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A brief overview of background and experience

A short journey of beam dynamics, accelerator physics, machine operation, commissioning and code development

Cédric Hernalsteens

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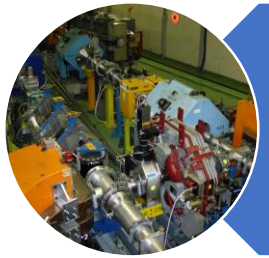
Outline



CERN Proton Synchrotron and Multi-Turn Extraction (MTE)

IBA Protontherapy

Accelerator Physics and PT at ULB

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CERN Proton Synchrotron and Multi-Turn Extraction (MTE)

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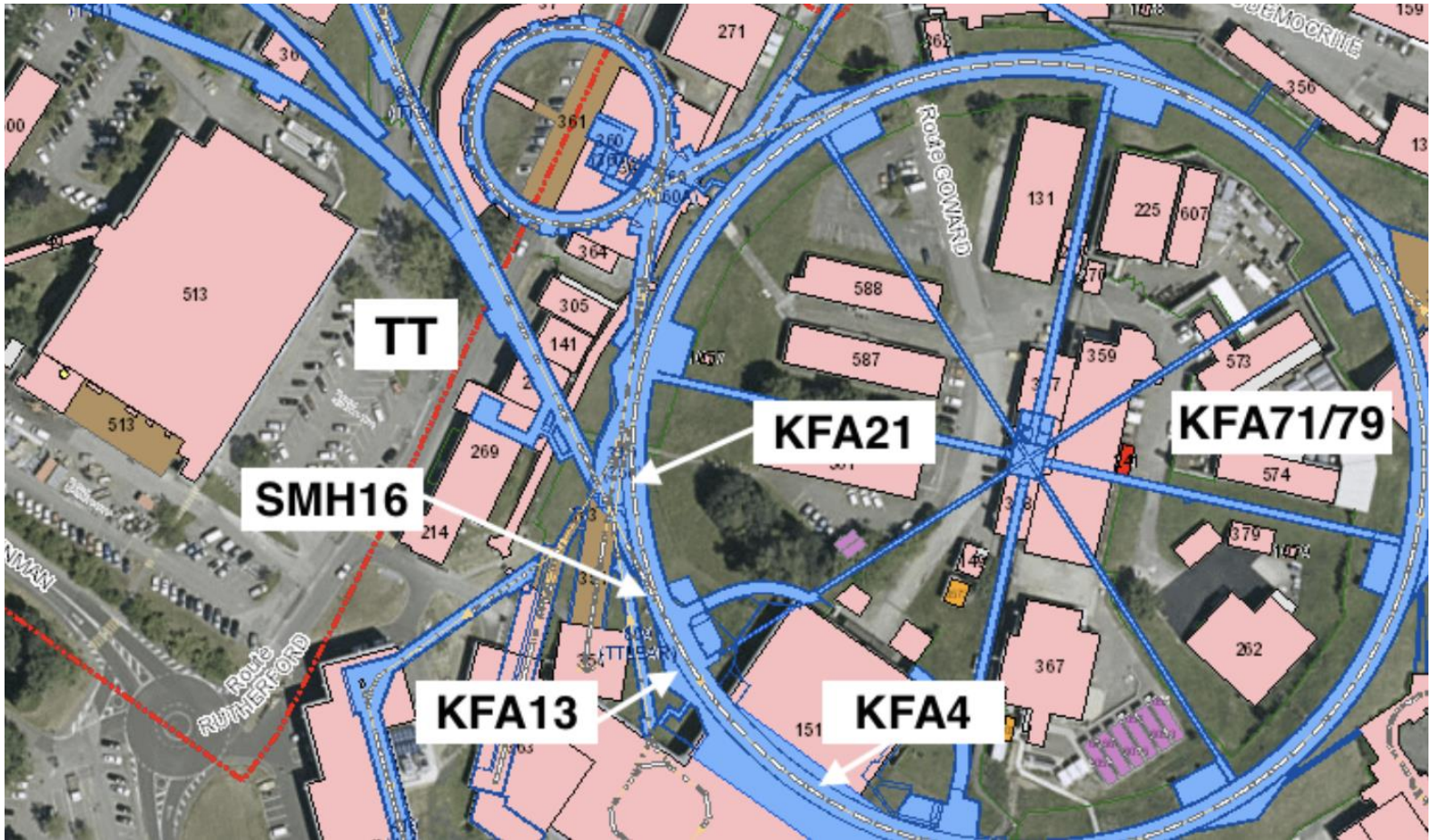
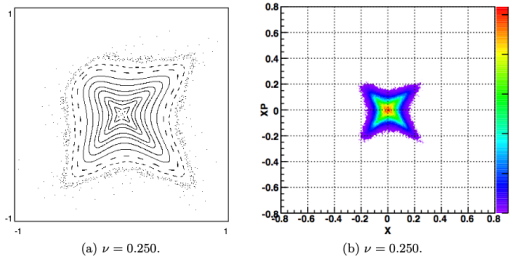
Multi-Turn Extraction (MTE)

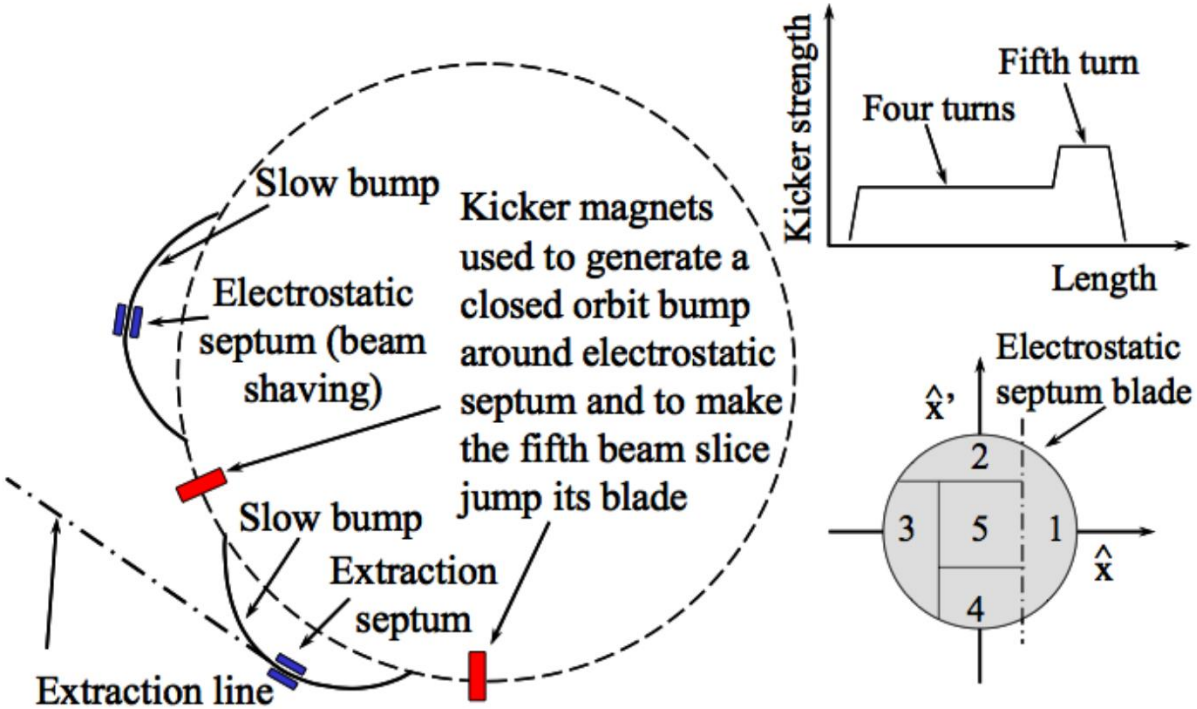
- PS extraction for high-intensity beams to the SPS

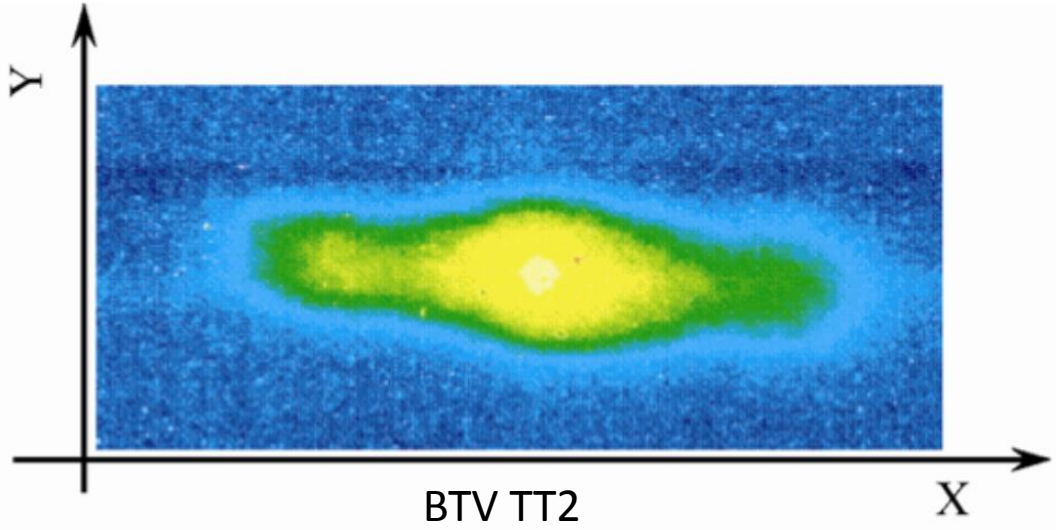


Multi-Turn Extraction (MTE)

