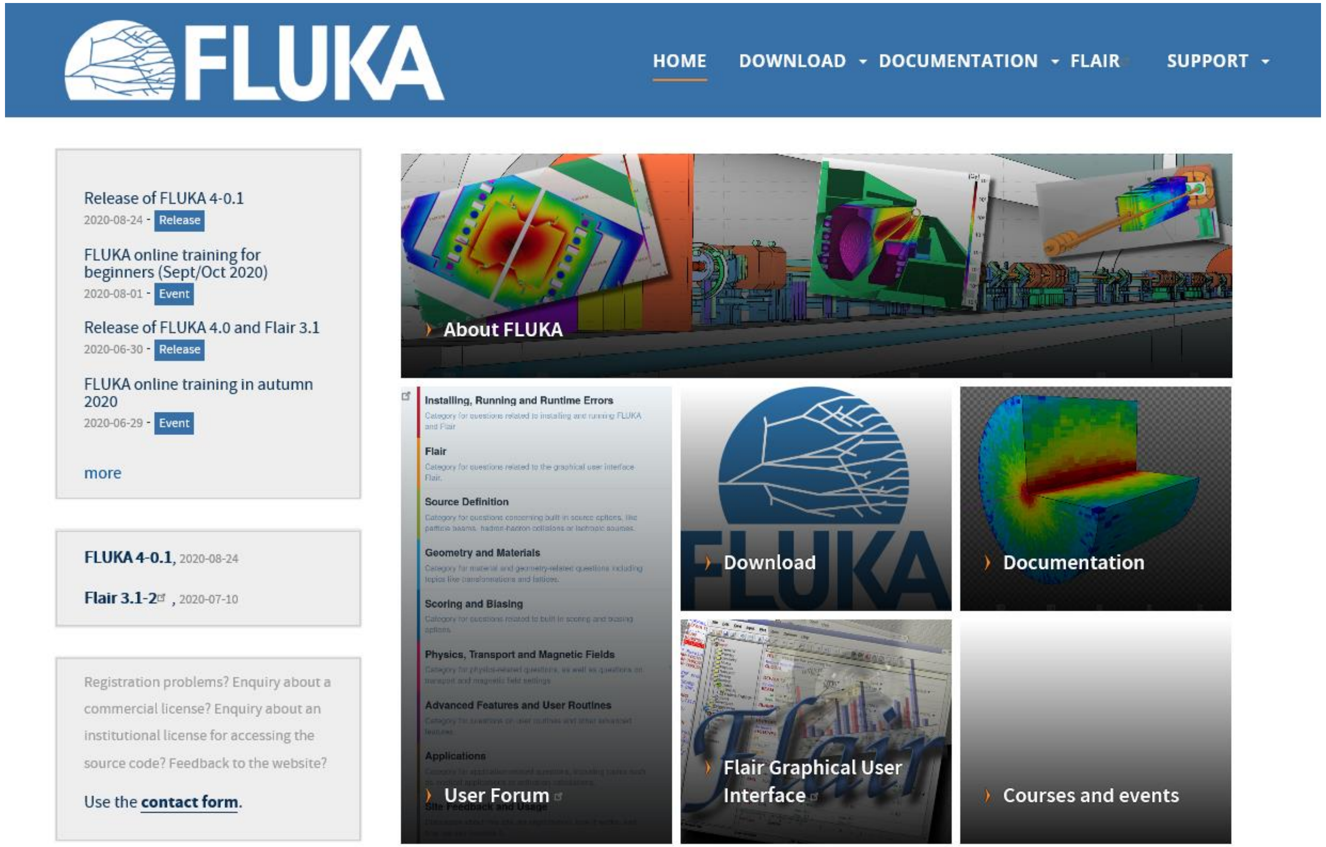
Introduction to FLUKA

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

FLUKA 4-2 released on October 2021

FLUKA 4-2.1 released on December 2021

FLUKA 4-2.2 released on **March 2022**

A fresh reference

New Capabilities of the FLUKA Multi-Purpose Code

C. Ahdida[1], D. Bozzato[1,2], D. Calzolari[1], F. Cerutti[1]*, N. Charitonidis[1], A. Cimmino[3], A. Coronetti[1,4], G. L. D'Alessandro[1], A. Donadon Servelle[1,5], L. S. Esposito[1], R. Froeschl[1], R. García Alía[1], A. Gerbershagen[1], S. Gilardoni[1], D. Horváth[3], G. Hugo[1], A. Infantino[1], V. Kouskoura[1], A. Lechner[1], B. Lefebvre[3], G. Lerner[1], M. Magistris[1], A. Manousos[1,6], G. Moryc[1], F. Ogallar Ruiz[1,7], F. Pozzi[1], D. Prelipcean[1,8], S. Roesler[1], R. Rossi[1], M. Sabaté Gilarte[1], F. Salvat Pujol[1], P. Schoofs[1], V. Stránský[3], C. Theis[1], A. Tsinganis[9], R. Versaci[3], V. Vlachoudis[1], A. Waets[1] and M. Widorski[1]

