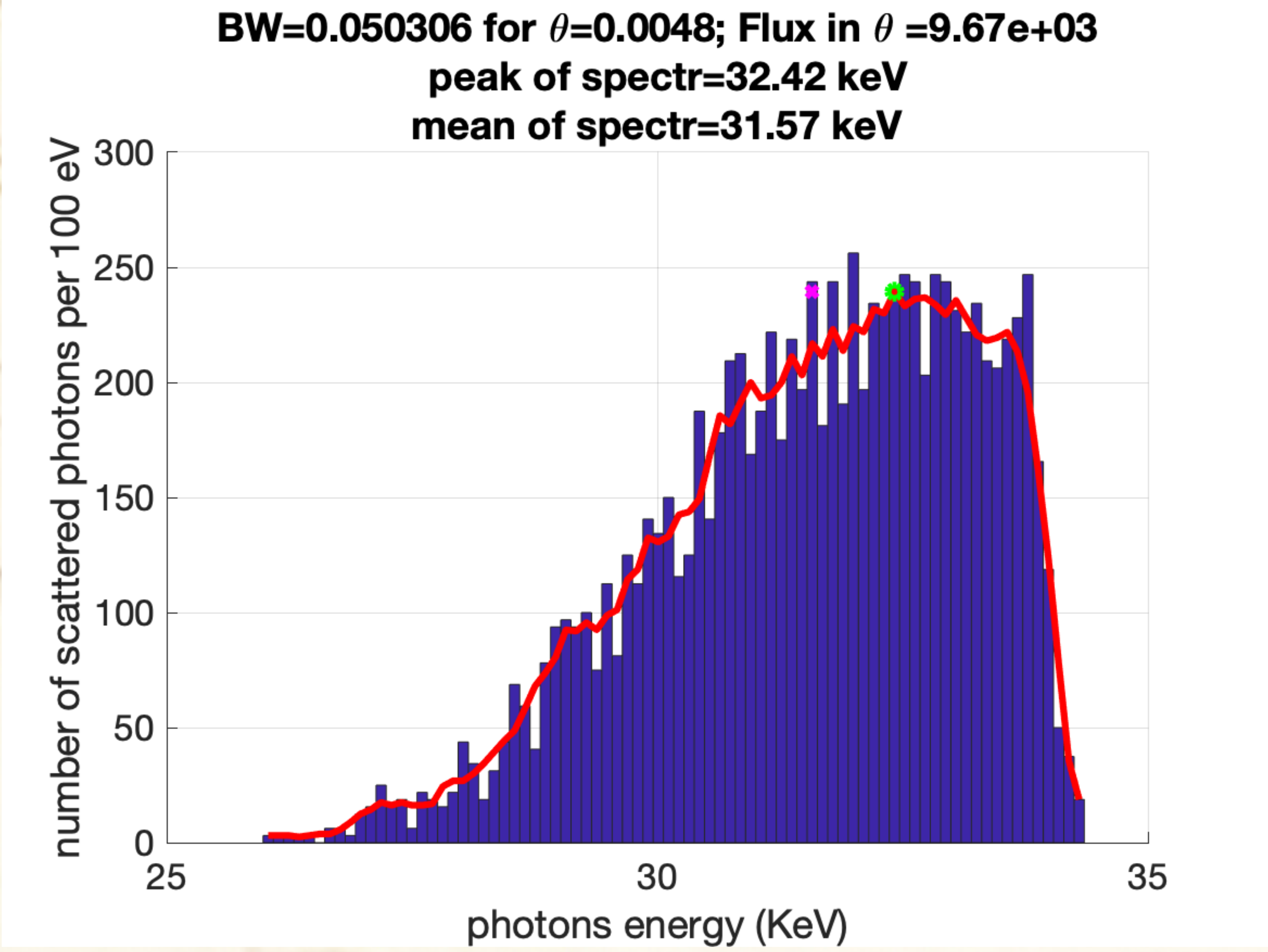
UNIVERSITAS STUDIORUM MEDIOLANENSIS

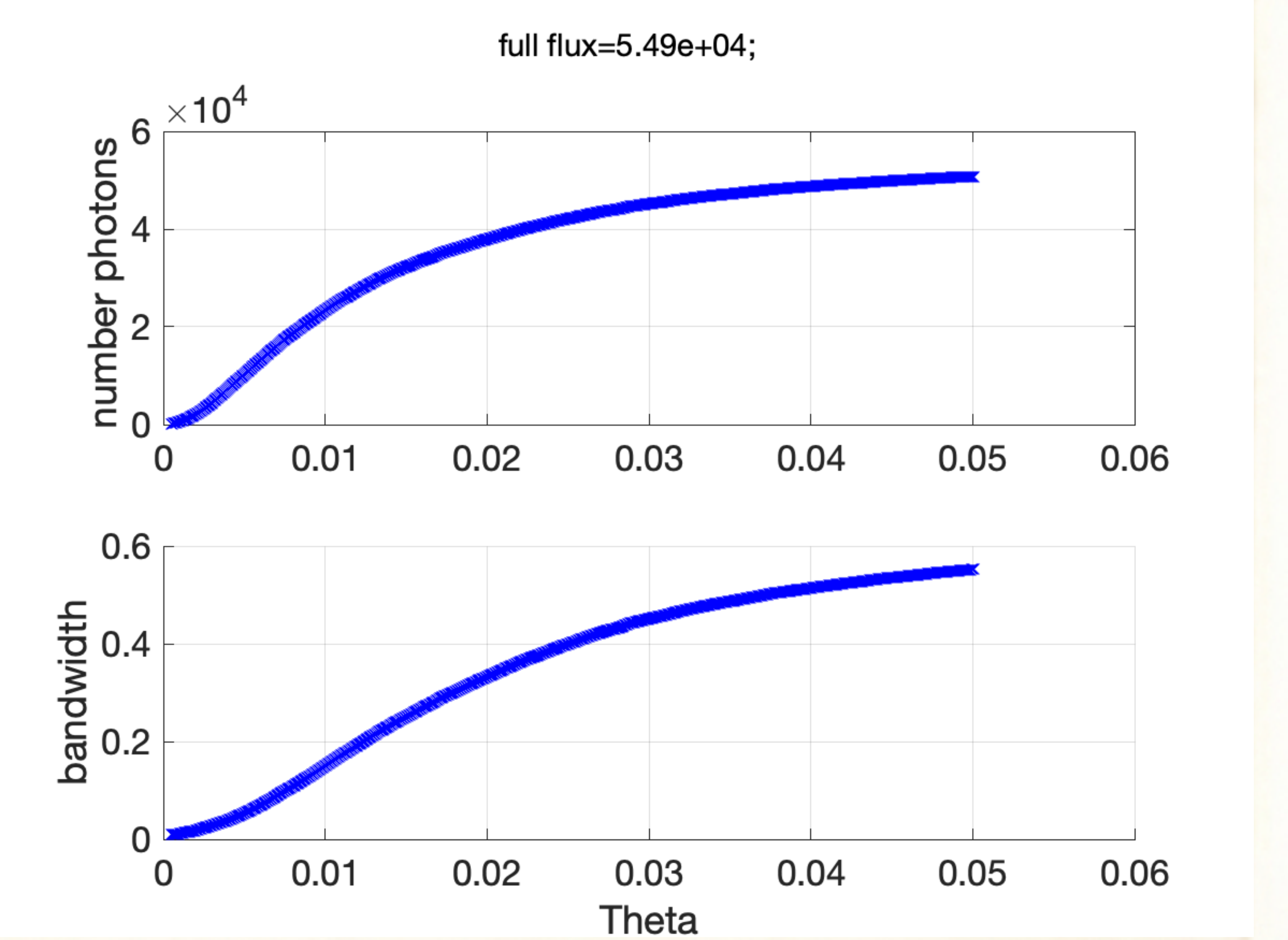
Characterization and optimization of the Inverse Compton X-ray source by in house developed Montecarlo code ROZE







