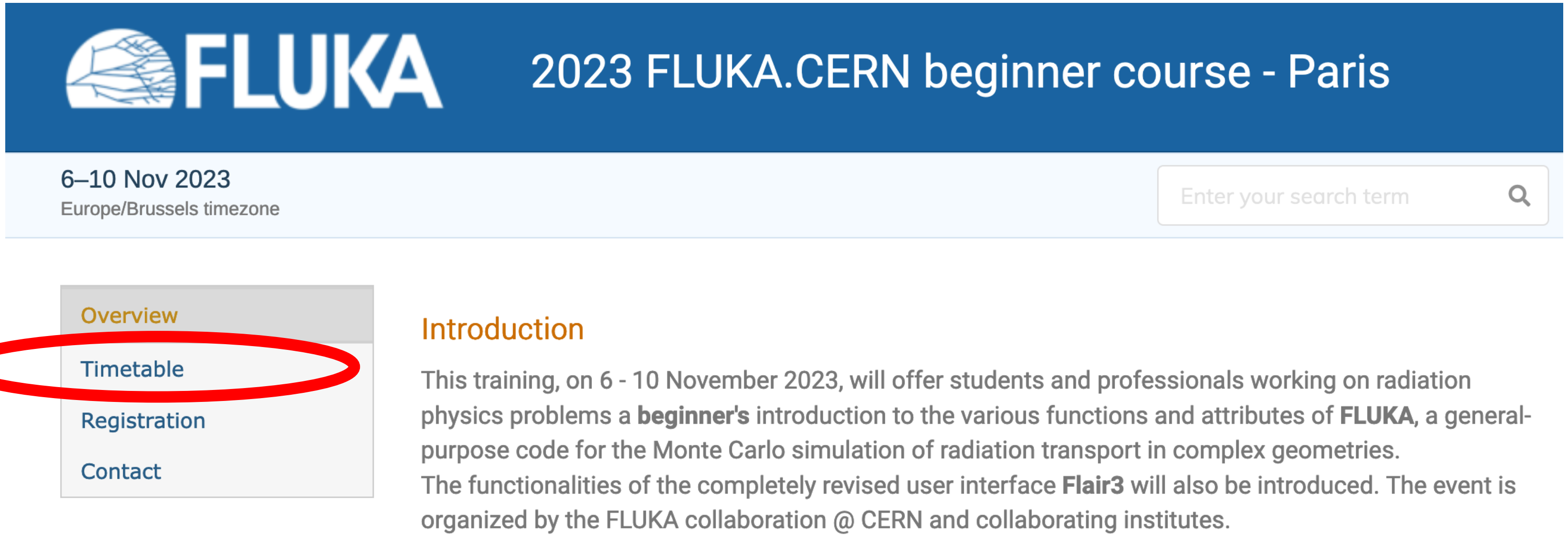
First of all…

Many thanks to
Elena POPLAVSKAIA and Catherine ROCHER THROMAS
(NEA) for the organizational effort!

Training site: https://indico.cern.ch/event/1296149/overview



Slides for lectures + exercises, as well as exercise input files (and solution files in due time…)