ORIGINAL RESEARCH article

Front. Phys., 27 January 2022 | https://doi.org/10.3389/fphy.2021.788253

[1]European Organization for Nuclear Research (CERN), Geneva, Switzerland
[2]Karlsruhe Institute for Technology (KIT), Karlsruhe, Germany
[3]ELI Beamlines Centre, Institute of Physics, Czech Academy of Sciences, Dolní Břežany, Czech Republic
[4]Department of Physics, University of Jyväskylä, Jyväskylä, Finland
[5]Ecole Polytechnique Fédérale de Lausanne, Institute of Physics, Lausanne, Switzerland
[6]Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
[7]Department of Atomic, Molecular and Nuclear Physics, University of Granada, Granada, Spain
[8]Department of Physics, Technical University of Munich (TUM), Munich, Germany
[9]European Commission, Joint Research Centre (JRC), Geel, Belgium

TABLE OF CONTENTS

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

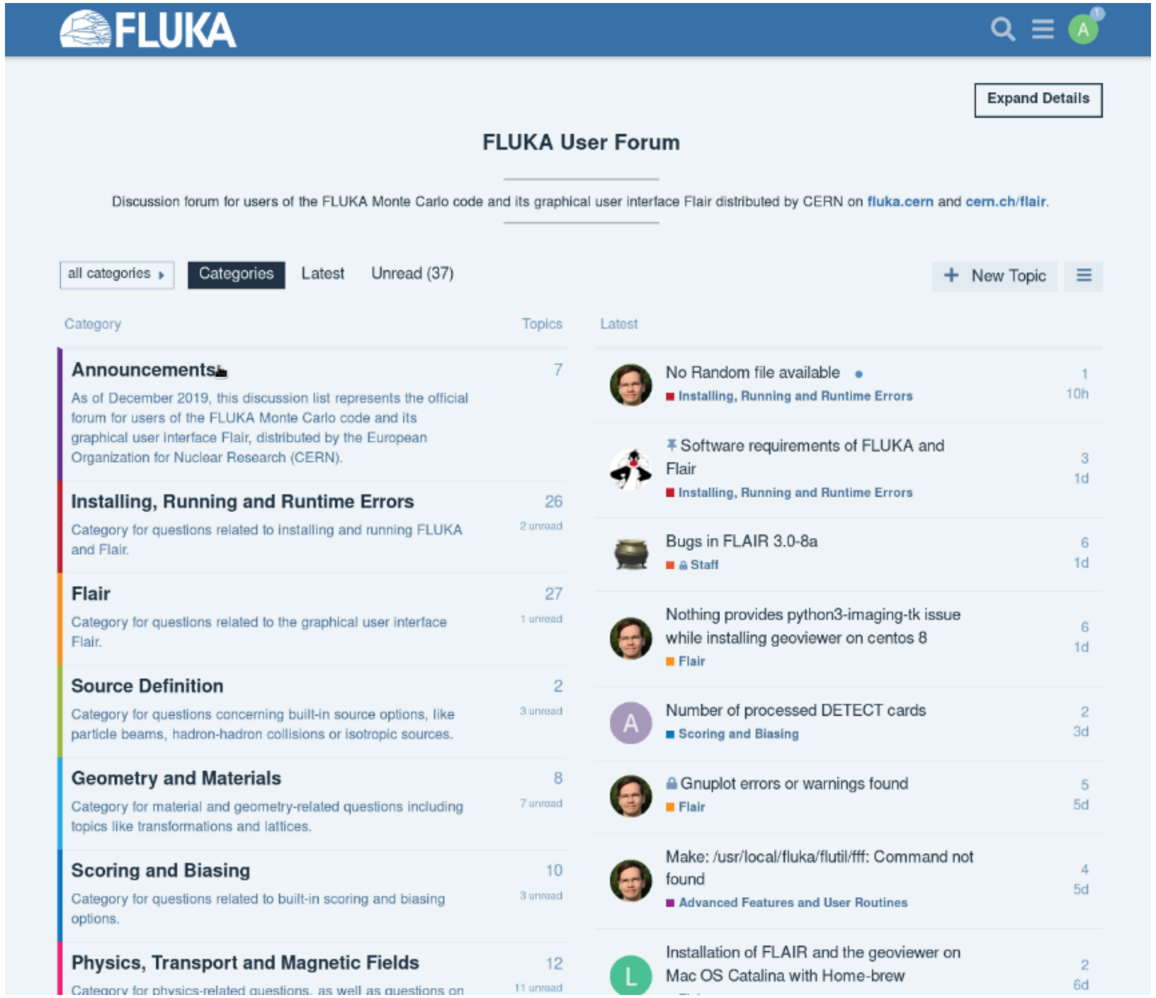
- **Licenses are free** except for commercial use
- They are granted for **non-military use** only

