Introduction to FLUKA

Where we come from

- FLUKA was born in the 60's at **CERN** with Johannes Ranft

- It was further developed in the 70s and 80s in a collaboration between **Leipzig University**, **CERN** and **Helsinki University** for applications, e.g., at CERN's high energy accelerators, and in the 90s with **INFN**, among others for the design of SSC and LHC

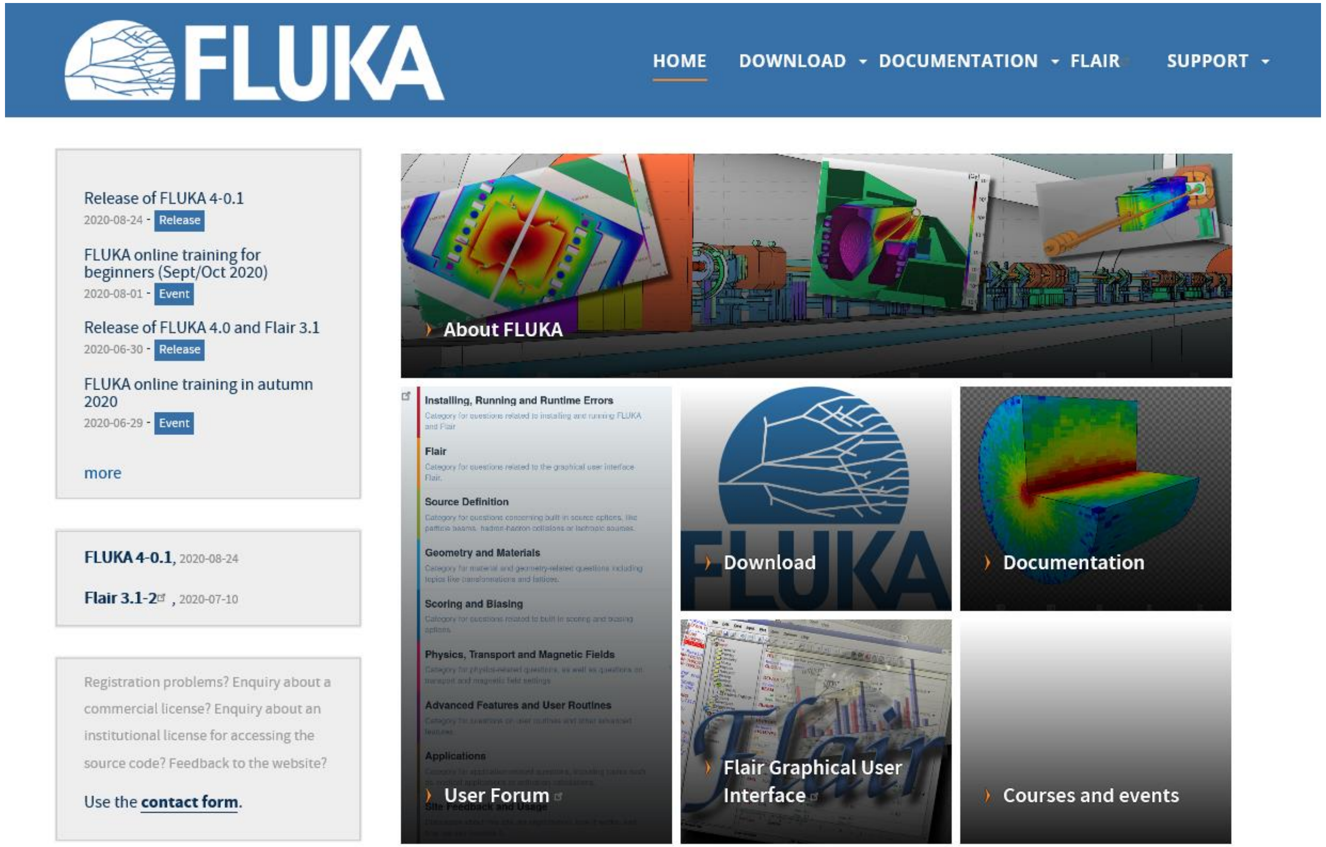
- From 2003 until August 2019 maintained and developed under a **CERN & INFN** agreement

- From December 2019, new **CERN** distribution aiming to ensure FLUKA's long-term sustainability and capability to meet the evolving requirements of its user community, welcoming contributions by both established FLUKA contributors as well as new partners within an **international collaboration**.

- Presently a joint development & management team based in the **CERN Accelerators and Technology Sector and Radiation Protection Group and at ELI-Beamlines (Prague),** with contributors from the CERN Research and Computing Sector and JRC Geel, is in place.

FLUKA.CERN Distribution

https://fluka.cern



Version history:

FLUKA 2011-3 released on December 2019

FLUKA 4-0 released on June 2020

FLUKA 4-0.1 released on August 2020

FLUKA 4-1 released on November 2020

FLUKA 4-1.1 released on **February 2021**

Licensing Scheme

Registration options
FLUKA **Single User License Agreement**
Affiliates of institutes with a FLUKA **Institutional License Agreement**
CERN Staff members and Fellows
Affiliates of institutes which signed the FLUKA **Memorandum of Understanding**
Companies which purchased a FLUKA **Commercial License Agreement**