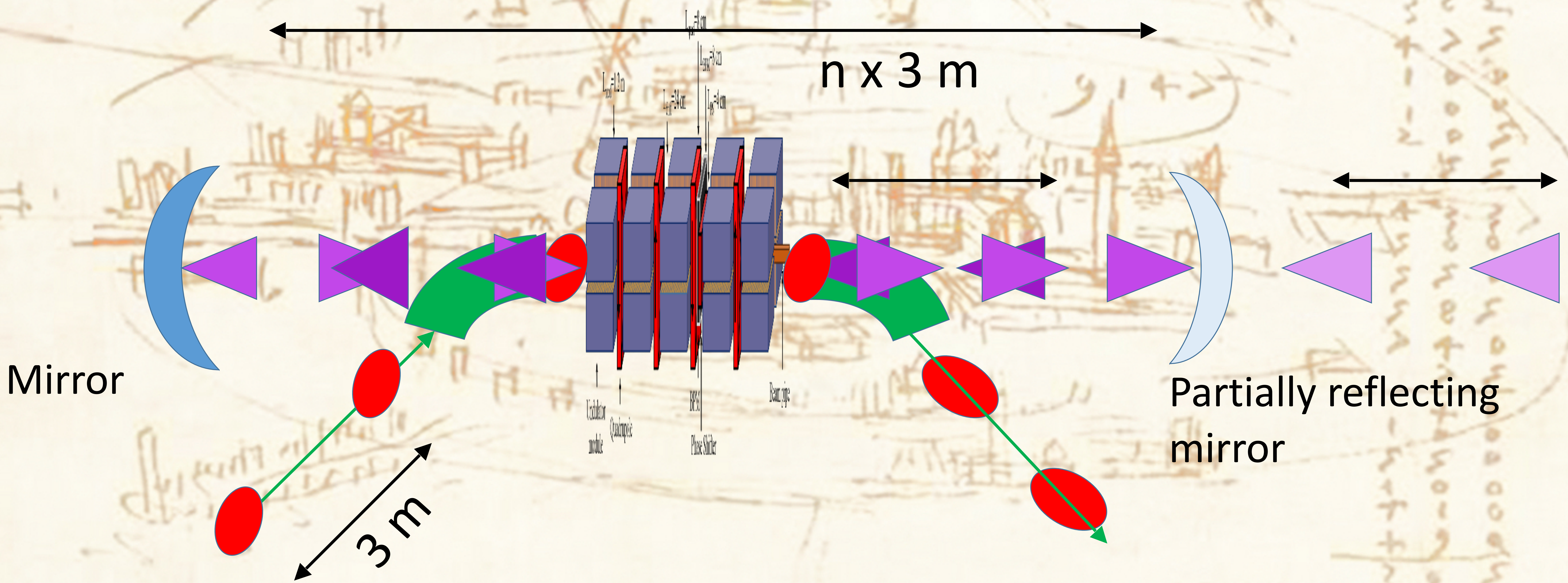




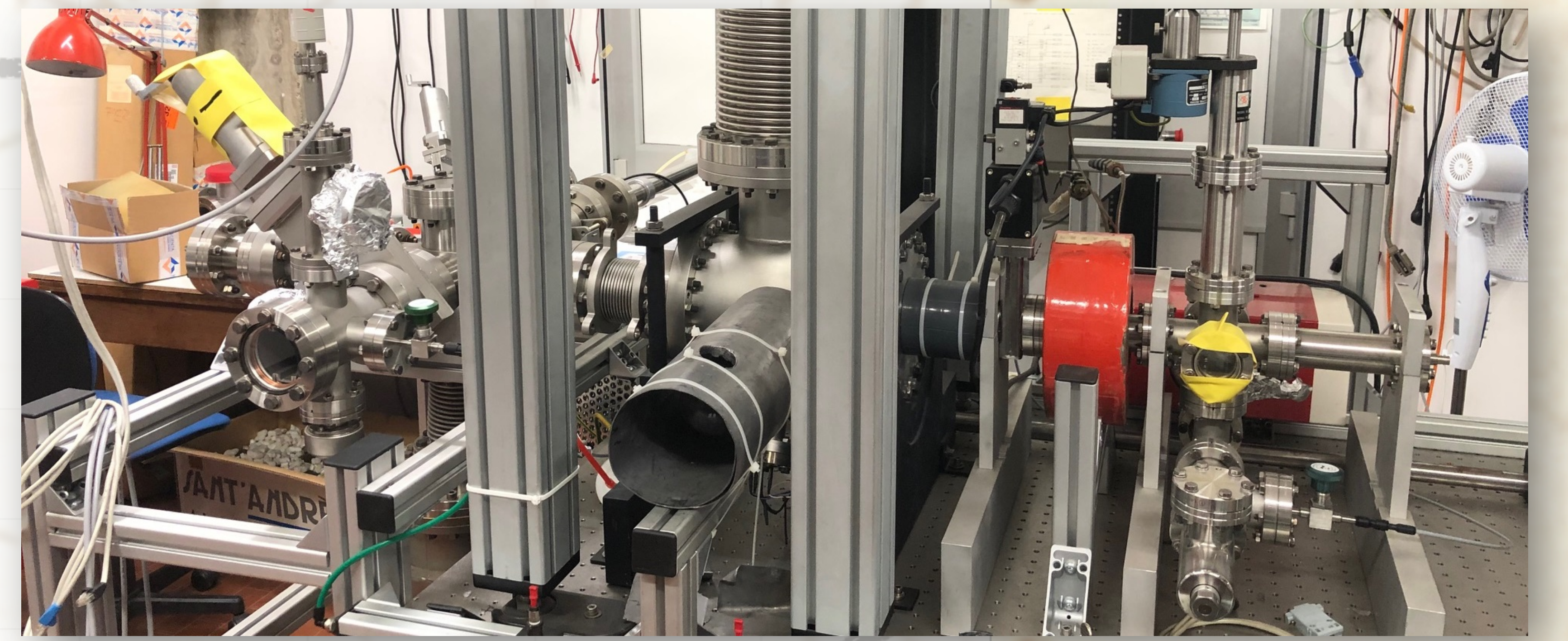
BriXSino FEL source

Oscillator mode Free Electron Source