User Support

FLUKA User Forum

https://cern.ch/fluka-forum

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



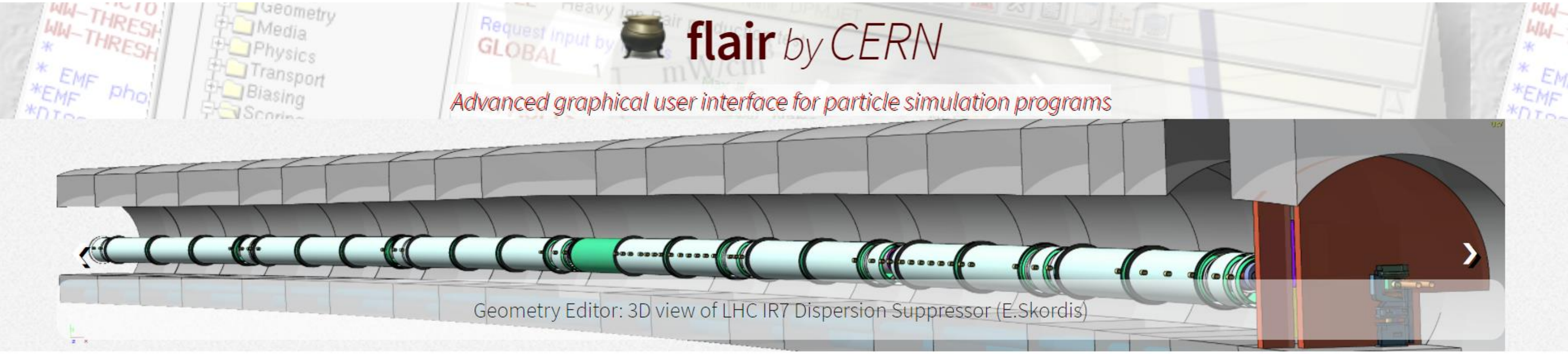
FLUKA Training

Three Beginner Online Training courses were held 2020 and one in 2021.

Advanced course planned for spring 2023 in the US.

FLAIR

https://flair.cern



Authors

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

Current Version

- Latest version: 3.1-15.1
- Released on: *Fri 22-Oct-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

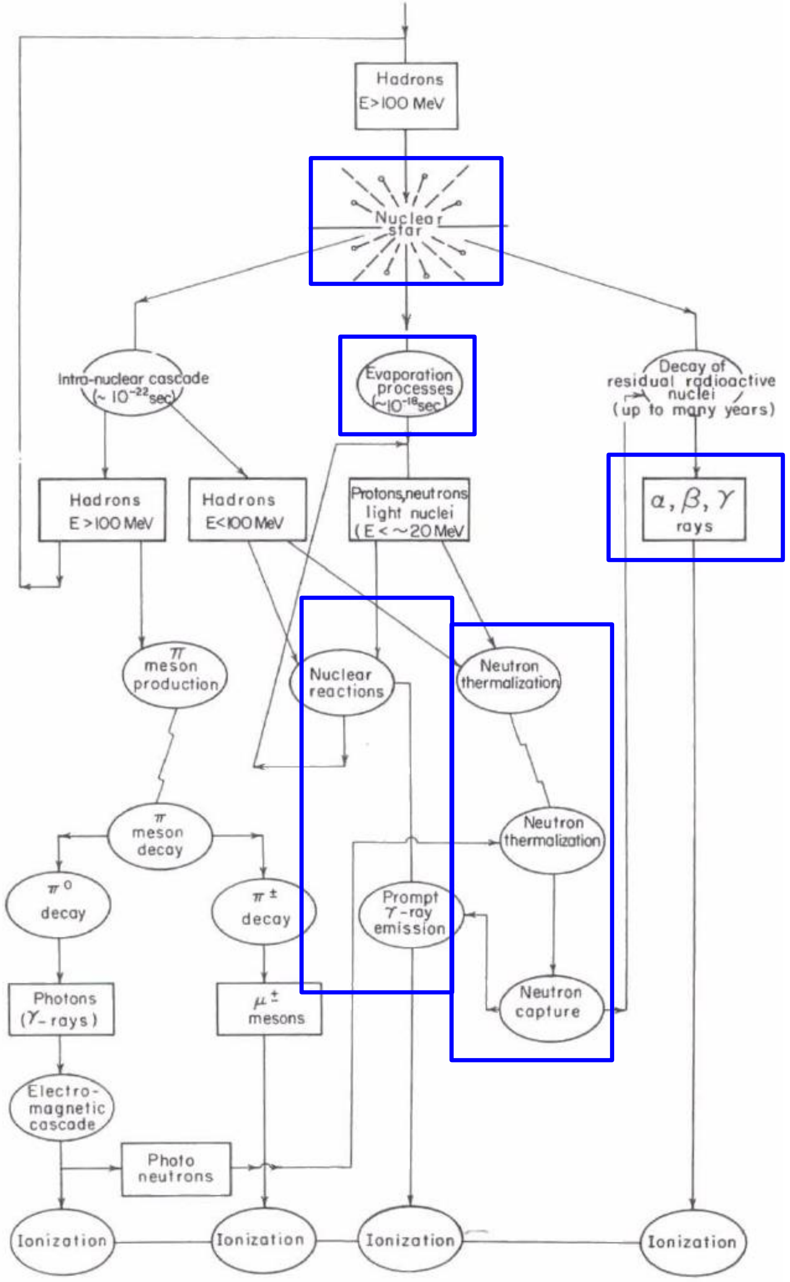
A (hadronic) shower implies a lot of different physics processes, touching a very broad energy [time-space] scale

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 (including deuterons!)
- 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)

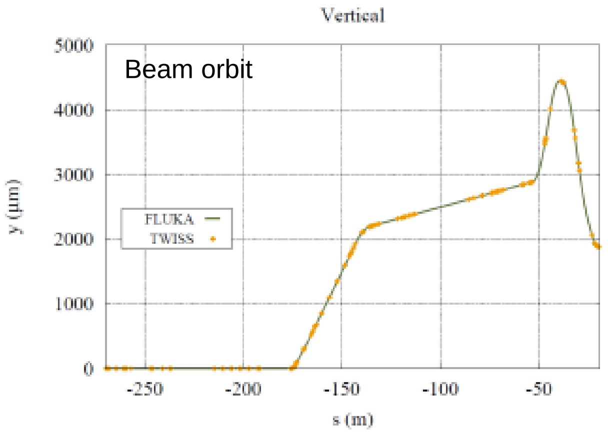
In support of a
wide range of applications