- Replacing the aging CT extraction for high(er) intensity beams to the SPS







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MTE splitting – Analytical models

- Started as a Technical Student in 2010-2011 on MTE with M. Giovannozzi

" Analytical and numerical studies of transverse beam splitting used for the CERN PS Multi-Turn Extraction "

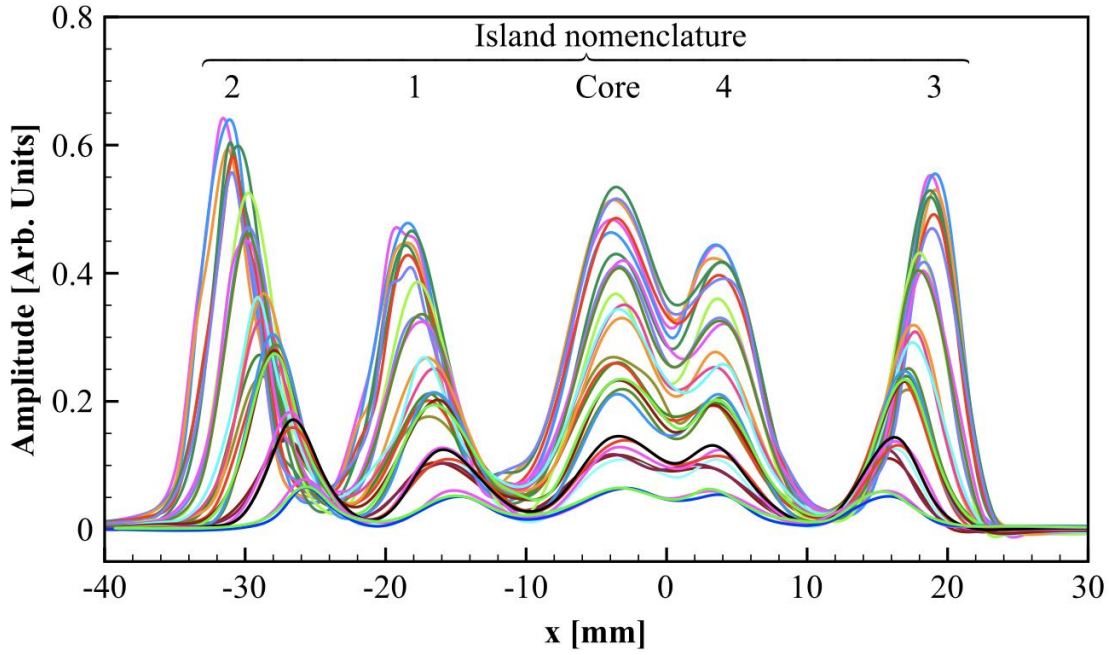
$$\begin{pmatrix} \hat{\boldsymbol{x}} \\ \hat{\boldsymbol{x}}' \\ \hat{\boldsymbol{y}} \\ \hat{\boldsymbol{y}}' \end{pmatrix}_{n+1} = \boldsymbol{R}(\omega_x, \omega_y) \circ \begin{pmatrix} \hat{\boldsymbol{x}} \\ \hat{\boldsymbol{x}}' + \sqrt{\beta_x}\left(\frac{K_2}{2}\beta_x^{3/2}(\hat{\boldsymbol{x}}^2 - \chi\hat{\boldsymbol{y}}^2 + \frac{K_3}{6}\beta_x^2(\hat{\boldsymbol{x}}^3 - 3\chi\hat{\boldsymbol{x}}\hat{\boldsymbol{y}}^2))\right) \\ \hat{\boldsymbol{y}} \\ \hat{\boldsymbol{y}}' + \sqrt{\beta_y}\left(-K_2\beta_x^{3/2}\chi\hat{\boldsymbol{x}}\hat{\boldsymbol{y}} - \frac{K_3}{6}\beta_x^2(\chi^2\hat{\boldsymbol{y}}^3 - 3\chi\hat{\boldsymbol{x}}^2\hat{\boldsymbol{y}})\right) \end{pmatrix}_n$$

MTE – Machine development

- MD's at the PS: the perfect playground

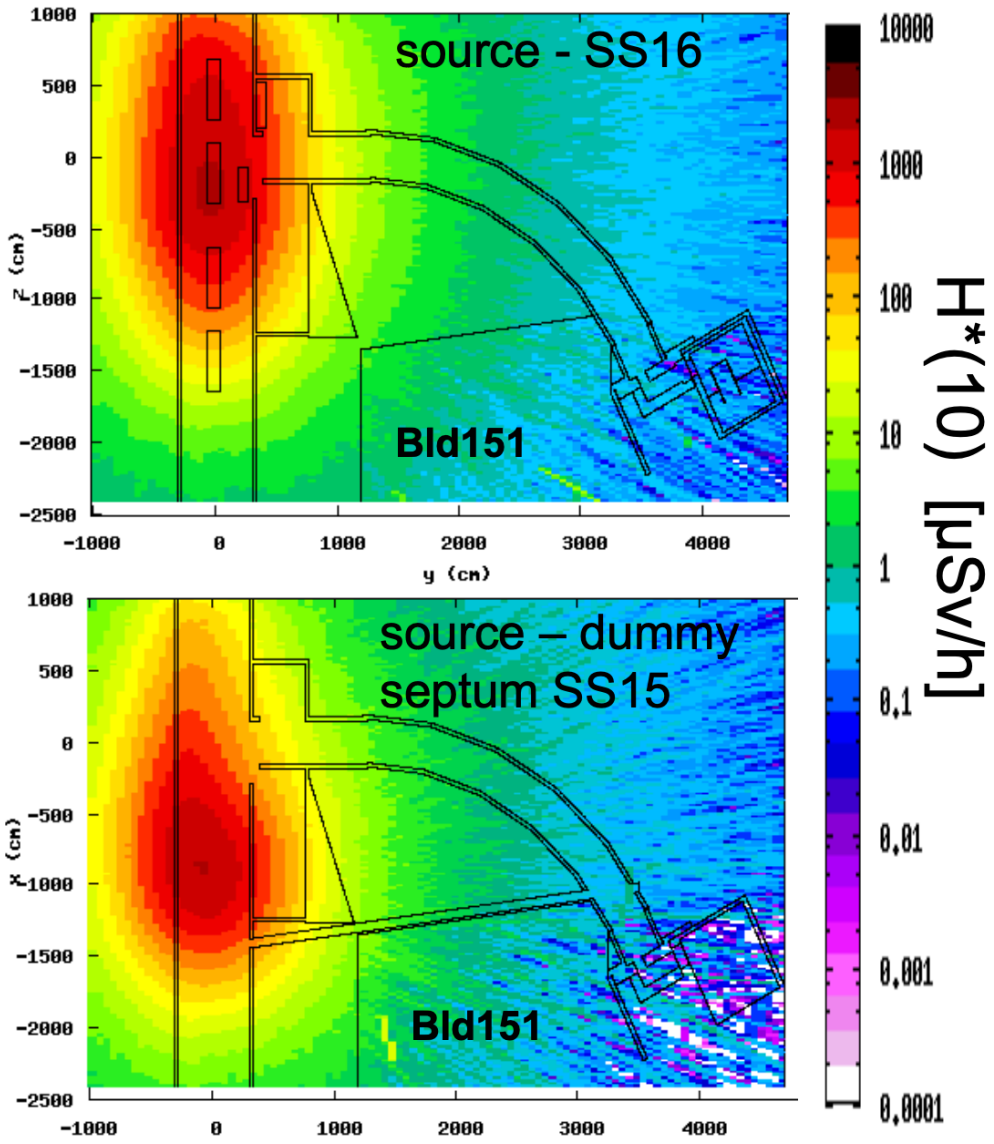
First observations of intensity-dependent effects for transversely split beams during multiturn extraction studies at the CERN Proton Synchrotron