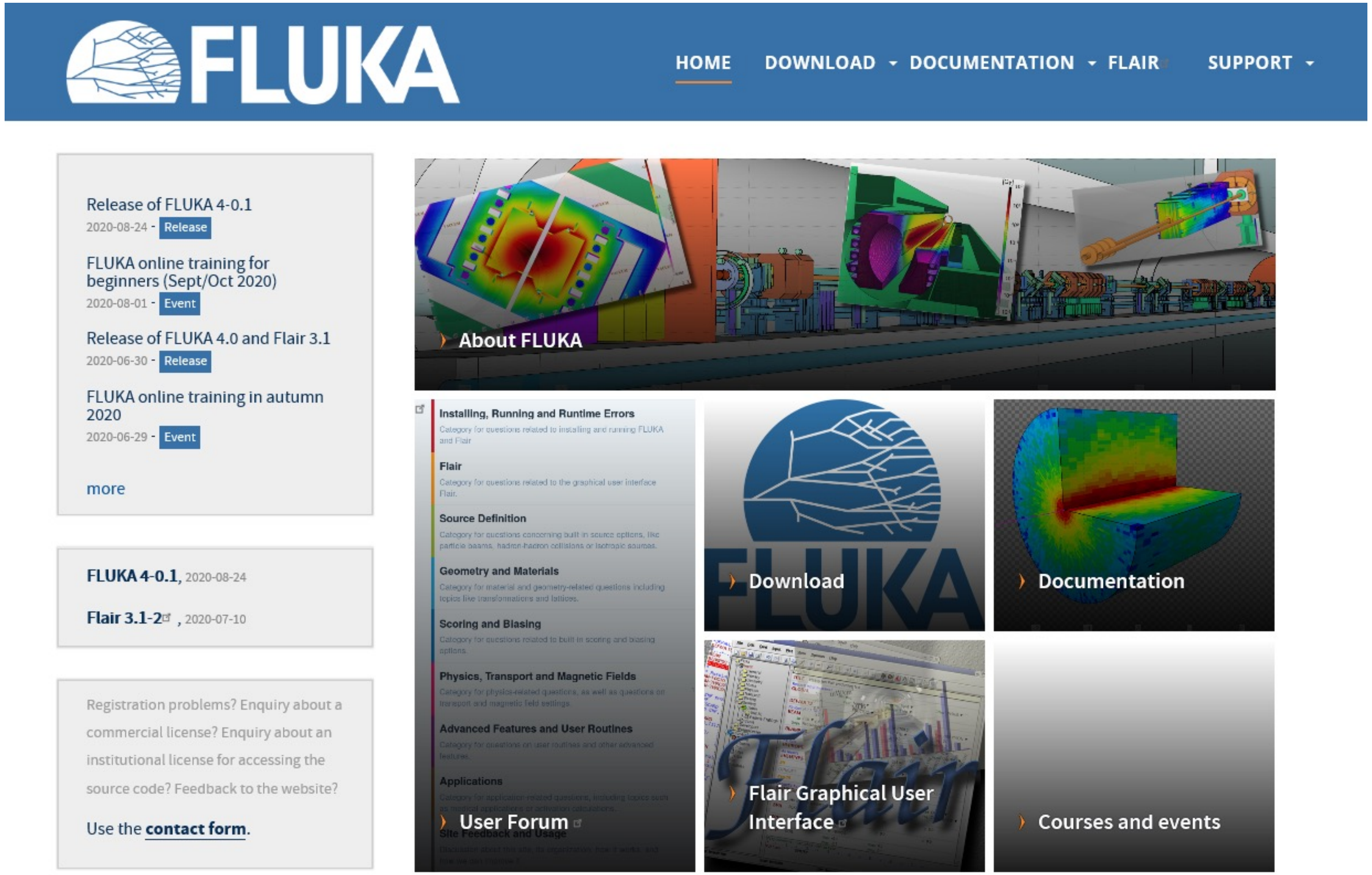
Introduction to FLUKA

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 of Technology** 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



Licensing Scheme

Registration options	Includes access to:
FLUKA **Single User License Agreement**	
Affiliates of institutes with a FLUKA **Institutional License Agreement**	**source code**
CERN Staff members and Fellows	**source code**
Affiliates of institutes which signed the FLUKA **Memorandum of Understanding**	**development version**
Companies which purchased a FLUKA **Commercial License Agreement**	

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

- For **central FLUKA installations on computing clusters** of universities/institutes it is not necessary to obtain an Institutional FLUKA Licence. However, it is mandatory that all FLUKA users register on this website and accept the Single User Licence Agreement.

Recent developments of FLUKA hosted by CERN at https://fluka.cern

HOME DOWNLOAD DOCUMENTATION FLAIR SIMPLEGEO SUPPORT

*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***

Coherent transport effects for charged particles in **bent crystals**; electric field in vacuum; electronuclear reactions; direct (p,n) reactions.

Compound nucleus spin and parity accounted for in evaporation and Fermi break-up; **new generation source** routine for users.

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

*FLUKA **4-2** released on **October 2021***

*FLUKA 4-2.1 released on **December 2021***

Low-energy **deuteron interaction** model; proton reaction cross section refinement; ICRP116 and ICRU95 dose equivalent conversion coefficients; simplified out-of-the-box usage of multiple magnetic fields

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

*FLUKA **4-3** released on **September 2022***

*FLUKA 4-3.1 released on **December 2022***

Point-wise treatment for **low-energy neutron** interactions; **synchrotron radiation** emission during charged particle tracking

*FLUKA 4-3.2 released on **March 2023***

*FLUKA 4-3.3 released on **May 2023***

*FLUKA 4-3.4 released on **September 2023***

*FLUKA **4-4** in preparation for **January 2024***

Proton nuclear elastic scattering improvement at low energies; gamma cascade improvement for thermal neutron capture; (d,2n) improvement on heavy targets

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]