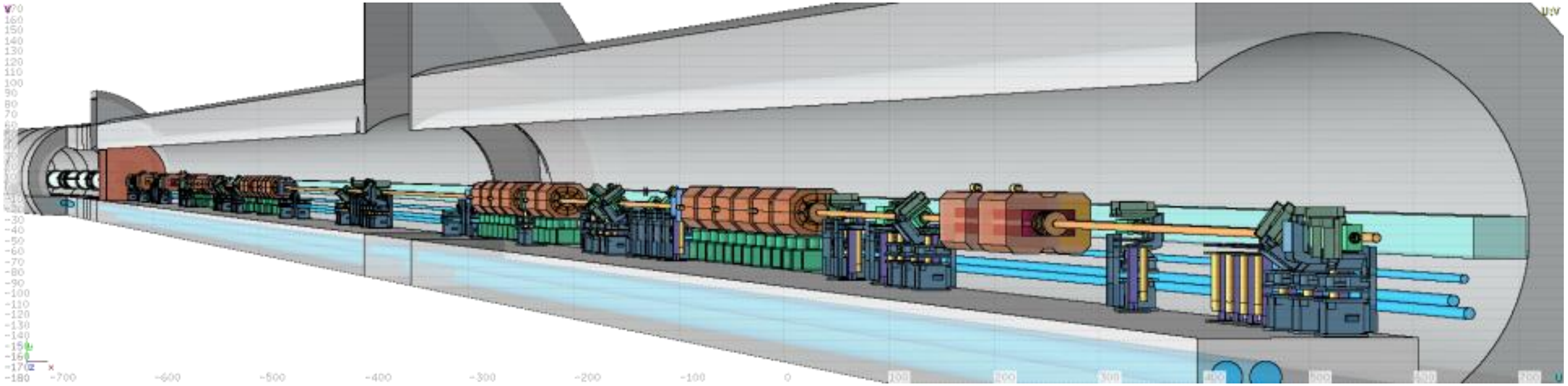
✓Accelerator design
✓Particle physics
✓Cosmic ray physics
✓Neutrino physics
✓Medical applications

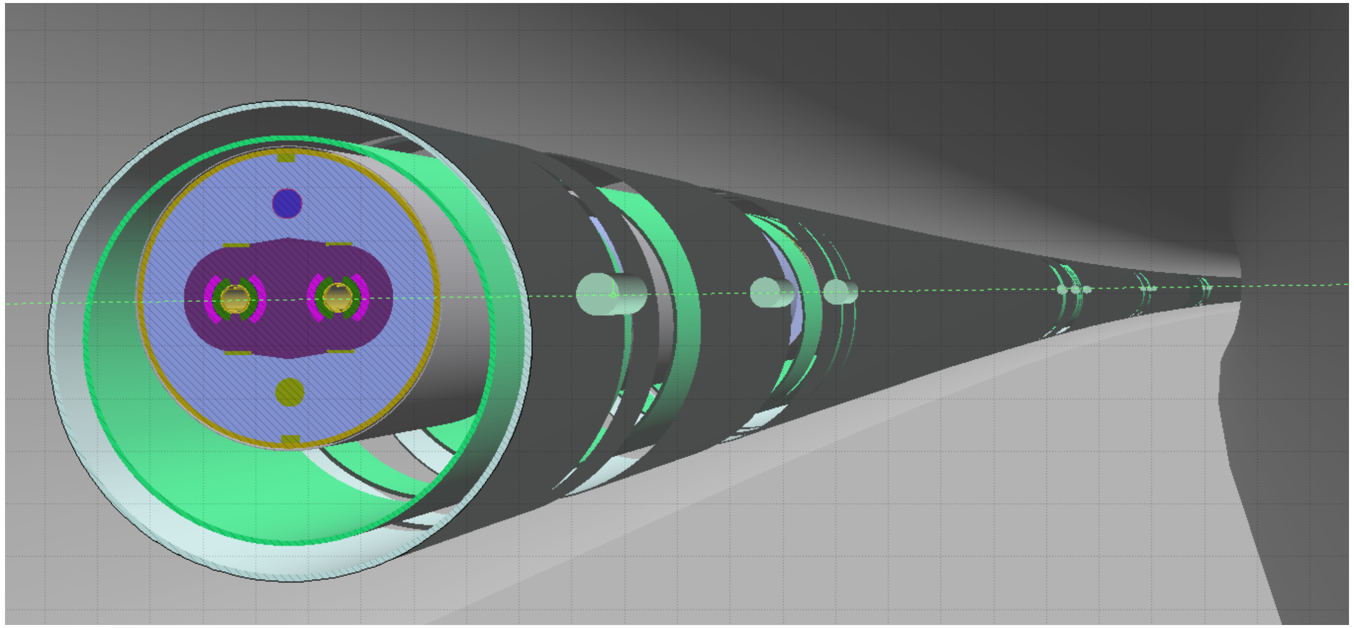
✓Radiation protection (shielding design, activation)
✓Dosimetry
✓Radiation damage
✓Radiation to electronics effects
✓ ADS systems, waste transmutation
✓Neutronics