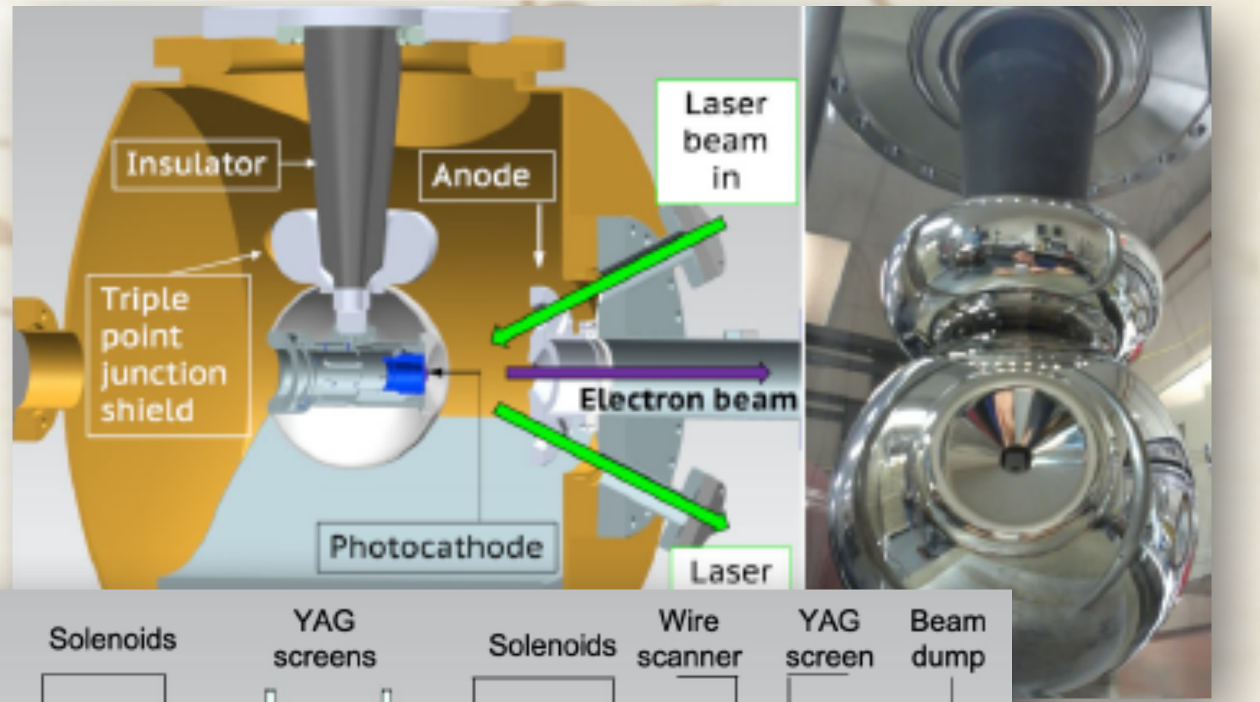
Full characterization and optimization of the FEL oscillator using Genesis and optical physics radiation transport codes.