Includes access to the

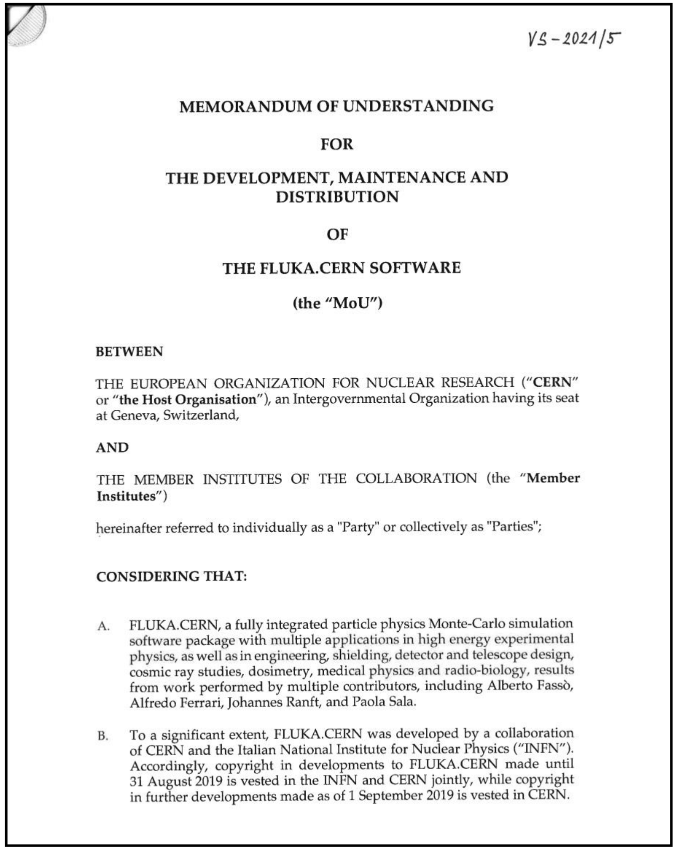
source code

development version

- **Licenses are free** except for commercial use
- They are granted for **non-military use** only
- ***Current situation:***
  - Institutional License established with 4 institutes and being set up with several other institutes
  - Commercial License acquired by about 6 companies
  - MoU signed between CERN and ELI Beamlines since early 2021

FLUKA Collaboration

First **Memorandum of Understanding for the development, maintenance and distribution of the FLUKA.CERN software** between ELI Beamlines (Prague) and CERN has been signed in February 2021



VS – 2021/5

MEMORANDUM OF UNDERSTANDING

FOR

THE DEVELOPMENT, MAINTENANCE AND DISTRIBUTION

OF

THE FLUKA.CERN SOFTWARE

(the "MoU")

BETWEEN

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH ("**CERN**" or "**the Host Organisation**"), an Intergovernmental Organization having its seat at Geneva, Switzerland,

AND

THE MEMBER INSTITUTES OF THE COLLABORATION (the "**Member Institutes**")

hereinafter referred to individually as a "Party" or collectively as "Parties";

CONSIDERING THAT:

A. FLUKA.CERN, a fully integrated particle physics Monte-Carlo simulation software package with multiple applications in high energy experimental physics, as well as in engineering, shielding, detector and telescope design, cosmic ray studies, dosimetry, medical physics and radio-biology, results from work performed by multiple contributors, including Alberto Fassò, Alfredo Ferrari, Johannes Ranft, and Paola Sala.

B. To a significant extent, FLUKA.CERN was developed by a collaboration of CERN and the Italian National Institute for Nuclear Physics ("INFN"). Accordingly, copyright in developments to FLUKA.CERN made until 31 August 2019 is vested in the INFN and CERN jointly, while copyright in further developments made as of 1 September 2019 is vested in CERN.

18.4 Where, notwithstanding the efforts of the CB, a difference cannot be resolved, the Parties concerned may submit the matter to arbitration in accordance with a procedure to be specified by them.

For INSTITUTE OF PHYSICS OF THE CZECH ACADEMY OF SCIENCES RN

Dr. Michael Prouza, Ph.D.

Director

Date: 15. 02. 2021 ~~17 December 2020~~ Signature:……………………………

Institute of Physics
The Czech Academy of Sciences
182 21 Prague 8, Na Slovance 2
Czech Republic

For CERN

Frédérick Bordry

Director for Accelerators and Technology

Date: 17 December 2020 Signature:……………………………

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH CERN

Further Collaboration partners are very welcome!