Some examples

Accelerator geometries







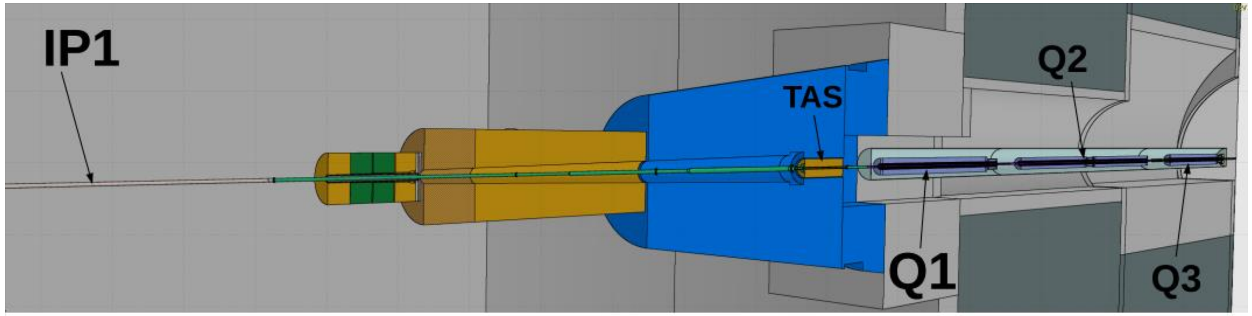
From DETAILED MODELS OF ACCELERATOR COMPONENTS WITH ASSOCIATED SCORING and the ELEMENT SEQUENCE AND RESPECTIVE MAGNETIC STRENGTHS, as given IN THE MACHINE OPTICS (TWISS) FILES,
the **AUTOMATIC CONSTRUCTION OF COMPLEX BEAM LINES**, including collimator settings and element displacement (BLMs), is achievable,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

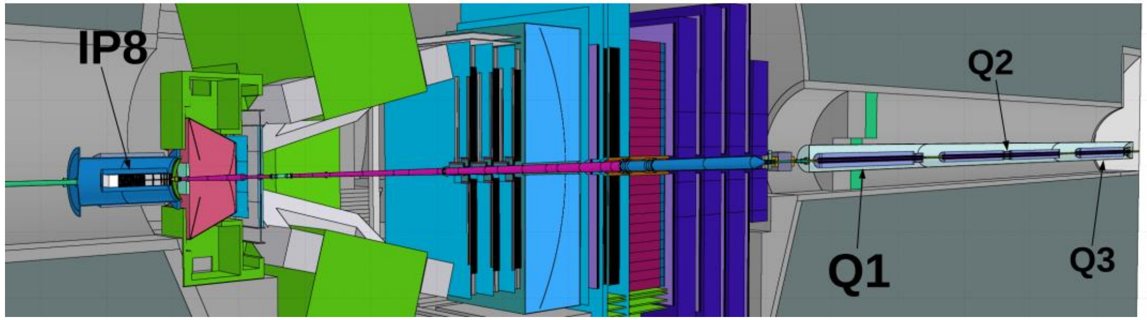
LINE BUILDER

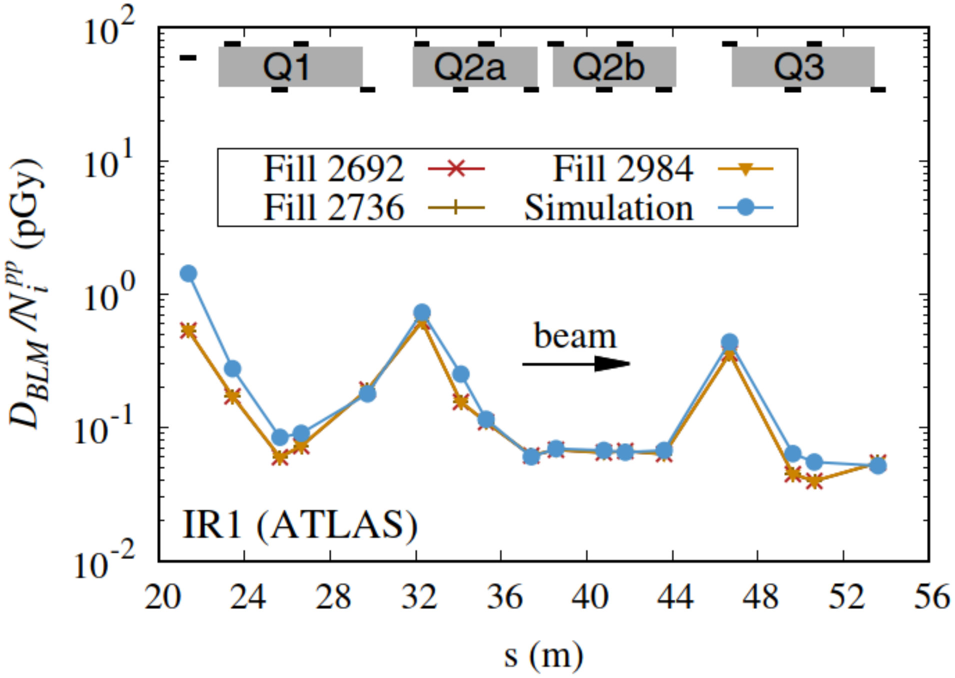
[A. Mereghetti et al., IPAC2012, WEPPD071, 2687]