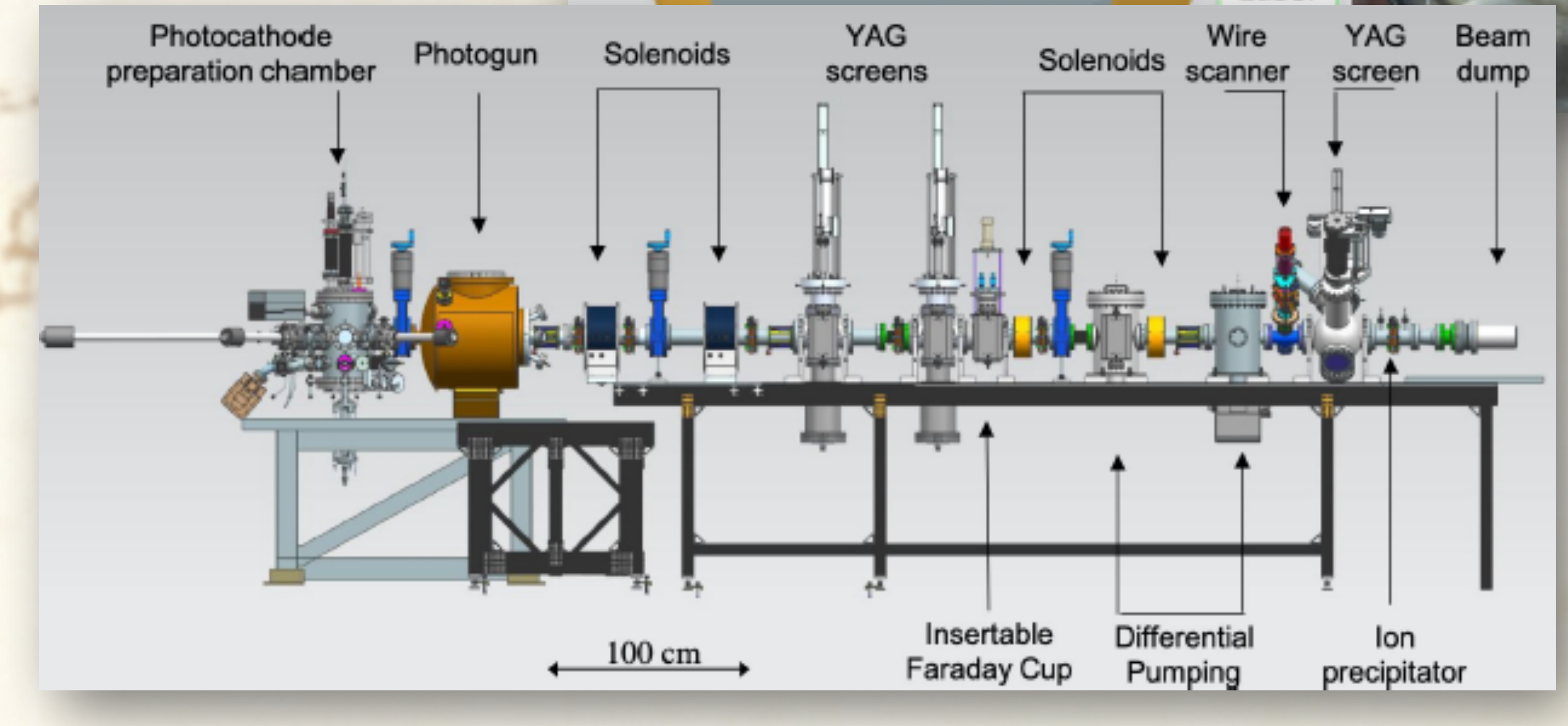


High current - high brightness electron sources

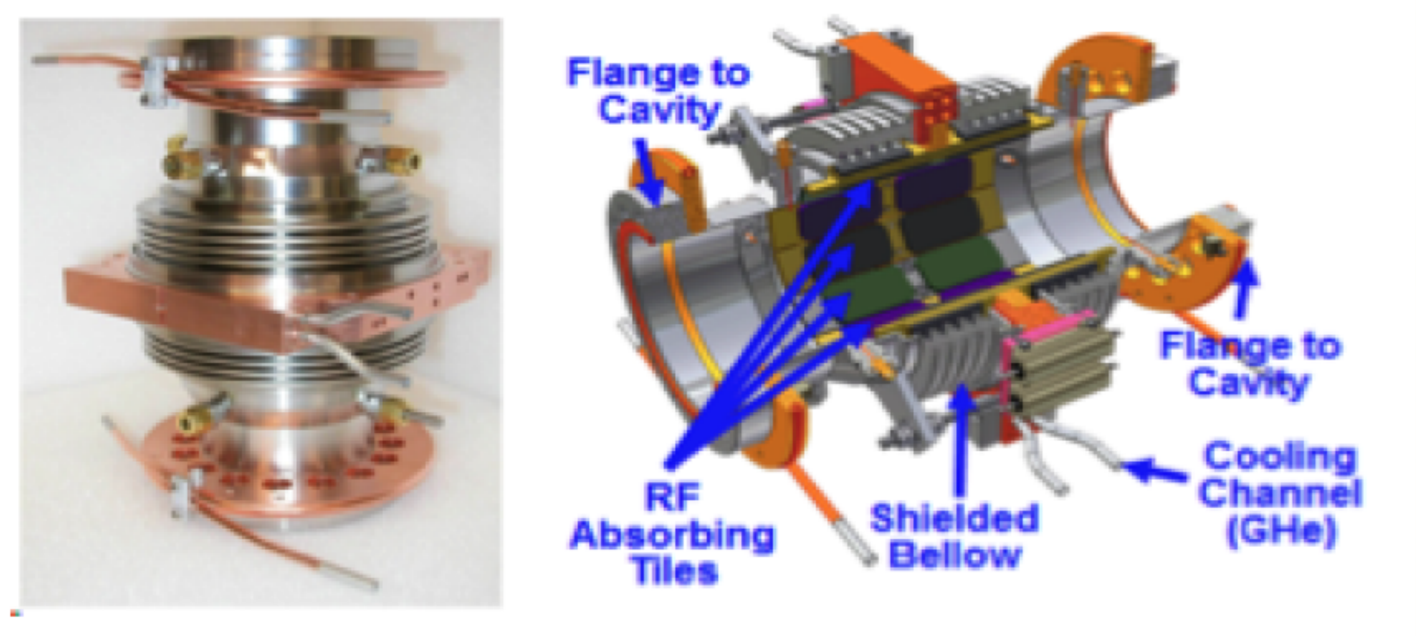


- High current –high brightness electron sources are the workhorse of modern ERL machines.
- The challenges are:
  - High repetition rate operation to reach high currents
  - Generation of high brightness beams
- At INFN LASA we have a long experience on preparation of photocathodes for high brightness facilities (FLASH, XFEL, LCLS-II, APEX, PITZ).
- We are starting a long-term program for characterizing photocathodes in a DC gun at LASA for **high current** operation.
- Meanwhile, an R&D program towards the development of a new **high current/high brightness** electron source able to produce beams for CW/ ERL machines is beginning.
- For further info: daniele.sertore@mi.infn.it





Superconducting cavity development for ERL sources



ERL Linac based on SC cavities operating in CW challenges:

Minimize RF power dissipation for design E_{acc}

Beam instability and beam breakup

HOM excitation and extraction

Microphonics

High gradient stability

The PhD activity will be at INFN LASA. The SRF group at LASA has an outstanding and unique experience on designing, manufacturing and qualifying superconducting cavities for several accelerators project worldwide as E-XFEL, ESS and PIP-II.