Phys.Rev.ST Accel.Beams 16 (2013) **5**, 051001



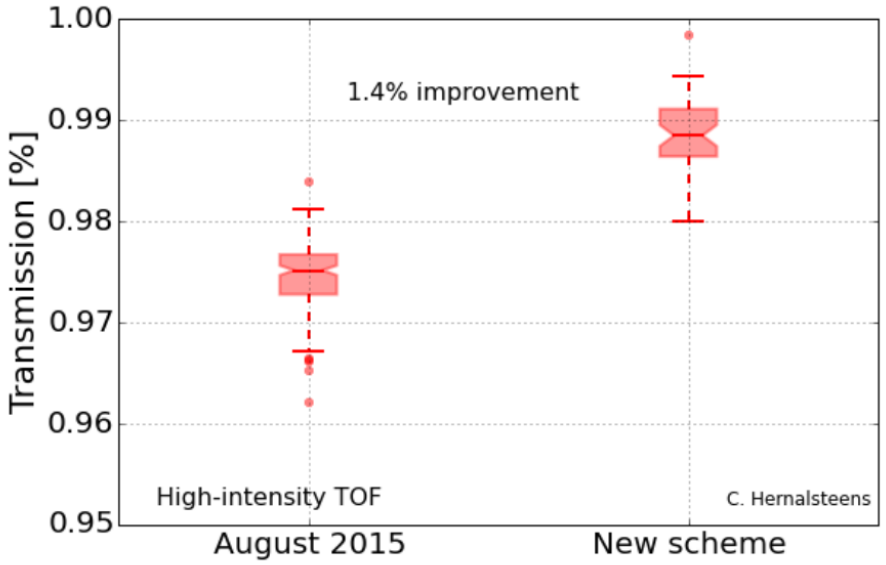
MTE – Losses reduction and dummy septum

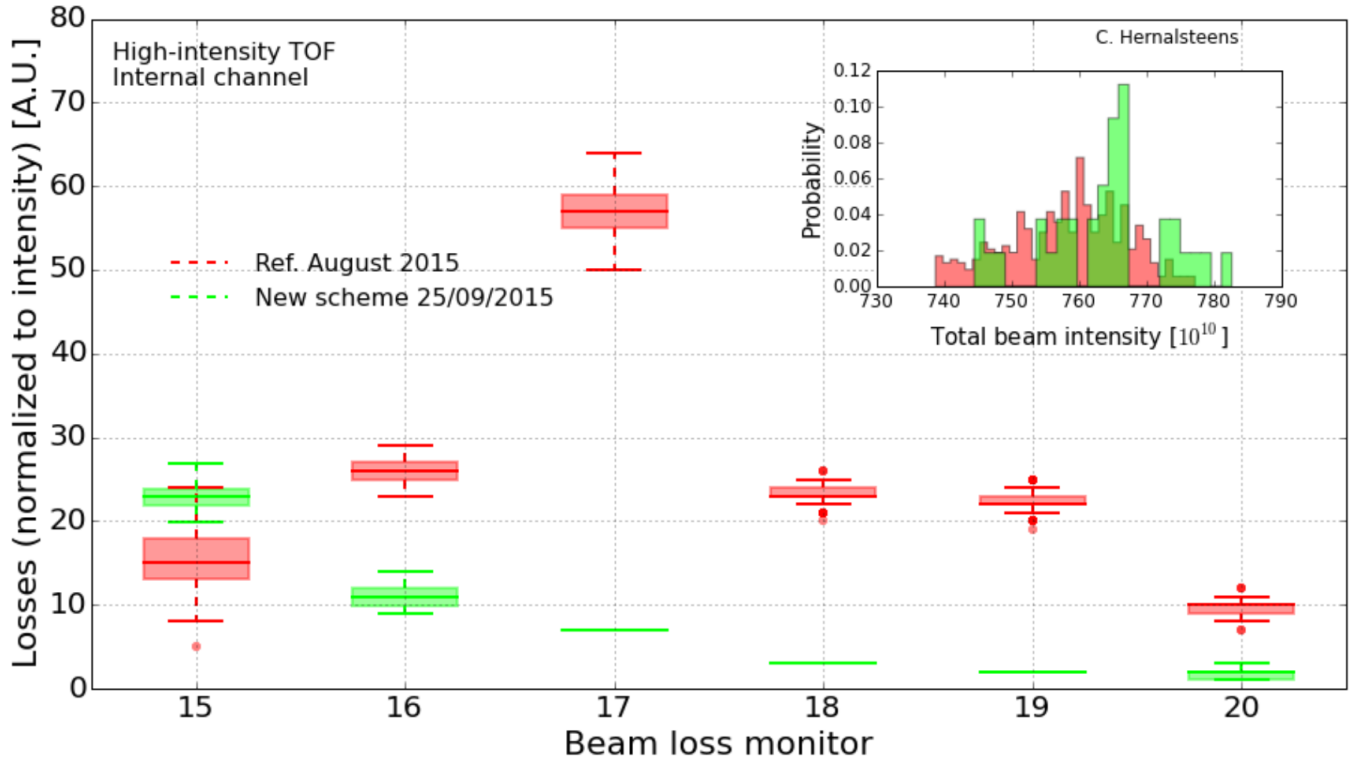
- Fewer losses but concentrated on the extraction septum SMH16
- Or why reliability for LHC operation is crucial!



MTE – Losses reduction and dummy septum

- New TOF extraction - 2015-present





MTE – Operation

- Support to OP and monitoring tools and displays
- Data logging and analysis
  - First “big” use of CALS for me
  - Ideas and discussions regarding next-CALS with BE/CO

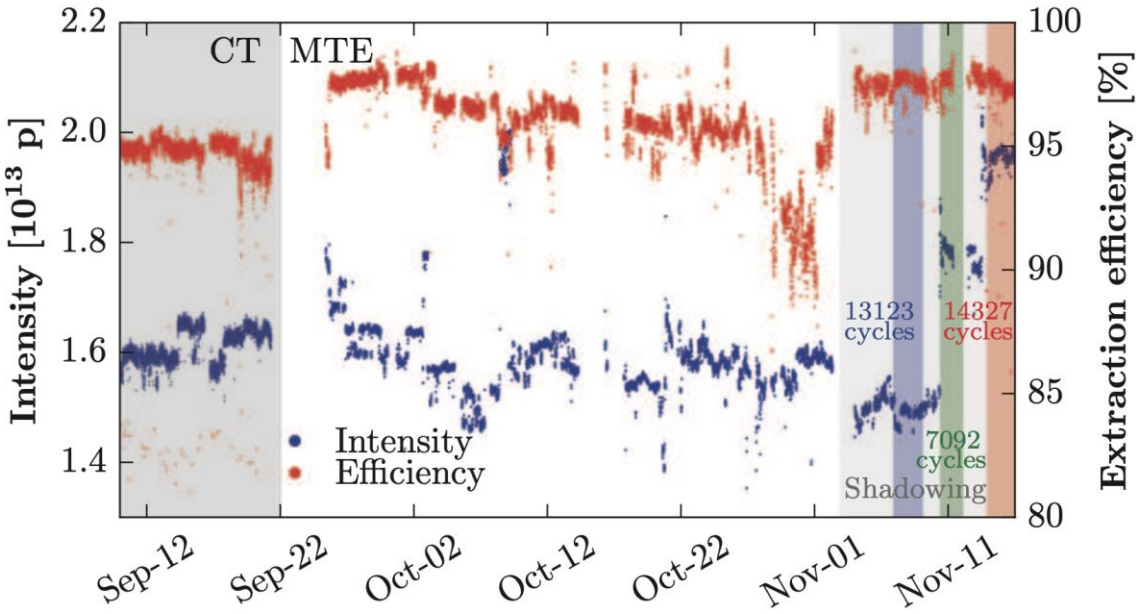


Fig. 8: (Colour online) Evolution of PS proton intensity prior to extraction and of η_{ext} for the 2015 MTE run. The main events and the periods selected for the statistical analysis are marked.

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IBA Protontherapy

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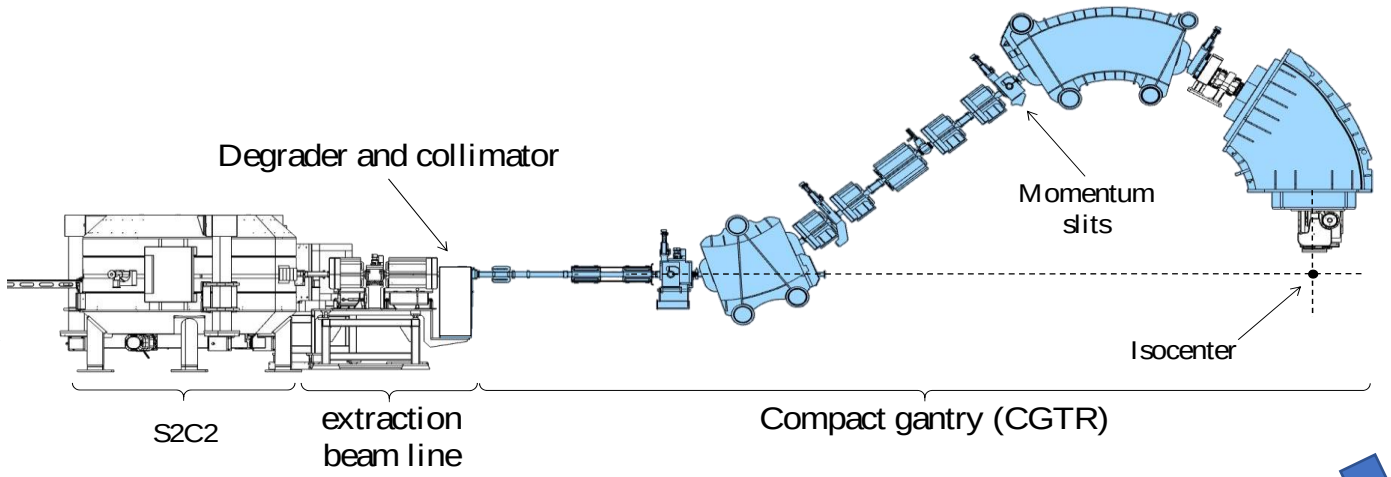
Ion Beam Applications - Protontherapy