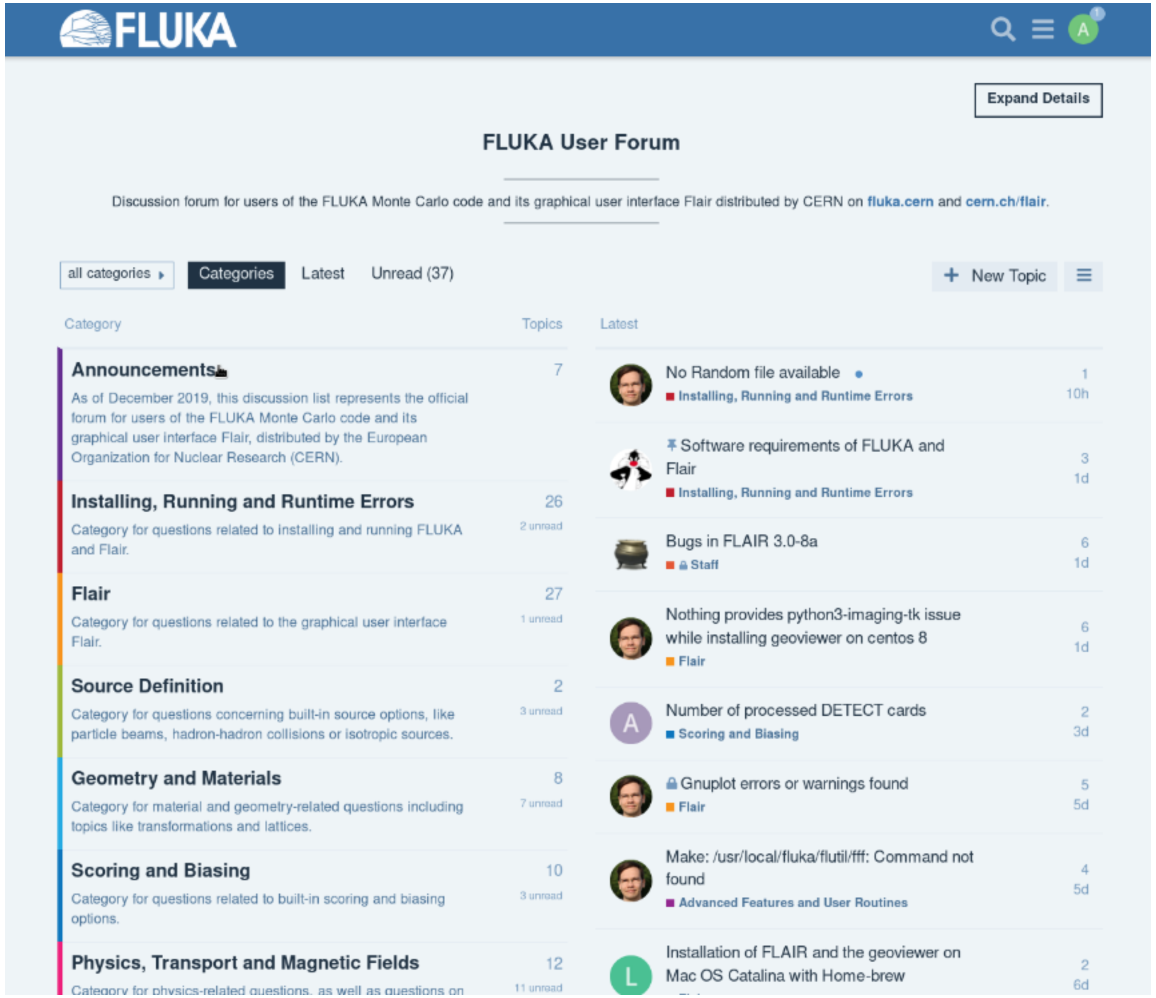
User Support

FLUKA User Forum

https://cern.ch/fluka-forum

Note: an independent one time registration is required to be able to participate

Currently more than 500 registered users



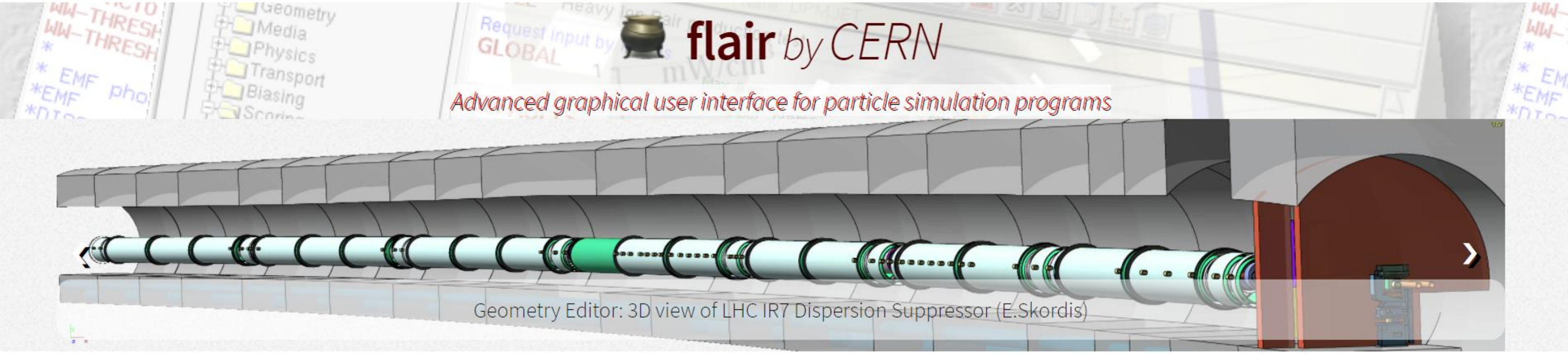
FLUKA Training

Three Beginner Online Training courses were held 2020.

We hope to be able to provide in person training again in the future.

FLAIR

https://flair.cern



Authors

authors: Vasilis Vlachoudis *(lead author)*
Christian Theis
Wioletta Kozlowska

Current Version

- Latest version: **3.1-13**
- Released on: ***Tue 20-Apr-2021***
- Powered by python**3**, tkinter, gnuplot, pydicom

Features

- modern and intuitive design
- Input editor for error free inputs
- Interactive geometry editor, photorealistic ray tracer and debugger
- run and monitor the simulation
- back-end for post-processing of results
- I/O of other simulation formats (MCNPX,GDML,...)
- Medical file importing, DICOM, RT-PLAN,DOSE,...
- extended material library

Microscopic process modeling for macroscopic quantity assessment

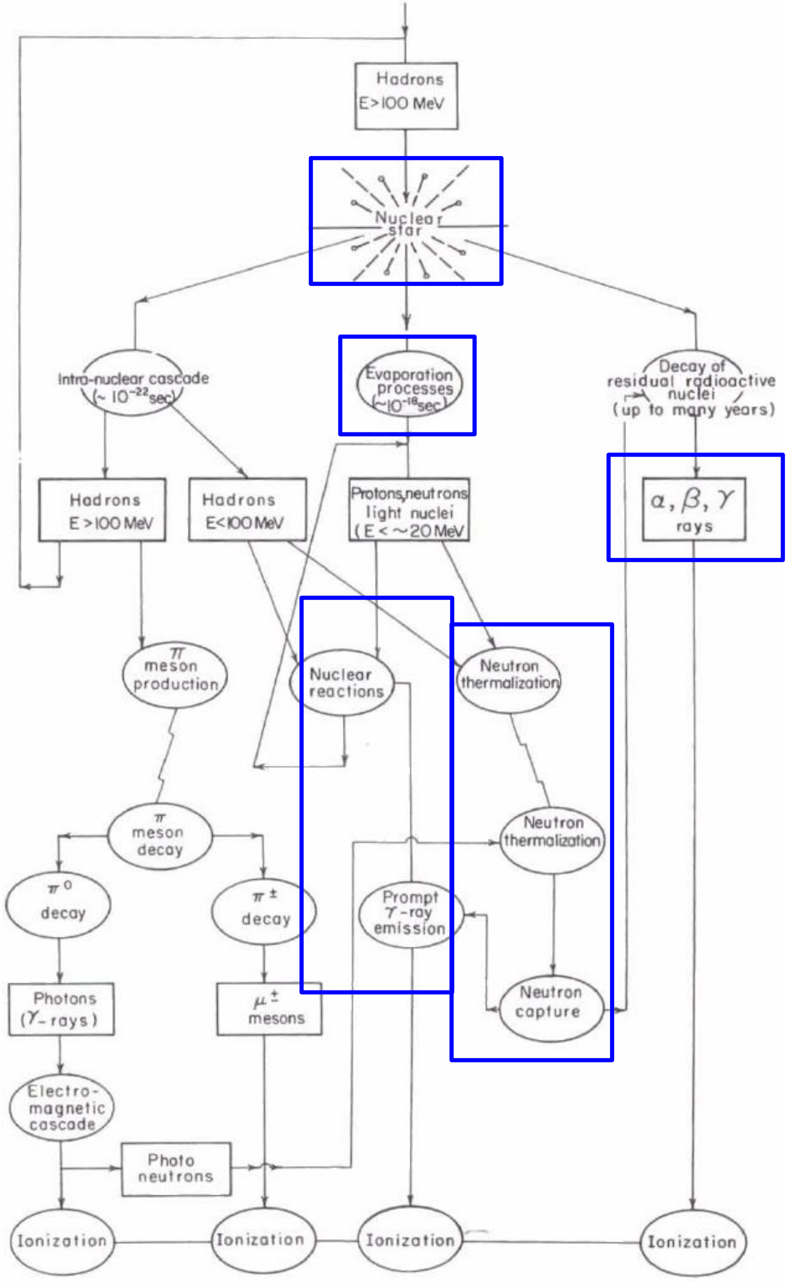
A (hadronic) shower implies a lot of different physics processes, touching a very broad energy [time-space] scale

Its description relies on the organic integration of diverse **theories and models**, and requires as essential pieces of **information**:

- reaction cross sections
- exclusive fragment production
- nuclide structure and decay data
- evaluated quantities of neutron induced reactions

Monte Carlo simulation is an effective way to calculate macroscopic quantities (such as energy deposition, dpa, particle fluence, activation and residual dose rate) with an accuracy reflecting the quality of the critical processes implementation

Multipurpose widespread codes are available: FLUKA, GEANT4, MARS, MCNP, PHITS, ...