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The quest toward high-Q for future proton acceleration

High-Q regime for superconducting cavities allows accelerators operation with high duty factors, up to 100% (continuos wave)

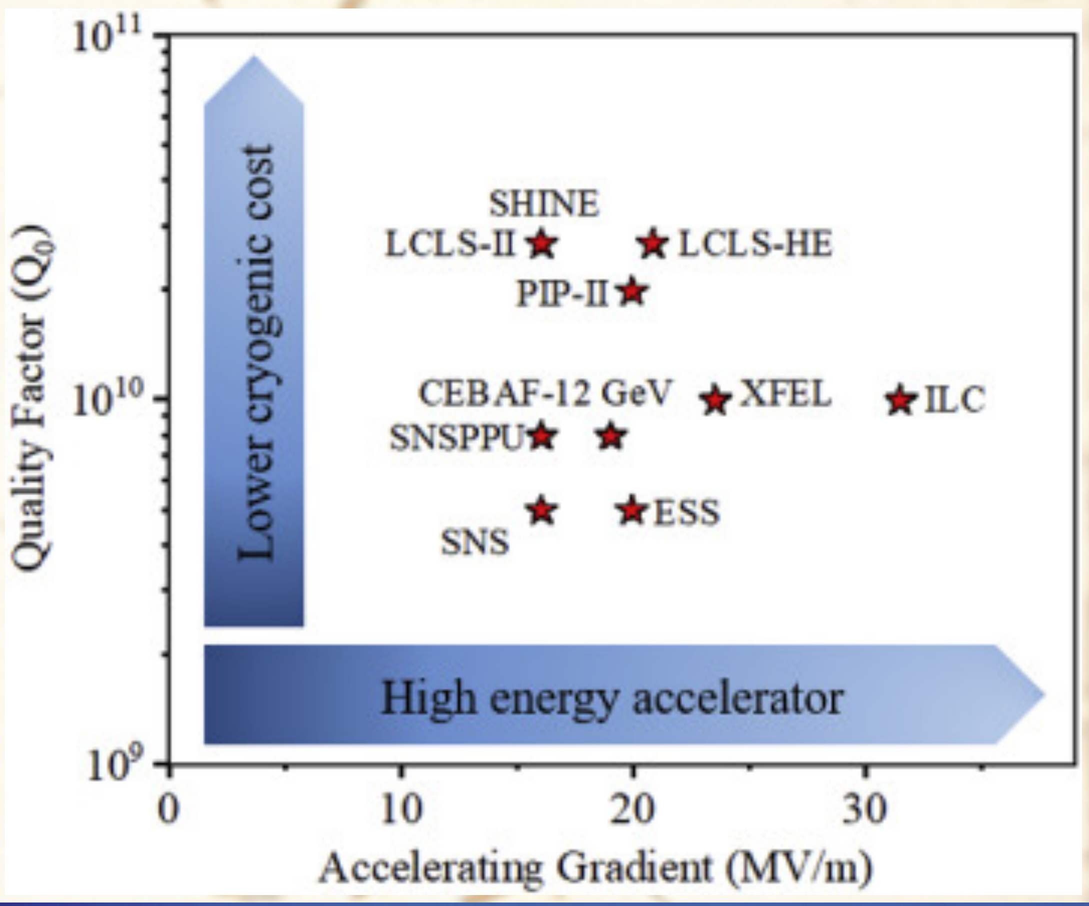
Nowadays, electron linear CW accelerators are under development, thanks to the maturity of high-Q technology for TESLA-shaped 1.3 GHz cavity.

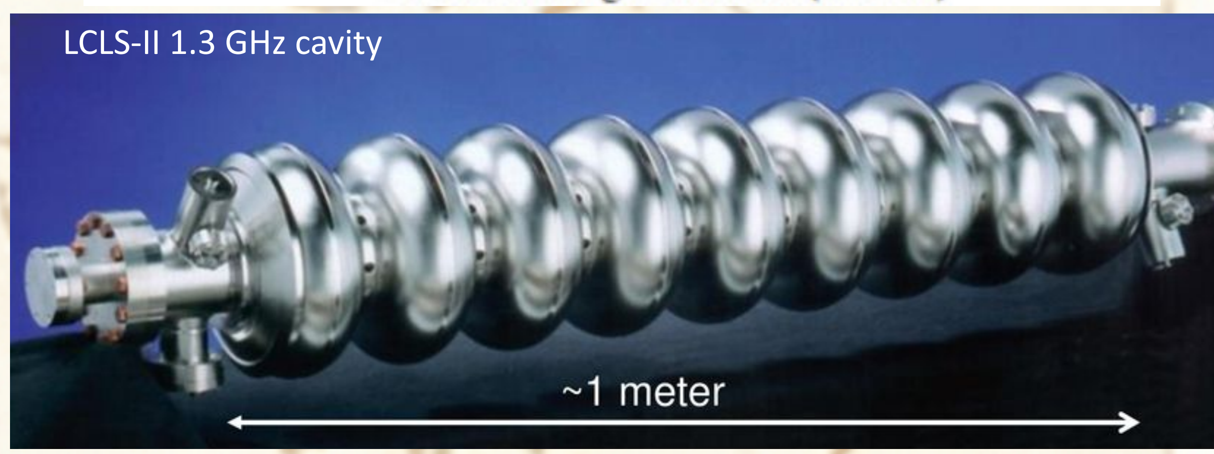
At LASA, we are involved in the production of sub-GHz SRF cavities for proton acceleration (ESS and PIP-II projects). PIP-II linac is a CW machine, which delivers a high intensity 800 MeV proton beam to a booster circular accelerator. High-Q cavities are therefore needed.

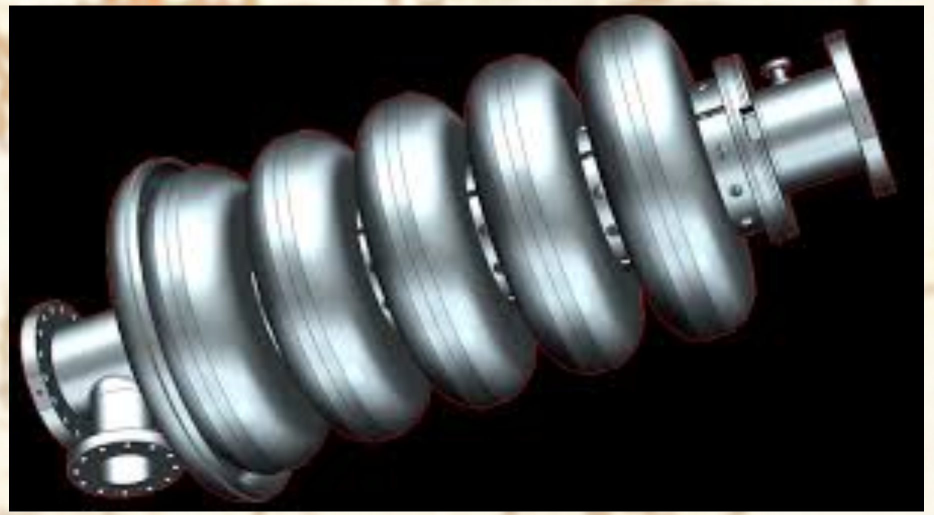
We have started a R&D program aimed to develop the high-Q technology to sub-GHz cavities. The main challenge is adapt the processing techniques to the different shape and size of such cavities and reach a «golden standard»