- R&D physicist at Ion Beam Applications (IBA), Louvain-la-Neuve, Belgium

- Numerical tools for the modeling, upgrade and design of proton therapy beamlines

- Upgrade projects
  - **Pencil Beam Scanning in Chicago, IL**
  - **Eye treatment room in Essen, Germany**

IBA Proteus One



« Golden standard »

- **MAD-X / PTC**

Ad-hoc, fast, optimisation-oriented model

- **Manzoni (Python / JIT)**

Magnetic models

- **AOC**
- **Zgoubi via Georges**

3D realistic model

- **BDSim**

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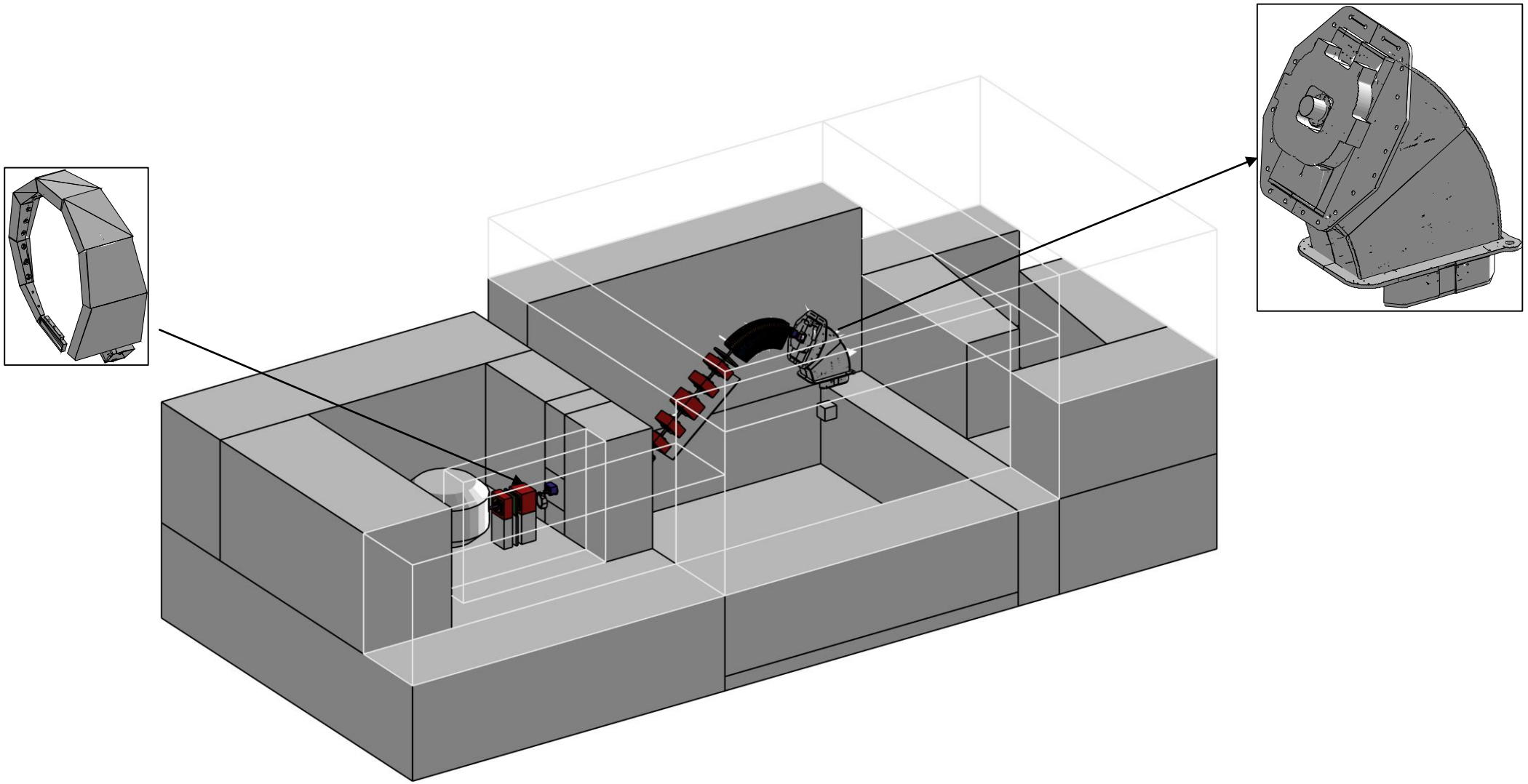
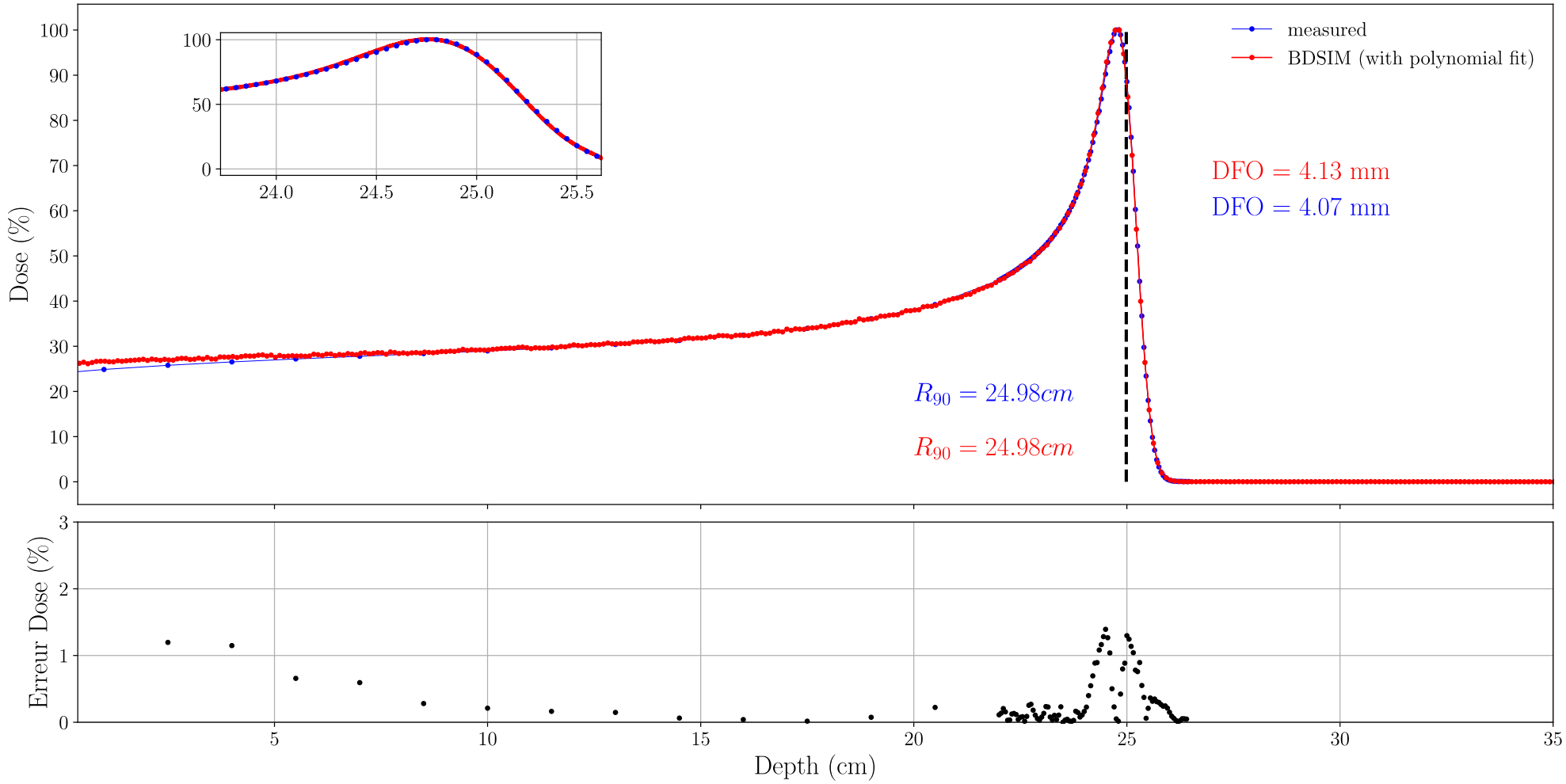
IBA Proteus One – BDSIM Model