FLUKA capabilities

- hadron-hadron and hadron-nucleus interactions
- nucleus-nucleus interactions
- photon interactions (>100 eV)
- electron interactions (> 1 keV; including electronuclear)
- muon interactions (including photonuclear)
- neutrino interactions
- low energy (<20 MeV) neutron interactions and transport
- particle decay
- ionization and multiple (single) scattering (including all ions down to 250 eV/u)
- coherent effects in crystals (channelling)
- magnetic field, and electric field in vacuum

- combinatorial geometry and lattice capabilities
- voxel geometry and DICOM importing
- analogue or biased treatment
- on-line buildup and evolution of induced radioactivity and dose
- built-in scoring of several quantities (including DPA and dose equivalent)

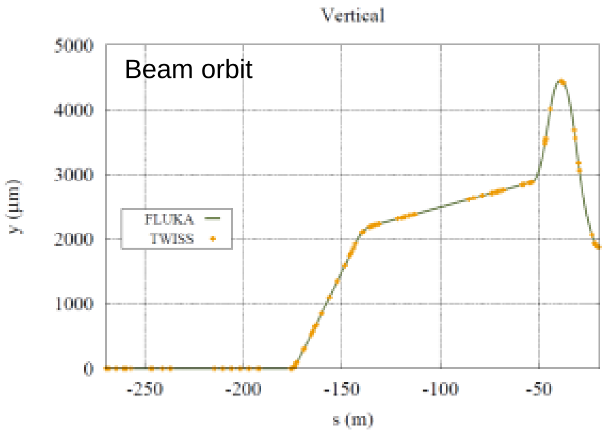
In support of a
wide range of applications

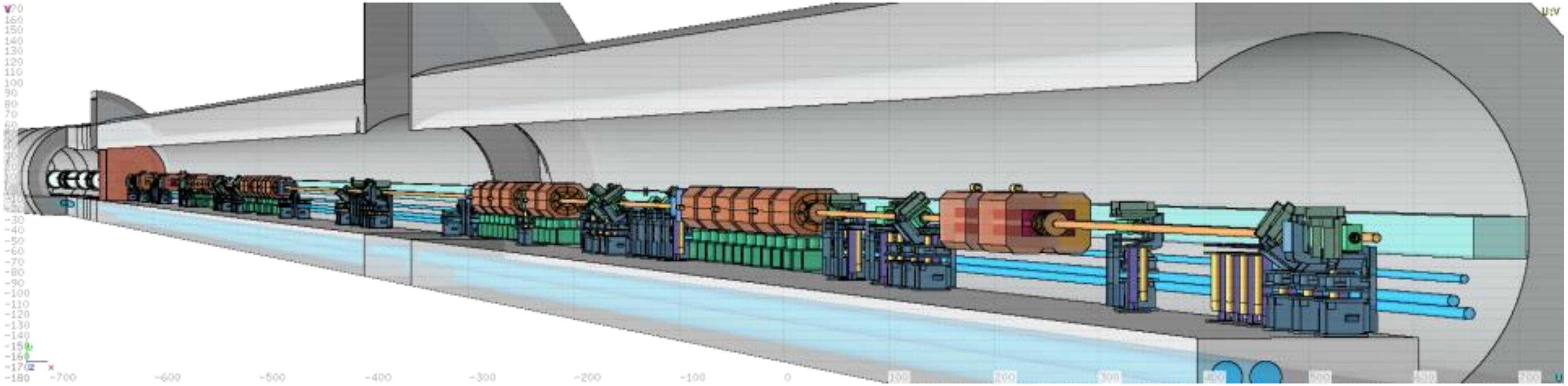
✓Accelerator design
✓Particle physics
✓Cosmic ray physics
✓Neutrino physics
✓Medical applications

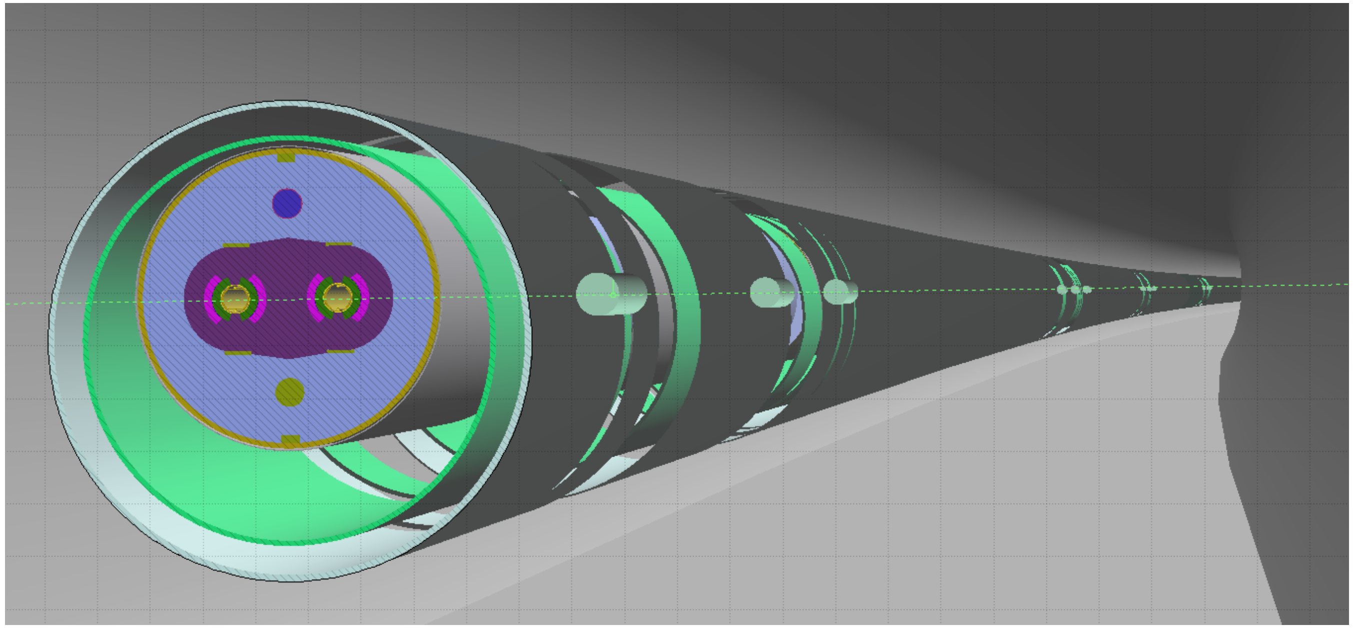
✓Radiation protection (shielding design, activation)
✓Dosimetry
✓Radiation damage
✓Radiation to electronics effects
✓ ADS systems, waste transmutation
✓Neutronics