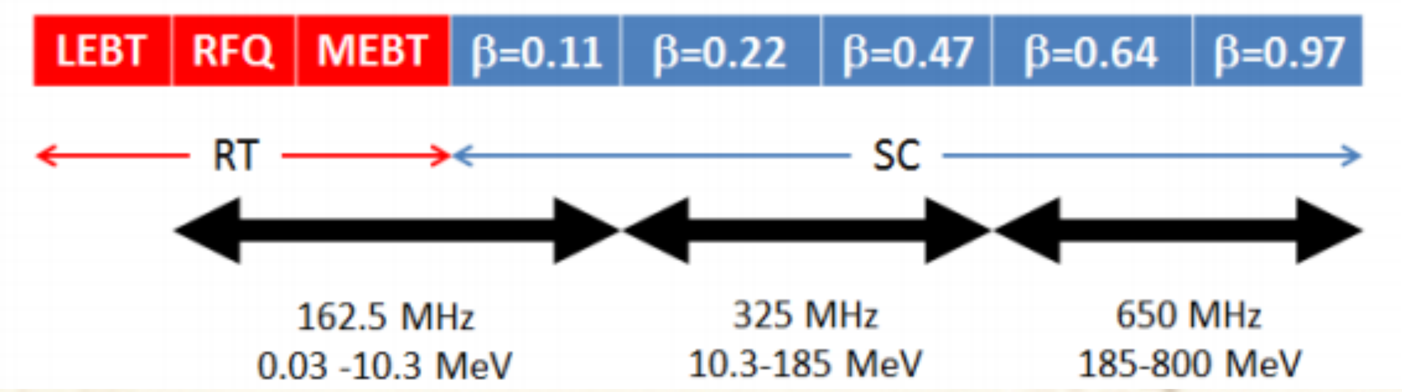
A vast experimental and analytical activity is foreseen at LASA for the next years on the main techniques involved in high-Q:

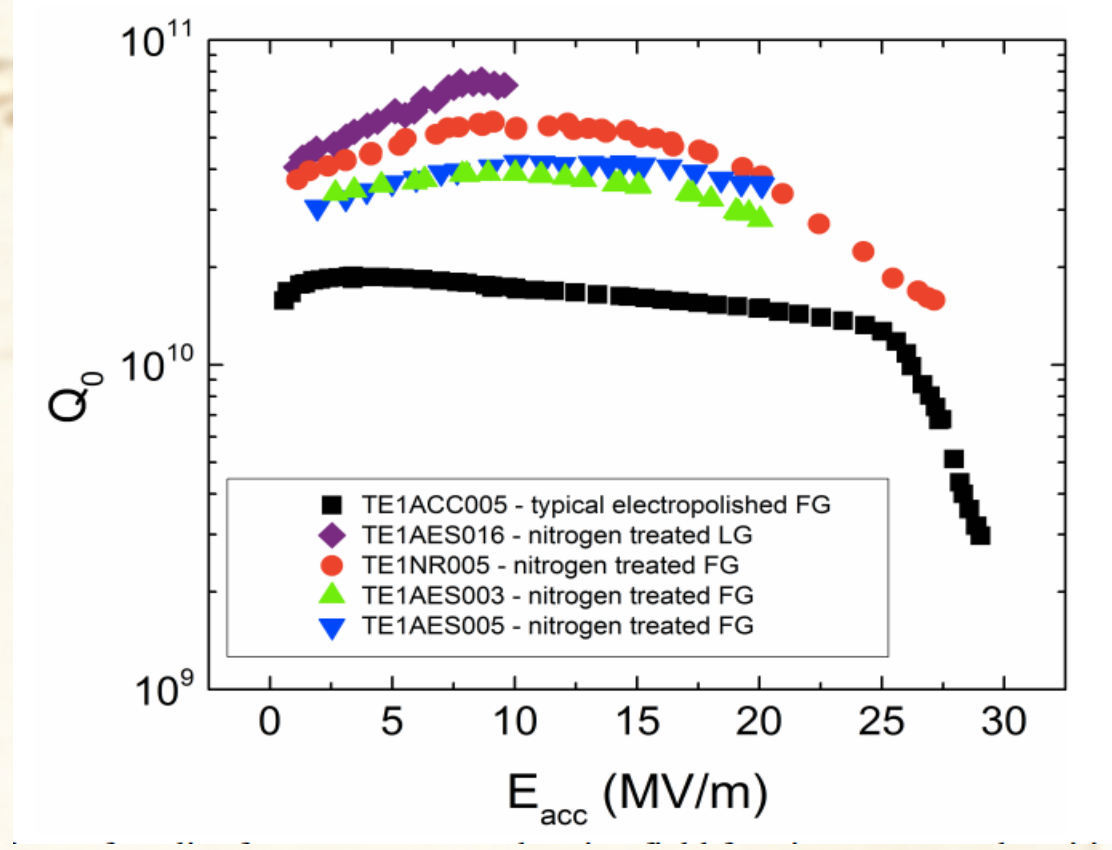
- Nitrogen doping and\or Infusion
- Bulk and Cold Electropolishing
- Magnetic flux expulsion
- High temperature annealing
- Fast cavity cooldown