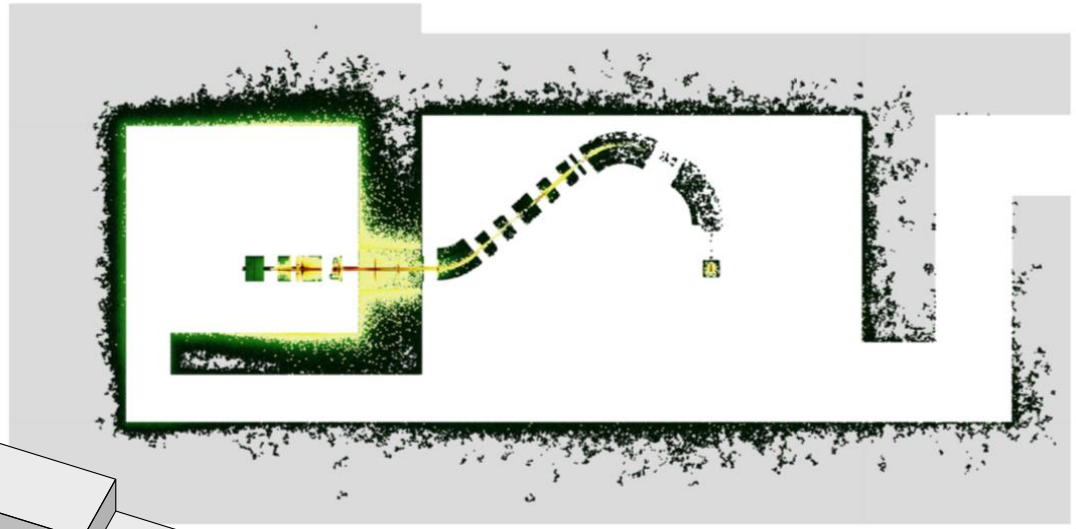


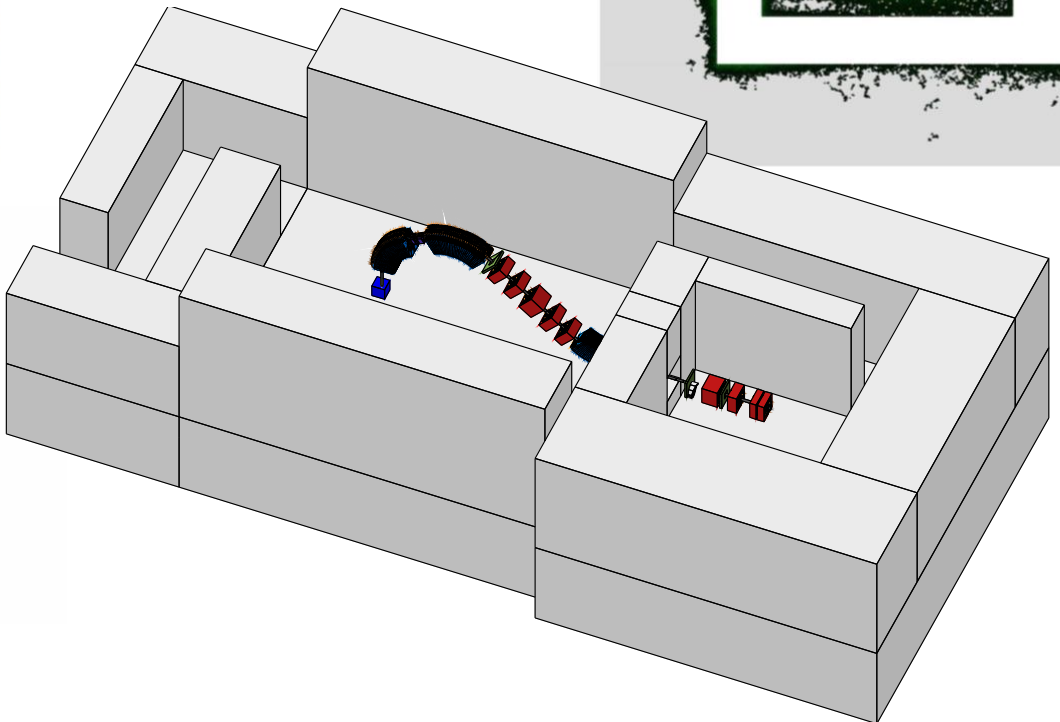
IBA Proteus One – BDSIM Model

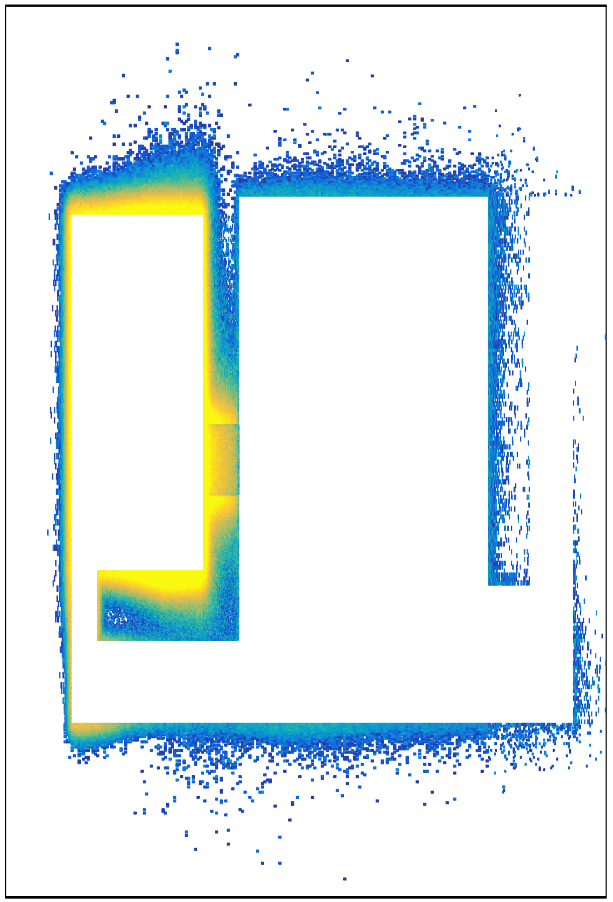


IBA Proteus One – BDSIM Model

Protons and neutrons interactions







Europium activation of the shielding

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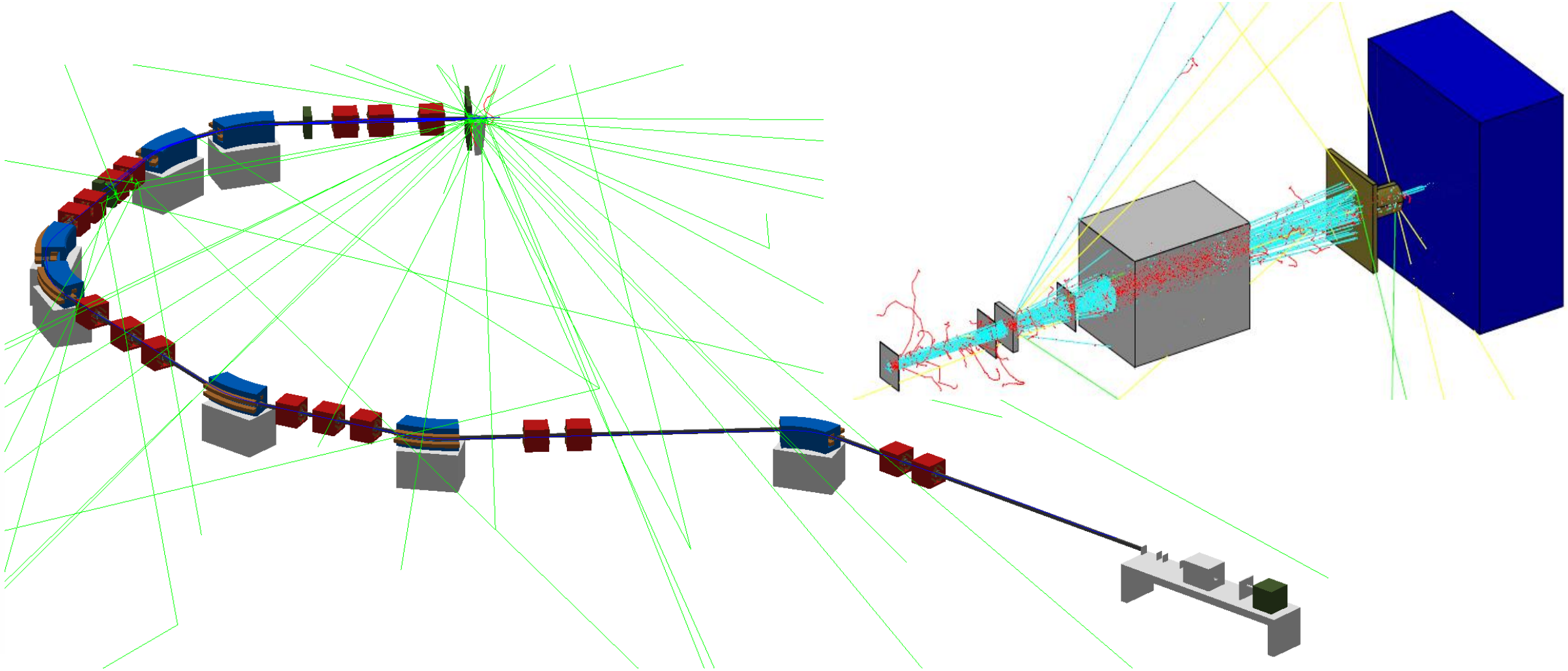
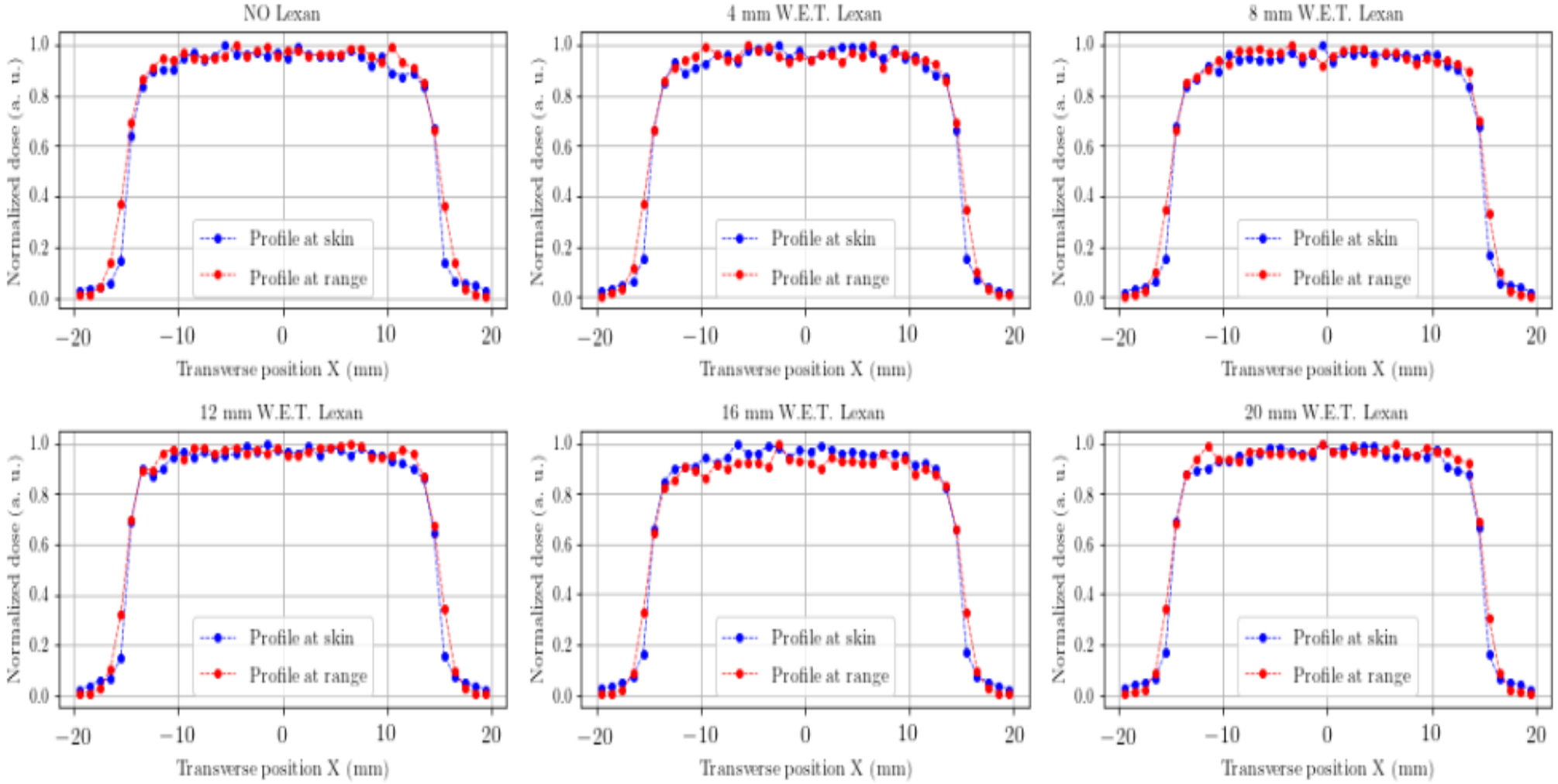
IBA Proteus Plus – Eye treatment room