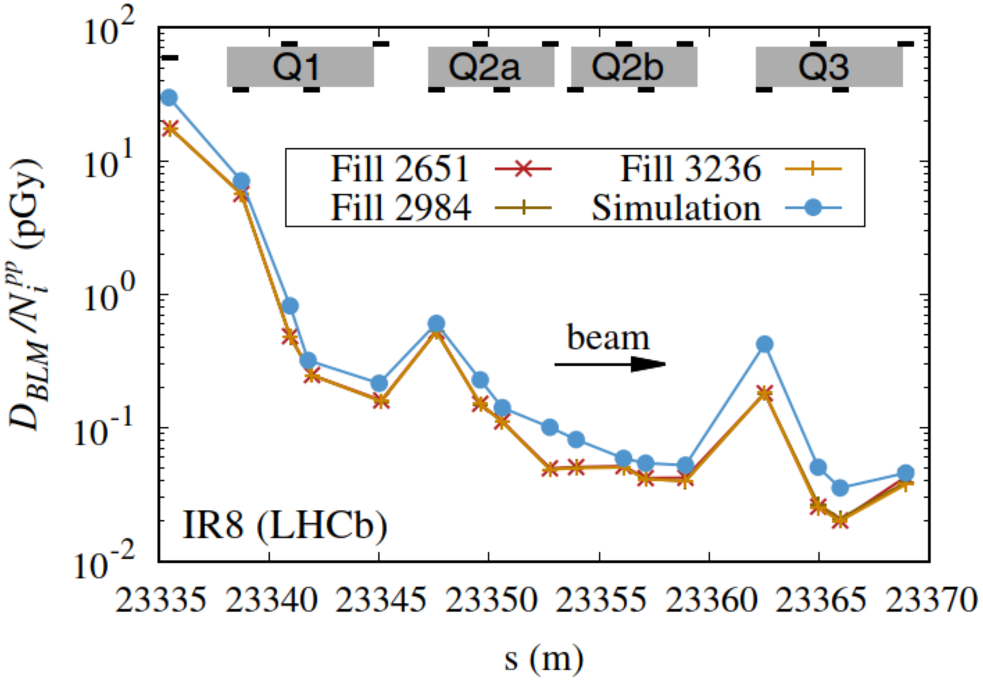
Beam loss description at the LHC

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









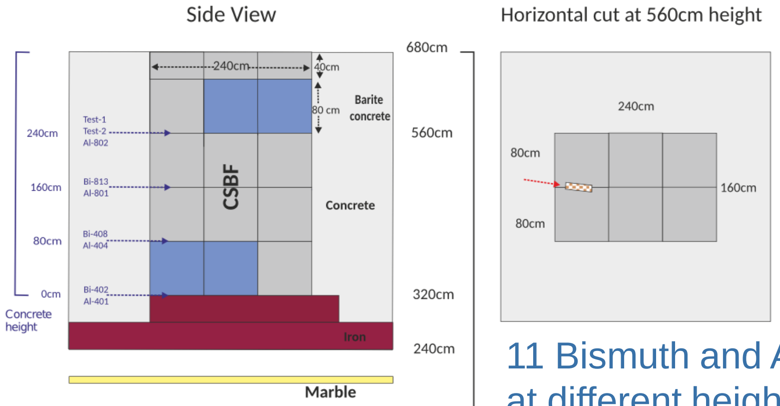
Activation benchmarking

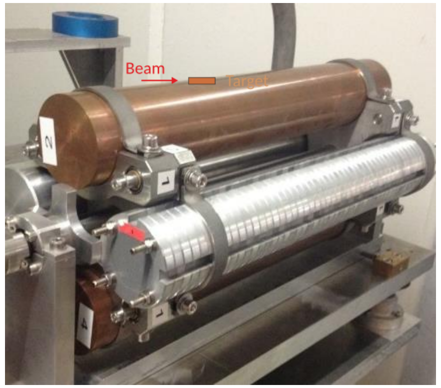
@ CERN SHIELDING BENCHMARK FACILITY (24 GeV/c p)

[E. Iliopoulou and R. Froeschl]