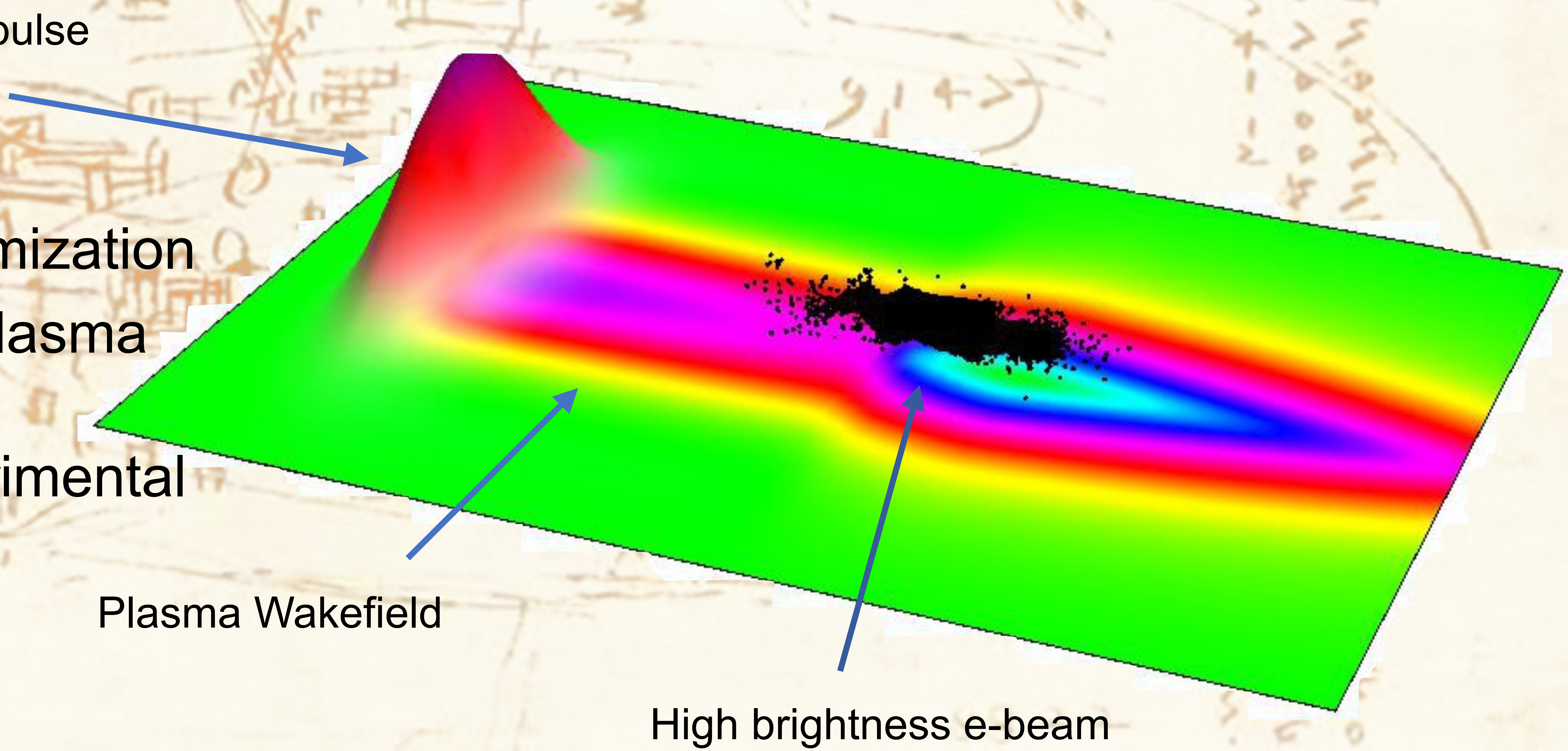


For further info: michele.bertucci@mi.infn.it

Laser Wakefield Acceleration: External Injection Experiment

The External Injection experiment will take place @LNF. We also collaborate for the EuPRAXIA @ SPARC_LAB project

- Beam dynamics optimization
- Characterization of plasma booster
- Participation in experimental runs (from 2023)
- Data analisys



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Plasma based Acceleration: modeling and theory

Plasma based acceleration simulations require tons of computational power, so reduced models, catching only the relevant physics for acceleration, allow to scale hardware requirements to tabletop resources.

At present, we are pursuing two distinct strategies:

- Moment equations for beam dynamics:

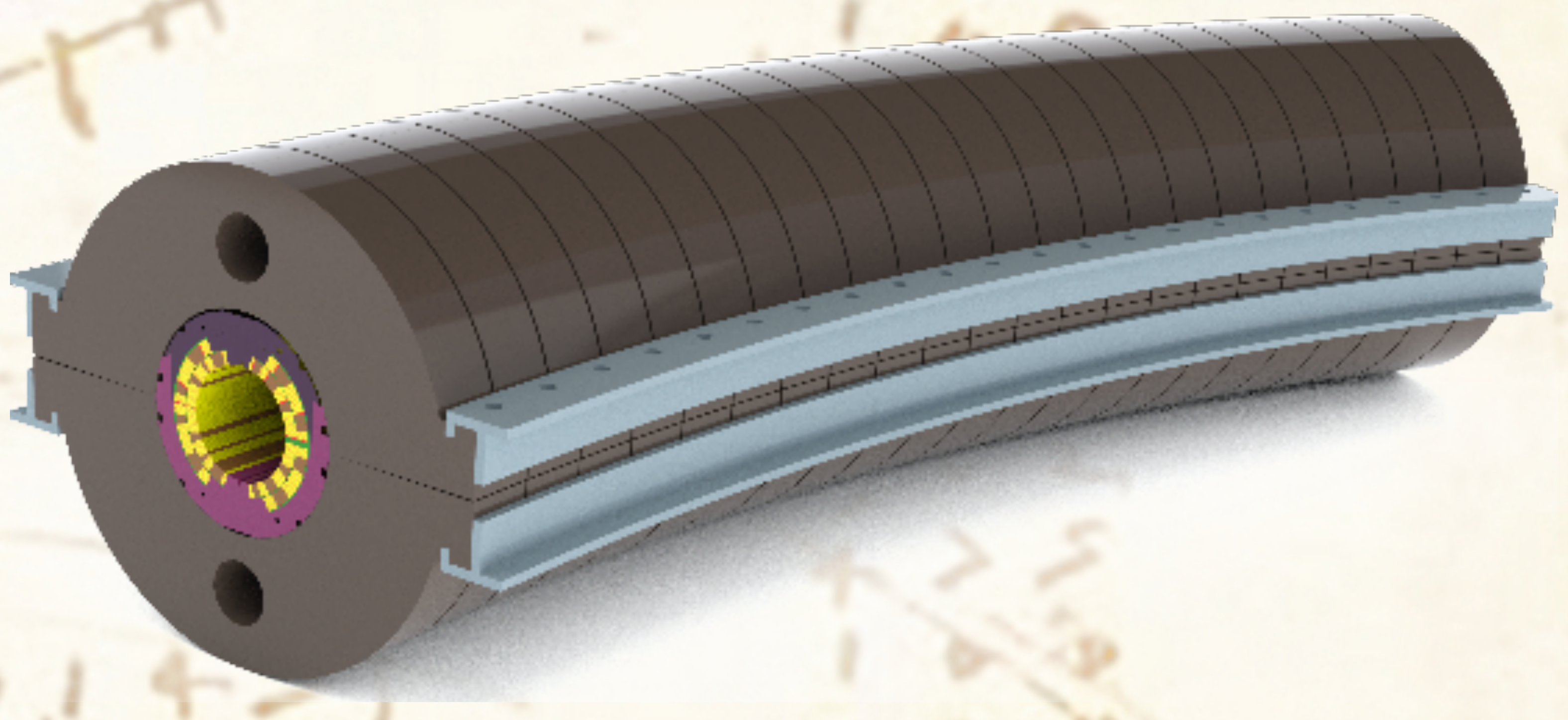
$$\partial_t < \Phi > = < p_x/\gamma \partial_x \Phi > + < F_x \partial_{p_x} \Phi > + < F_z \partial_\gamma \Phi >$$