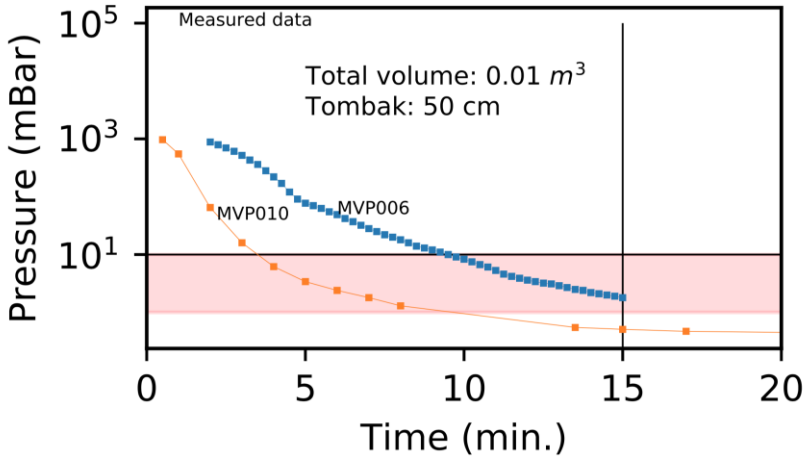
IBA Proteus Plus – Eye treatment room

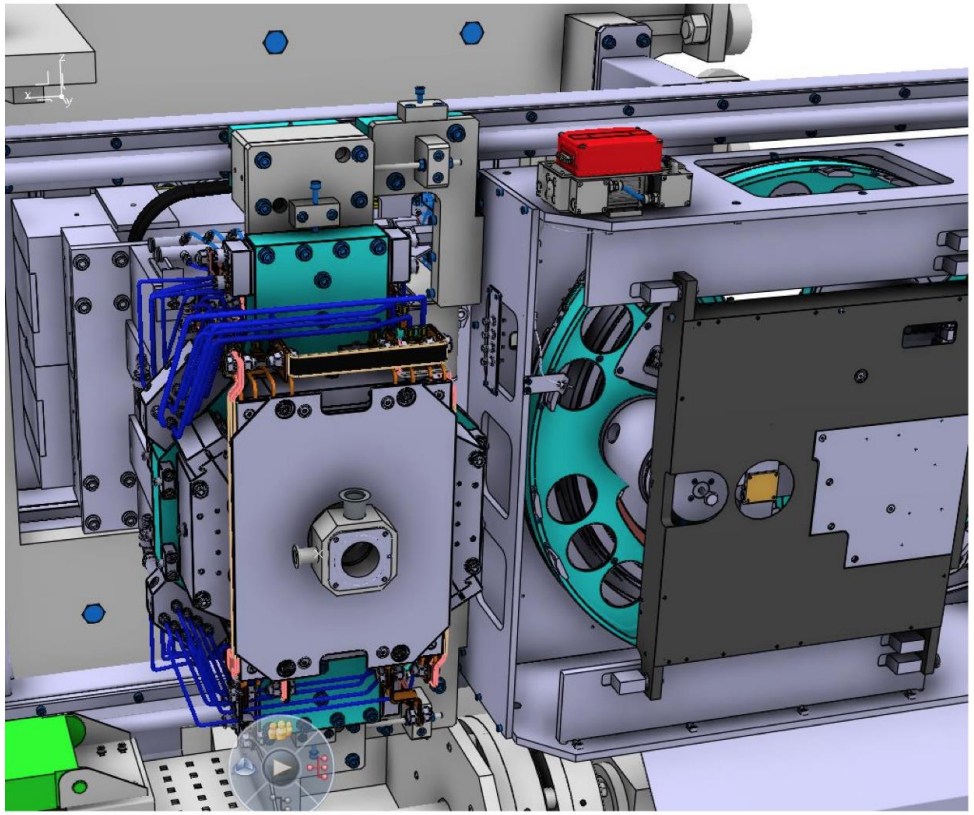


IBA Proteus Plus – Pencil beam scanning

- Specific hardware
  - Dedicated vacuum system for the nozzle (beamline down to IC1 + nozzle down to SM exit window)
  - Semi-automatic switching

- Safety aspects and IEC compliance





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Codes development and LHeC applications