Some examples

Accelerator geometries







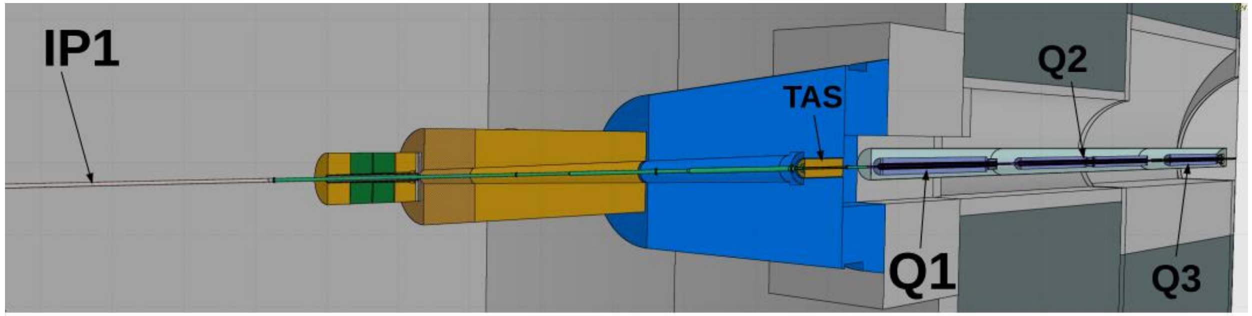
From DETAILED MODELS OF ACCELERATOR COMPONENTS WITH ASSOCIATED SCORING and the ELEMENT SEQUENCE AND RESPECTIVE MAGNETIC STRENGTHS, as given IN THE MACHINE OPTICS (TWISS) FILES,
the **AUTOMATIC CONSTRUCTION OF COMPLEX BEAM LINES**, including collimator settings and element displacement (BLMs), is achievable, profiting from roto-translation directives and replication (lattice) capabilities.

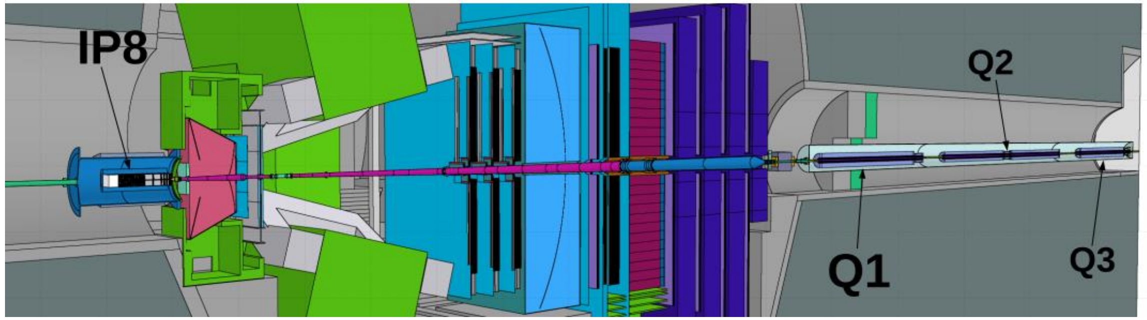
LINE BUILDER

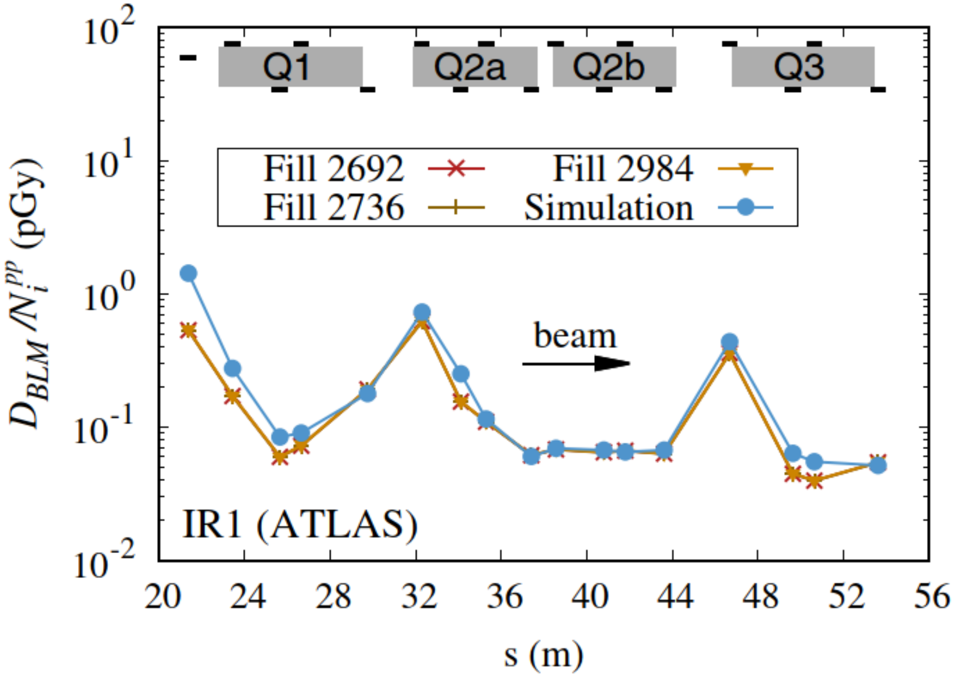
[A. Mereghetti et al., IPAC2012, WEPPD071, 2687]