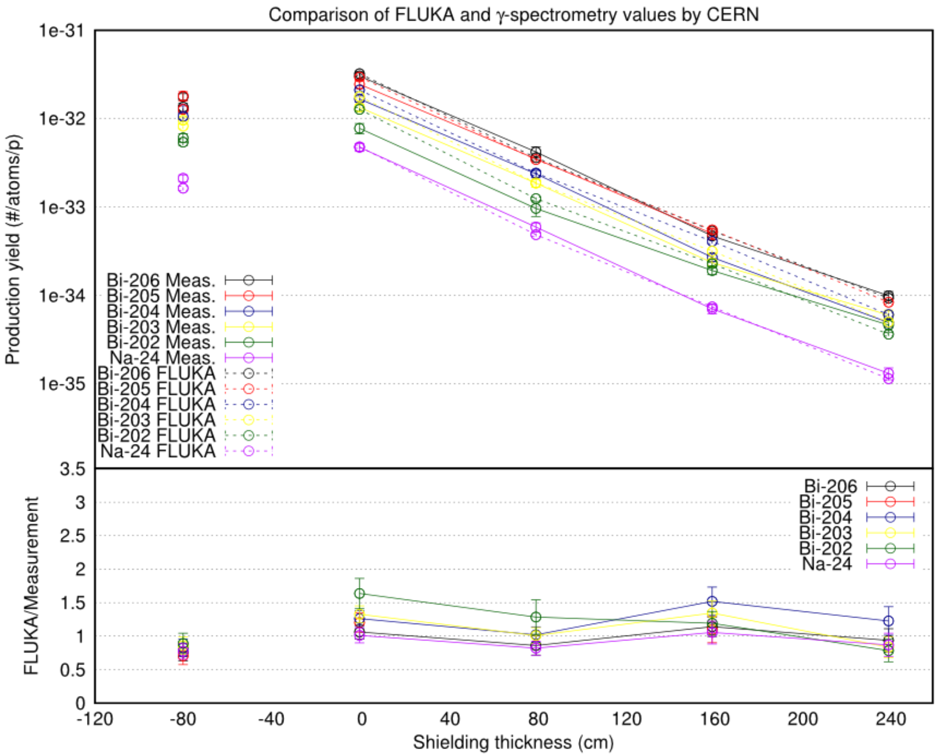
Situated laterally above the CHARM target
for deep shielding penetration studies (Detector calibration, Detector inter-comparison, Activation)

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)

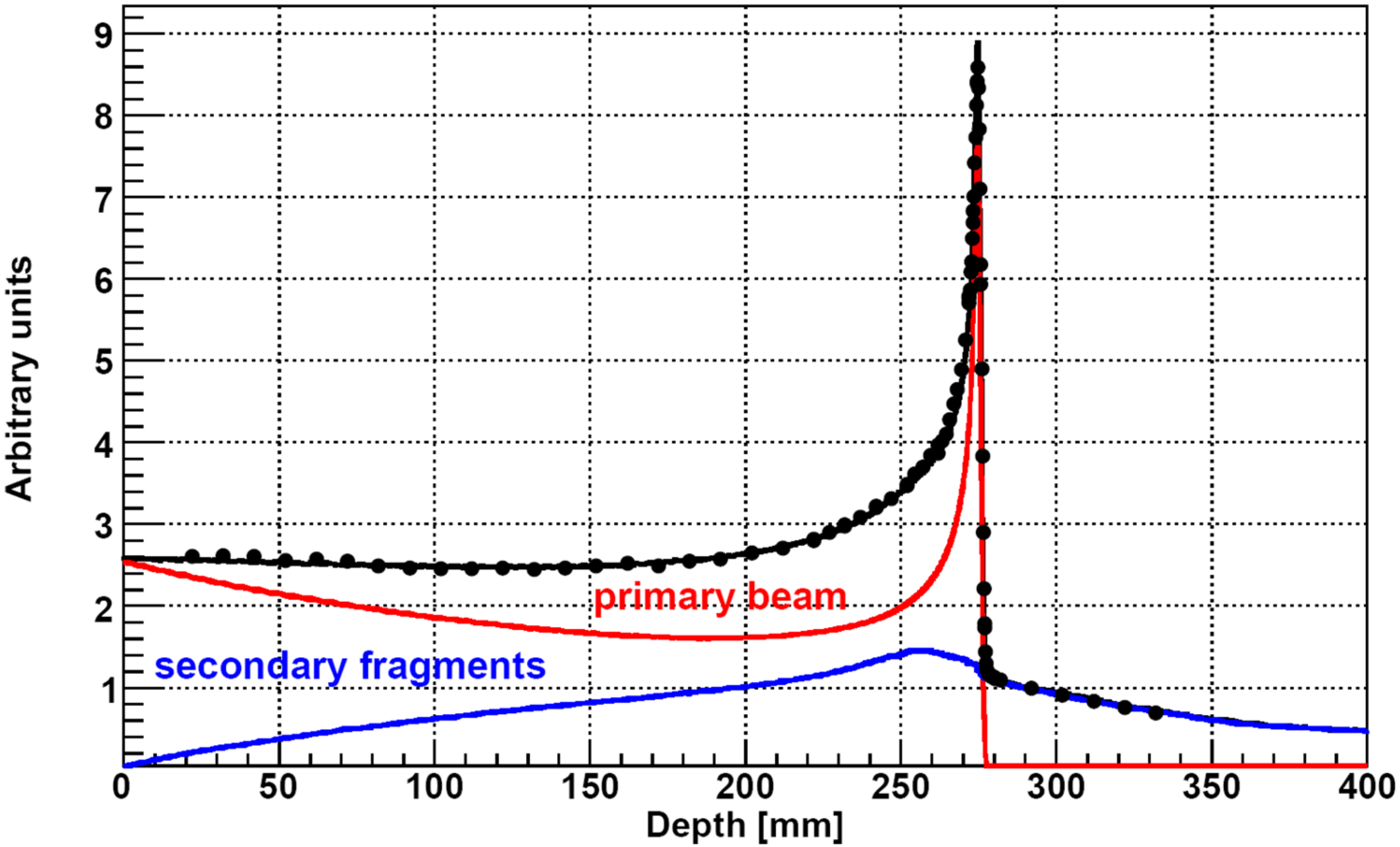


@ CHARM (CERN High energy AcceleRator Mixed field facility,

to study radiation effects on electronic components)