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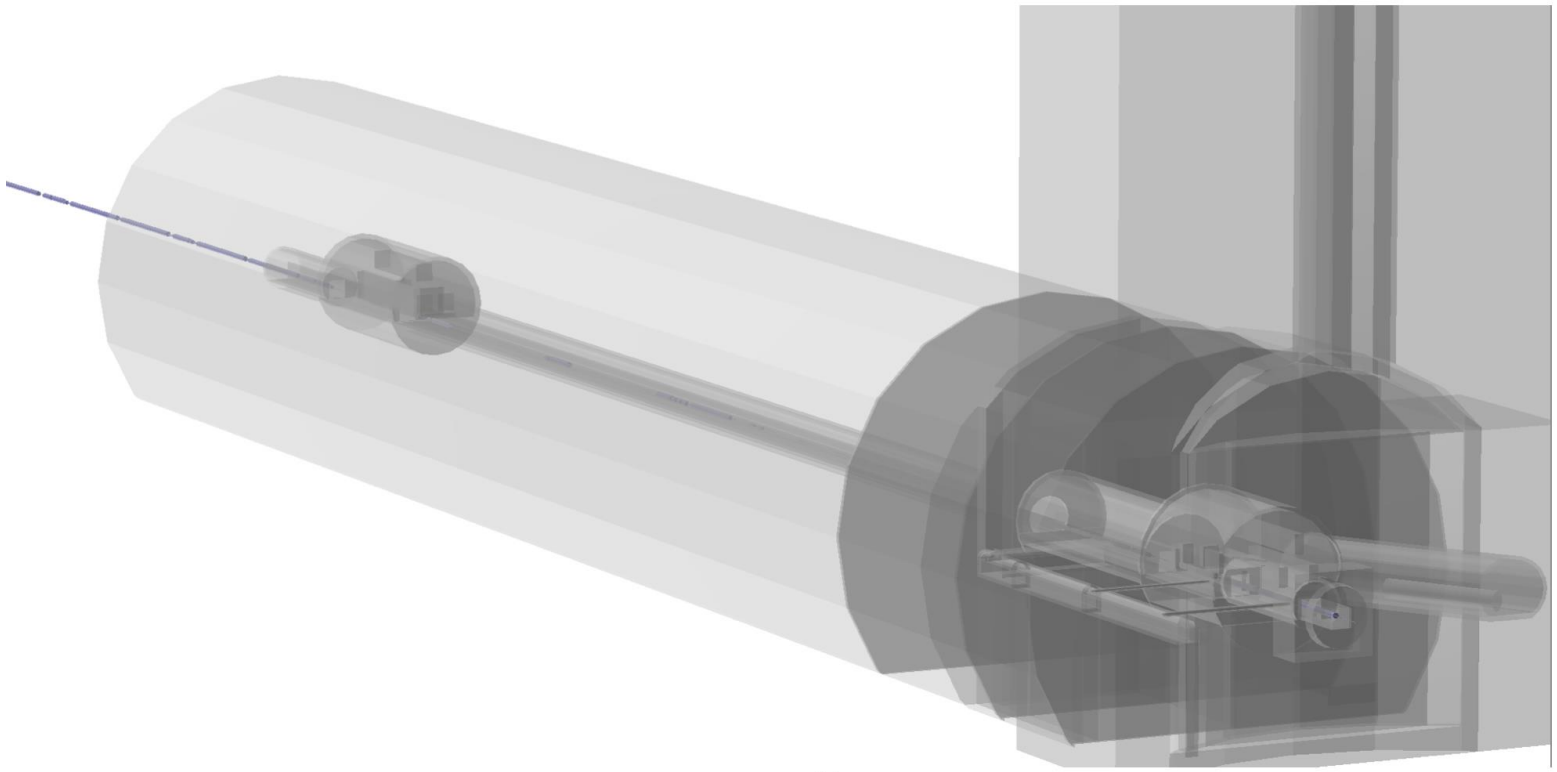
Integrated toolbox for accelerator physics

- Pure Python
- 5 libraries, including
  - A fast-tracking code (sixtrack like) in pure Python + Numba (JIT) suitable for large scale optimization schemes
  - An interface to the Zgoubi ray-tracing beam dynamics code
  - Integrates with cpymad (MAD-X/PTC)
- Main applications:
  - Proton therapy
  - FFAG
  - CERN PS
  - LHeC

BDSIM applications to the LHC

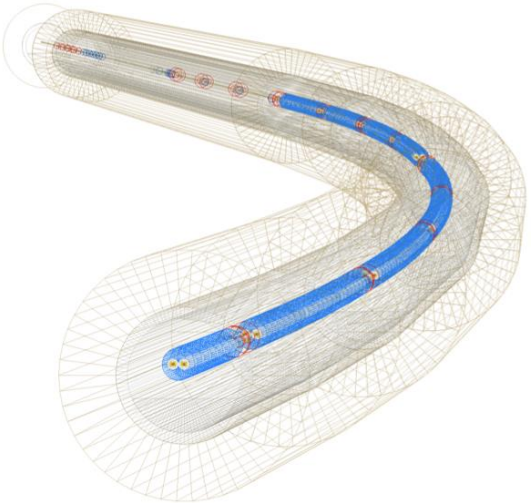
- Tunnel and shielding placed around BDSIM beam line

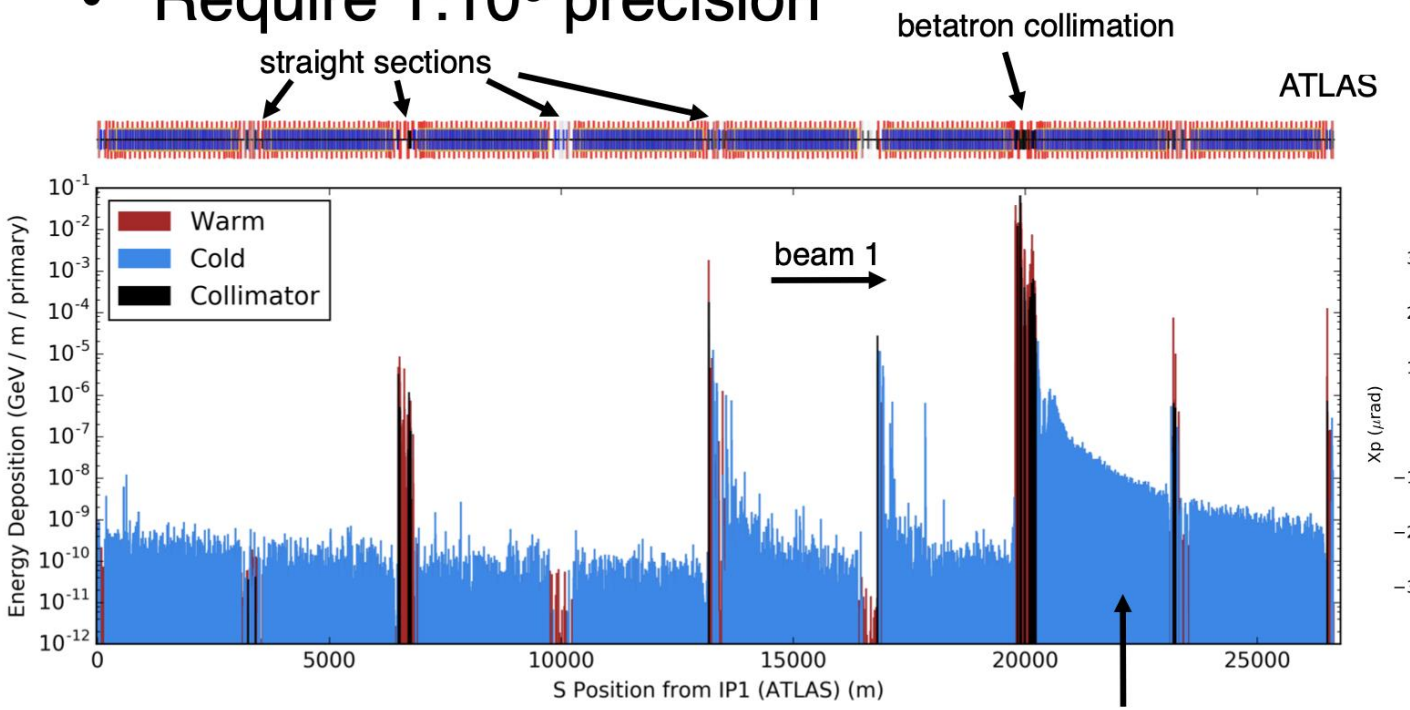


S. Walker, S. Gibson

LHC Collimation

- Halo populated during beam storage
- Continually removed
- Simulate halo as it touches collimators
- LHC-style dipoles & quadrupoles
- Require 1:10^6 precision