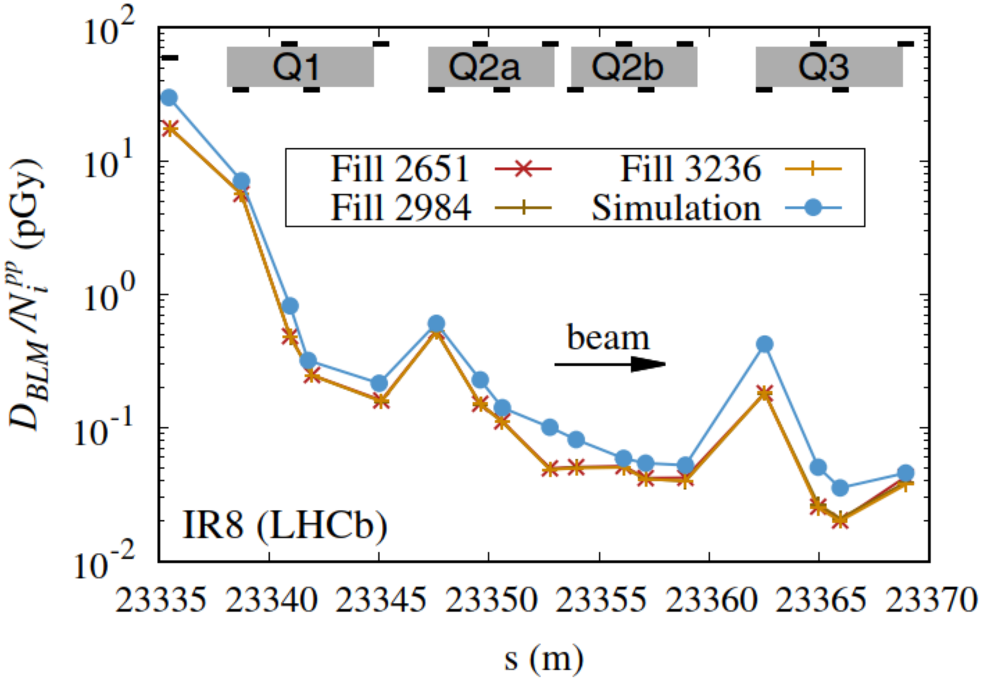
Beam loss description at the LHC

[A. Lechner et al., Phys. Rev. AB 22 (2019) 071003]









Activation benchmarking

@ **C**ERN **S**HIELDING **B**ENCHMARK **F**ACILITY (24 GeV/c p)

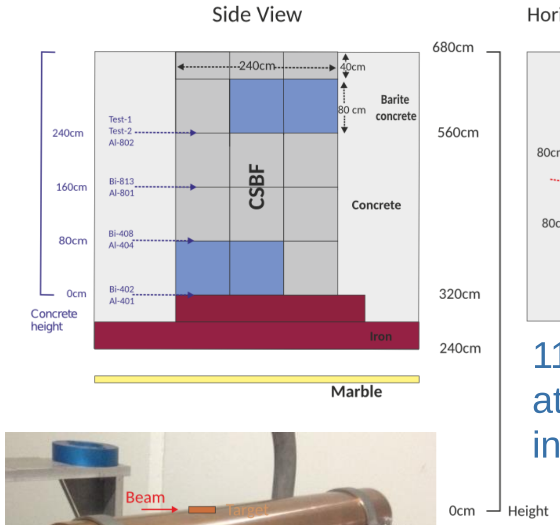
[E. Iliopoulou and R. Froeschl]

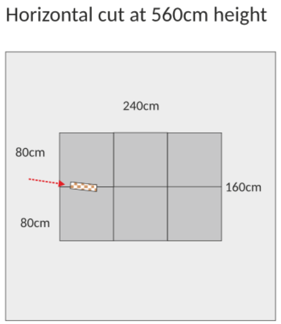
Situated laterally above the CHARM target

for deep shielding penetration studies (Detector calibration, Detector inter-comparison, Activation)