- Transverse expansion for plasma physics:

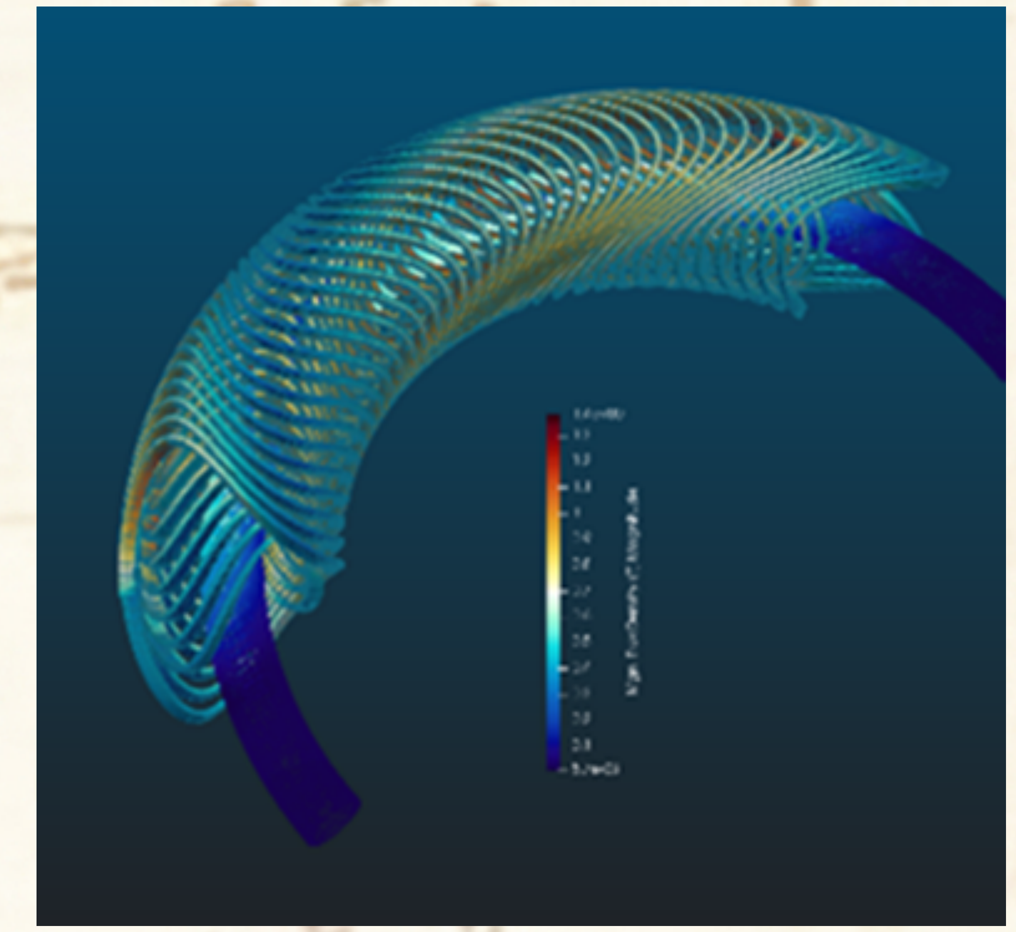
$$\Pi_0'(\zeta) - \frac{1}{\Pi_0^2(\zeta)} + \frac{1}{2} - \alpha S_0 g(\zeta) - \frac{2\Pi_2(\zeta)}{\Pi_0^2(\zeta)} - \frac{2}{1+\Pi_2(\zeta)}\left[\Pi_0'(\zeta)\Pi_2'(\zeta) - \frac{3\Pi_0(\zeta)\Pi_2'^2(\zeta)}{1+2\Pi_2(\zeta)} + \Pi_0(\zeta)\Pi_2''(\zeta)\right] = 0$$

Pulsed SC magnets for Advanced Hadron Therapy

- SC Magnets of 3.5 – 8 T range, curved (3-5 m radius), ramped (0.5-5 T/S), CCT layout
  dipole-quadrupole combined functions
- No LHe – simple, low cost, reliable
- **CHALLANGING, never done! Big collaboration federating:**
  - **CNAO-MedAustron with CERN-NIMMS – INFN-Mi & Ge, CEA, CIEMAT, …**
  - **Opportunity to desing a new facility:** https://seeiist.eu/ new project supported by EU.
- Support from **HITRI*plus* and I.FAST just funded by EC-H2020**
- **THESIS research activity to be done @ LASA Lab of INFN-Milano/Univ. of Milan:**
  - Studies and simulation work (FE and analytical suitably developed code) to optimize magnet configuration also in conjunction with beam dynamic studies and medical protocols
  - Design of the superconductors and of the SC magnet
  - Construction and test of a magnet demonstrator
- Final goal: establish HTS magnet technology for accelerator (also for HEP colliders)
- Collaborations with various EU Institutions/Universities and with Kyoto University and LBNL-USA.
- Requirements: Master degree in (Applied) Physics, Material Science, Engineering.



Horizon 2020
European Union Funding
for Research & Innovation



Summarizing

PhD projects relate to INFN-UniMi ongoing projects and activities: **BRiXSino, LWFA plasma acceleration, high power beam SC cavities, advanced magnets for applications,**

- **BriXSino**: beam dynamics of high brightness electron beams in photo-injectors, energy recovery linacs, two way linacs (with emphasis on sustainability of high average power beams, MW-class).
- **BriXSino**: all aspects of electromagnetic radiation production: CSR, Compton source, FEL; all driven by the high brightness electron beams.
- **BriXSino**: high current/high power electron sources and SC cavities.
- **LWFA**: beam dynamics/plasma acceleration modeling and simulations, ExIn experiment, in collaboration with LNF.
- **EuPRAXIA@SPARC_LAB**: BD related simulations, in collaboration with LNF.
- **AHT**: design of advanced SC magnets for beam delivery.