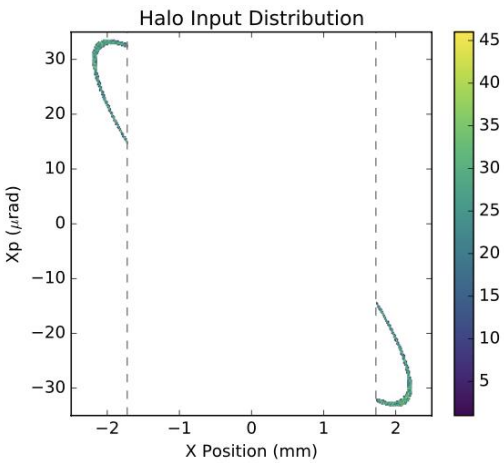




B1 4TeV energy deposition map

losses in cryogenic section

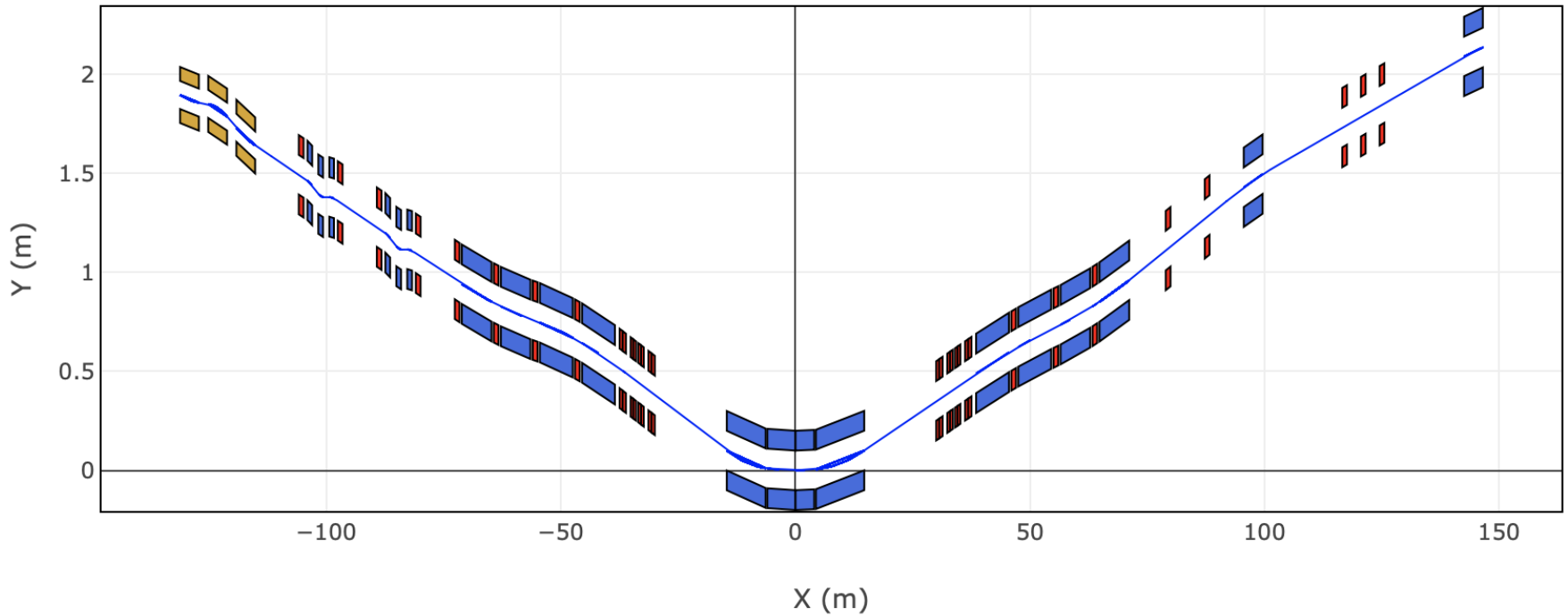
Example halo distribution



L. Nevay, S. Boogert

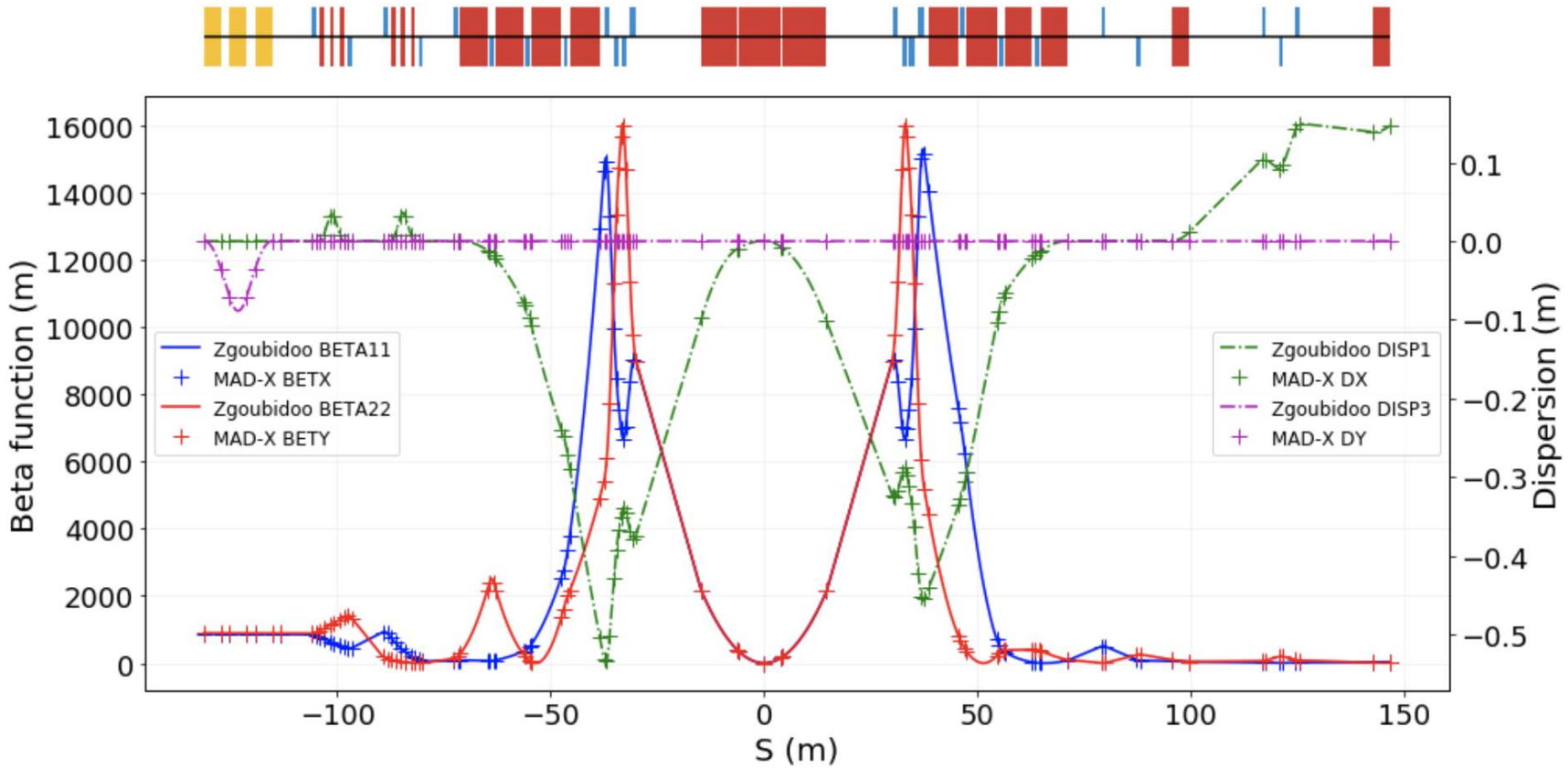
Applications to the LHeC studies

- In collaboration with K. Andre and B. Holzer
- Synchrotron radiation optimization; cross-validation with Zgoubi (on-going) and BDSIM (next)



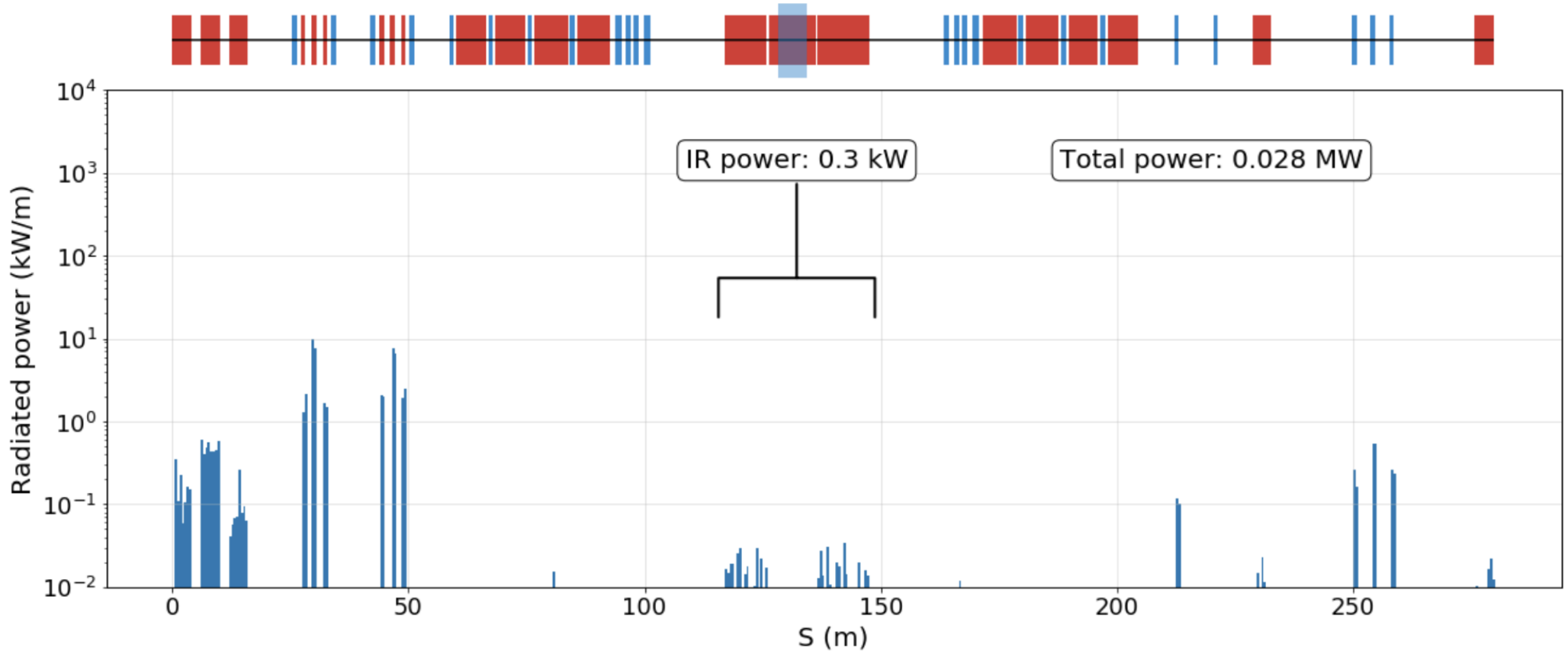
Applications to the LHeC studies

- Step-by-step computation of Twiss parameters



Applications to the LHeC studies

- Synchrotron radiation emission in arbitrary fields



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Accelerator Physics at ULB

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“Team Proton”

Scientific coordinator at the Université libre de Bruxelles; proton therapy and beam dynamics research group