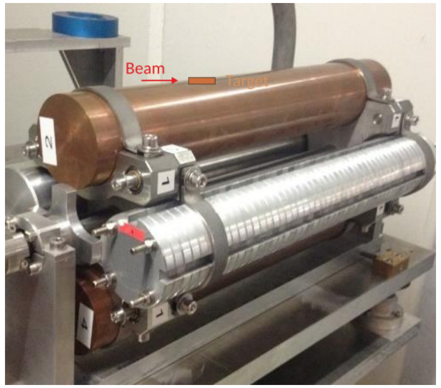
360cm of concrete and barite concrete

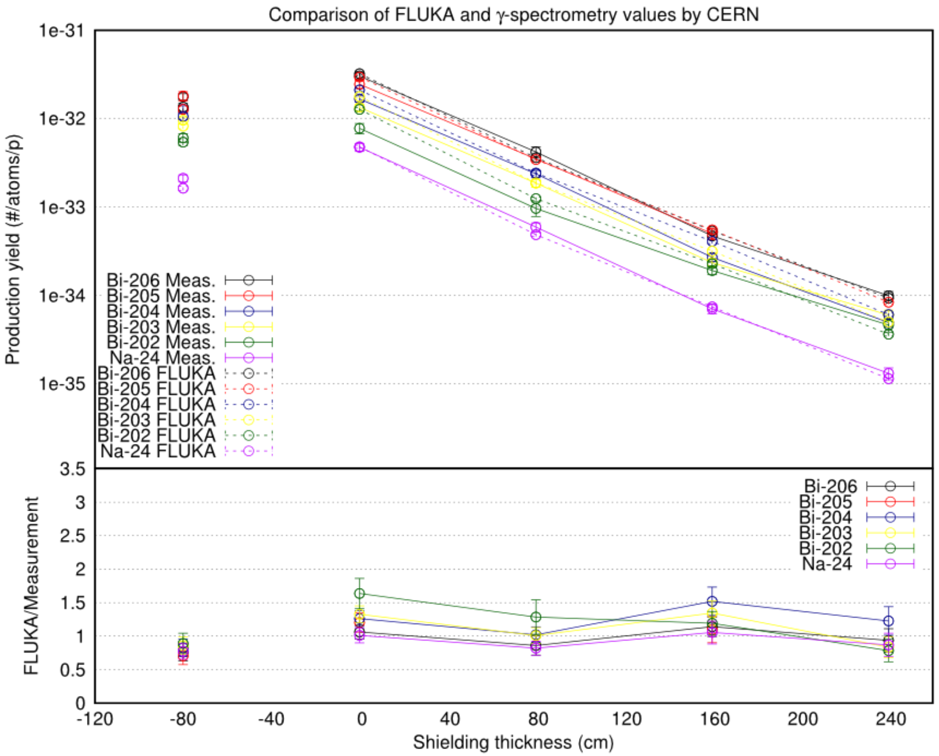
plus 80cm of cast iron





11 Bismuth and Aluminum samples at different heights in CSBF and also inside CHARM (@ -80cm)





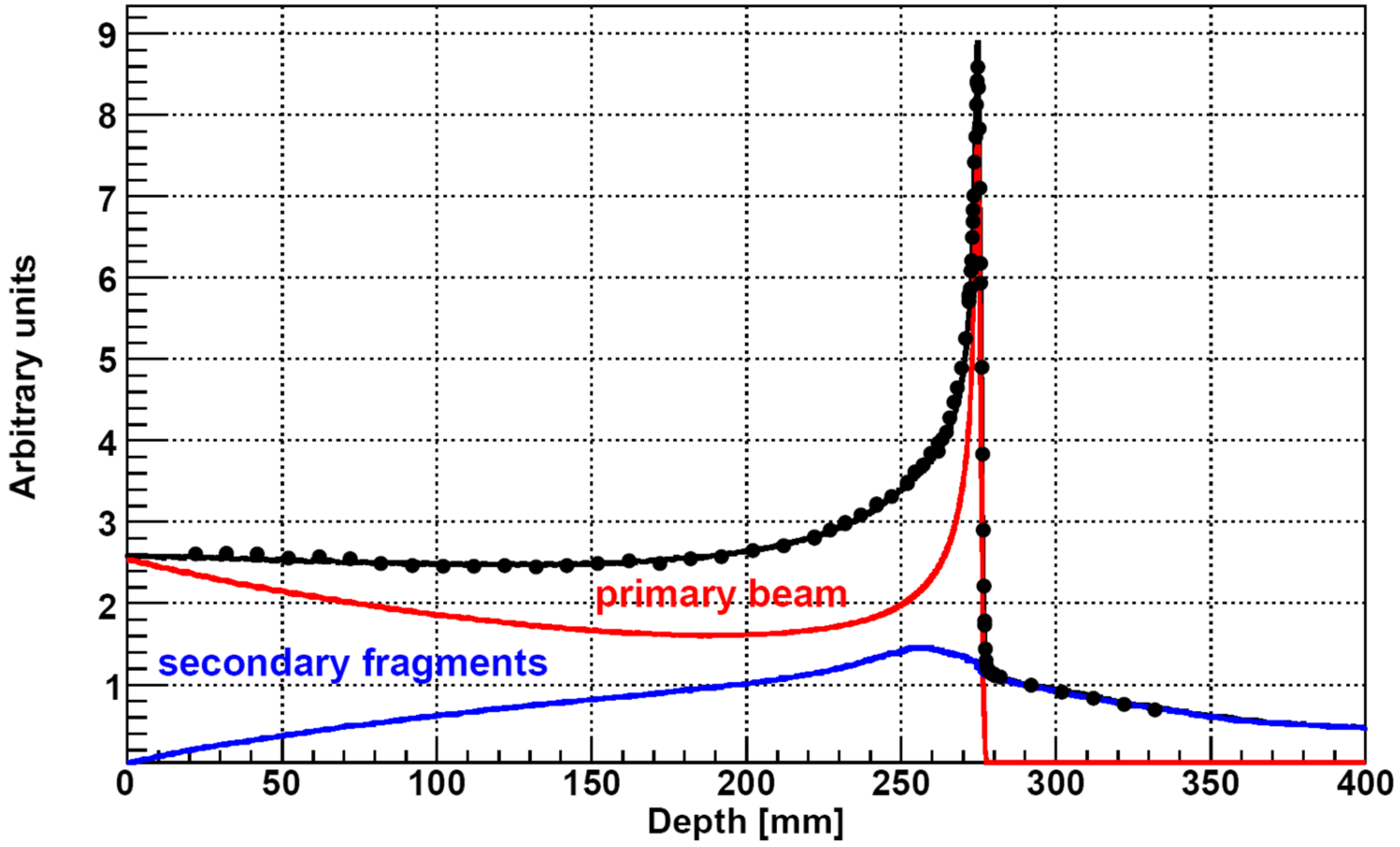
@ **CHARM** (**C**ERN **H**igh energy **A**ccele**R**ator **M**ixed field facility,

to study radiation effects on electronic components)

5×10^{11} protons/pulse, 350ms pulse length, max. average beam intensity 6.6×10^{10} p/s