5 x 10^{11} protons/pulse, 350ms pulse length, max. average beam intensity 6.6 x 10^{10} p/s
three 50cm long 8cm diameter targets: Copper, Aluminum, Aluminum with holes

Medical physics: radiotherapy



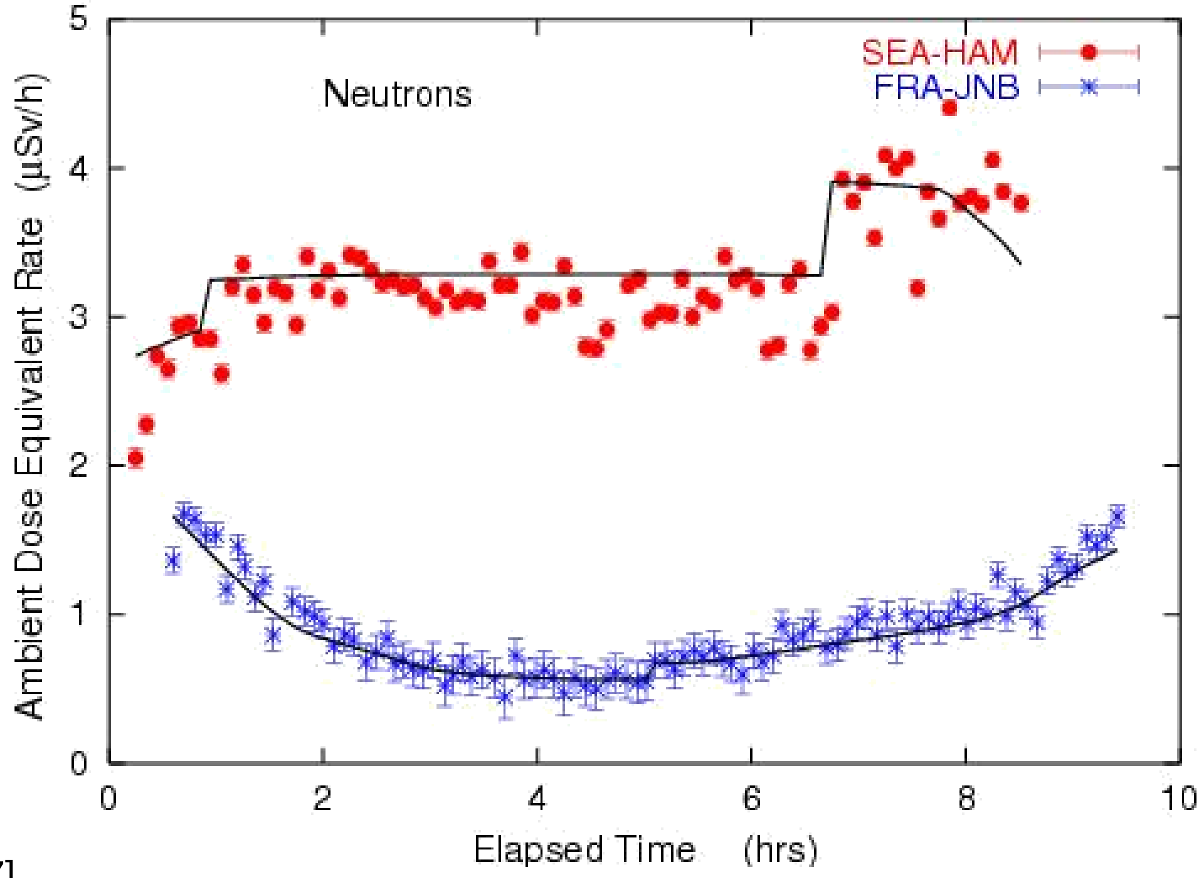
[Exp. Data (points) from Haettner et al, Rad. Prot. Dos. 2006
Simulation: A. Mairani PhD Thesis, 2007, Nuovo Cimento C, 31, 2008]

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

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

Schedule of the week

Hours: 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18

Monday	Introduction	Teachers/ participants Introduction	Coffee	Monte Carlo Basics	Basic Input / Introduction to Flair	Lunch	Basic Input / Flair 1st run	Geometry I	Coffee	Geometry I	
Tuesday	Geometry Editor	Geometry Editor	Coffee	Materials	Materials	Lunch	Scoring I : Intro & USRBIN	Scoring I : Intro & USRBIN	Coffee	Simple source & preprocessor	Simple source & preprocessor
Wednesday	EM & Thresholds	EM & Thresholds	Coffee	Scoring II : diff. spec.	Scoring II : diff. spec.	Lunch	Intermediate use of Flair	EM fields	Coffee	EM fields	Standard output and errors
Thursday	Interactions	Biasing	Coffee	Biasing	Geom II	Lunch	Geometry II	Source routines	Coffee	Source routines	
Friday	Activation and Scoring III	Activation and Scoring III	Coffee	Wrap Up Exercise	Lunch	Course Evaluation	Advanced Sources	Advanced topics	Coffee		

Lecture
Exercise
Pause

Many thanks to **ULB**: Marie-Mo VAEYENS, Nicolas PAULY, Pierre-Etienne LABEAU, Cedric HERNALSTEENS

FLUKA