three 50cm long 8cm diameter targets: Copper, Aluminum, Aluminum with holes

Medical physics: radiotherapy



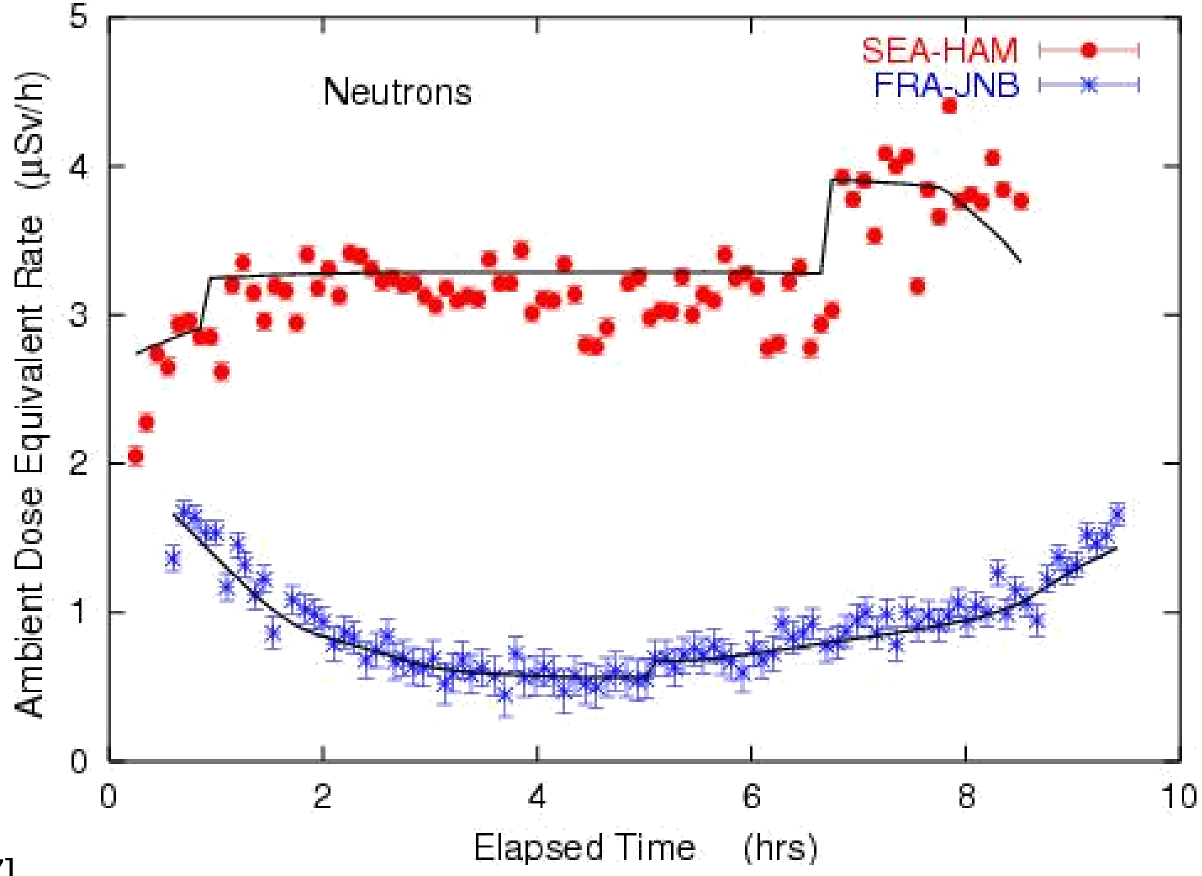
Bragg peak in a water phantom
400 MeV/A C beam:
The importance of fragmentation

[Exp. Data (points) from Haettner et al, Rad. Prot. Dos. 2006
Simulation: A. Mairani PhD Thesis, 2007, Nuovo Cimento C, 31, 2008]

Dosimetry and cosmic rays

- Complete simulation of cosmic rays interactions in the atmosphere, by means of a dedicated CR package available to users
- Model of airplane geometry
- Response of dosimeters

Ambient dose equivalent from neutrons
at solar maximum on commercial flights
from Seattle to Hamburg and from Frankfurt to Johannesburg



[Solid lines: FLUKA simulation
S. Roesler et al.,
Rad. Prot. Dosim. 98 (2002) 367]

Program of this course

8:00 – 12:00 CET every day

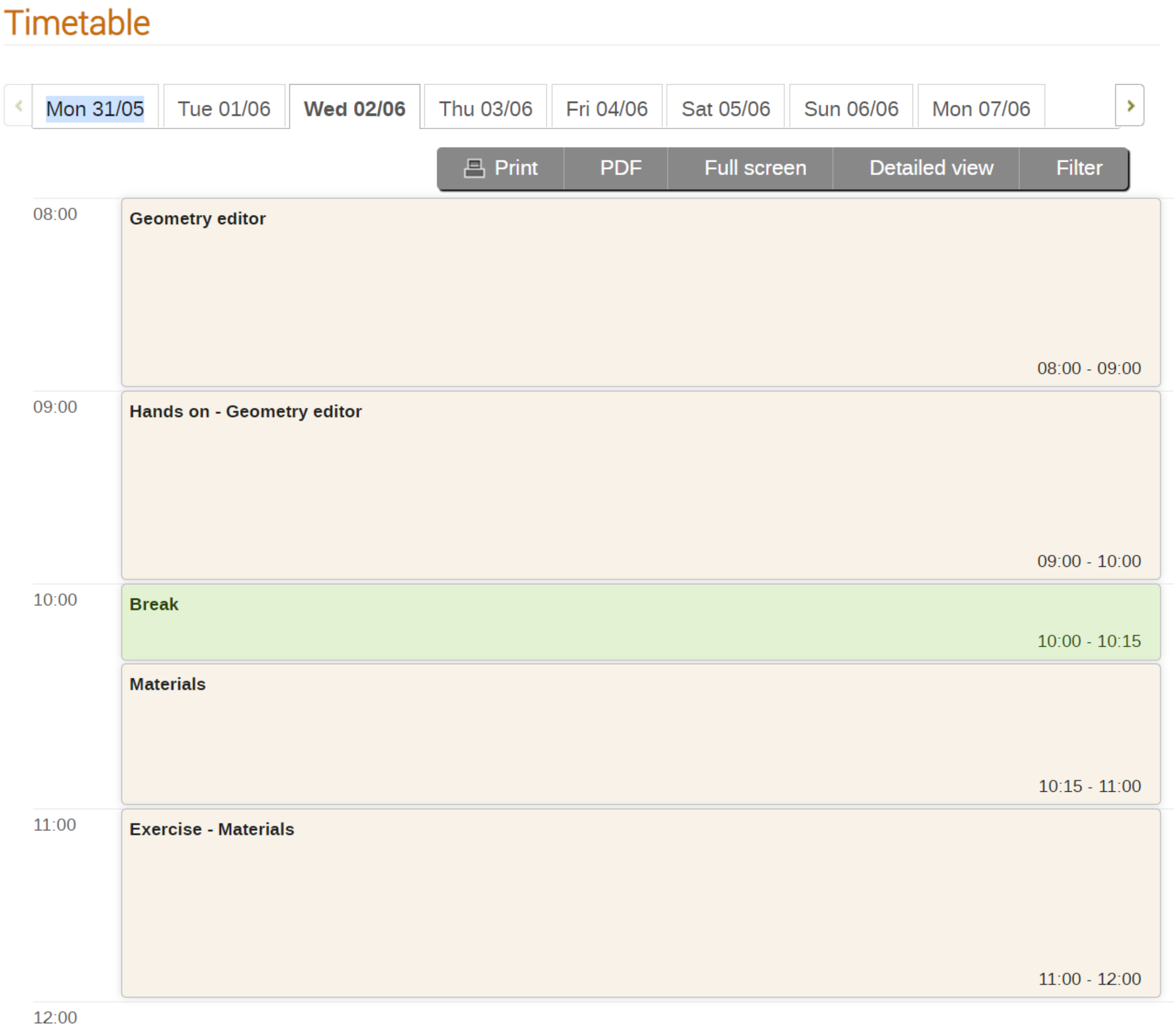
featuring

Lectures

Demos

Exercises

…and multiple-choice questionnaires



FLUKA