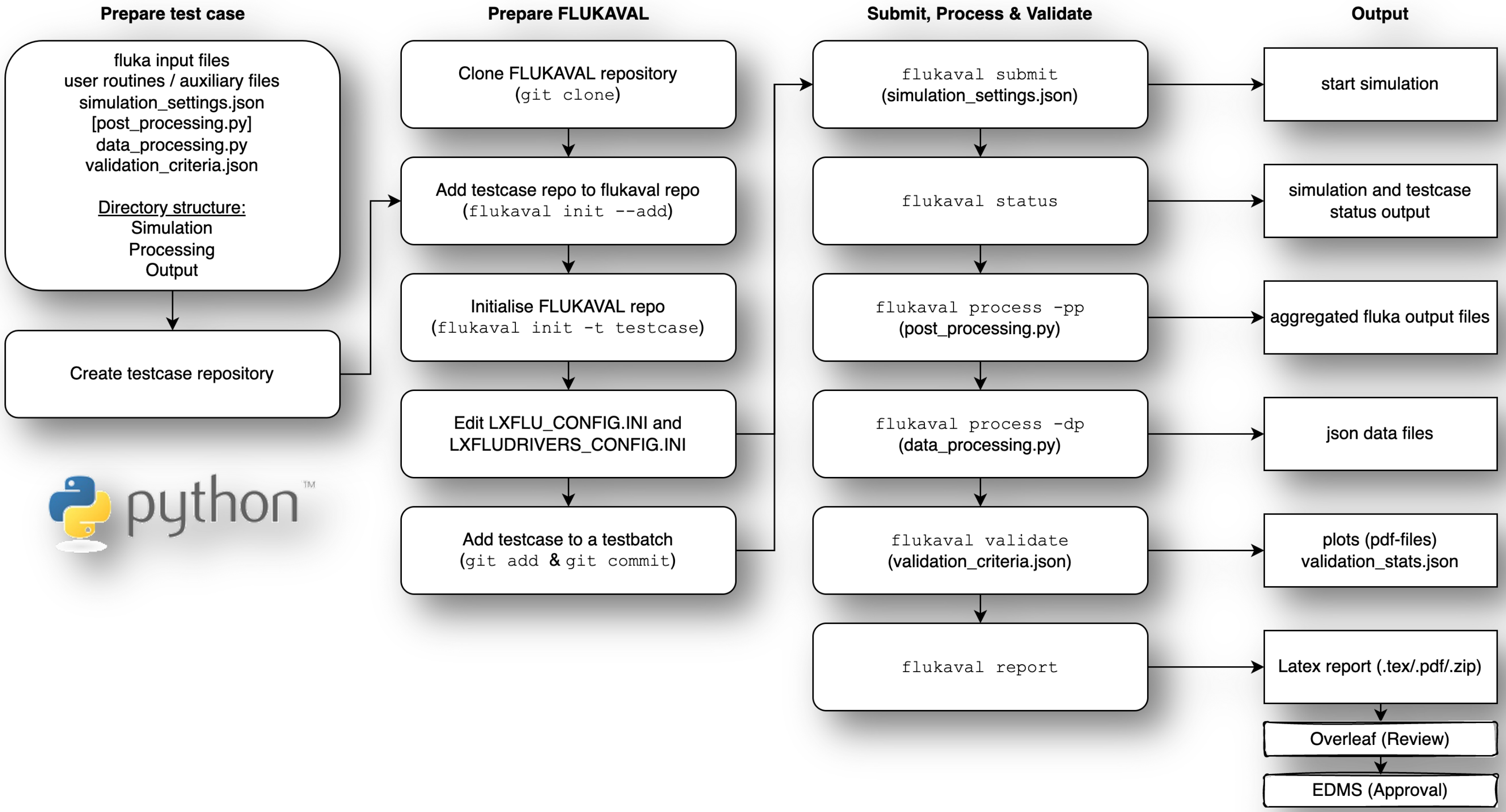
[1]European Organization for Nuclear Research (CERN), Geneva, Switzerland
[2]Karlsruhe Institute for Technology (KIT), Karlsruhe, Germany
[3]ELI Beamlines Centre, Institute of Physics, Czech Academy of Sciences, Dolní Břežany, Czech Republic
[4]Department of Physics, University of Jyväskylä, Jyväskylä, 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

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

TABLE OF CONTENTS

FLUKAVAL

Confirm that each release candidate FLUKA version, compared to a reference version, yields consistent results for a set of identical test cases, and produce a formal validation report



- Semi-automatic batch submission, processing and validation of test cases and report generation
- Any FLUKA input and dedicated tests having access to the FLUKA code at the model level can be integrated in a few steps
- Optimised for the submission of a large number of test cases to the CERN Batch Service, or any cluster running HTCondor
- Routinely used to validate new versions before release
- Python-based command line application
- Using the **git version control system** to store simulation and reference data

User Support

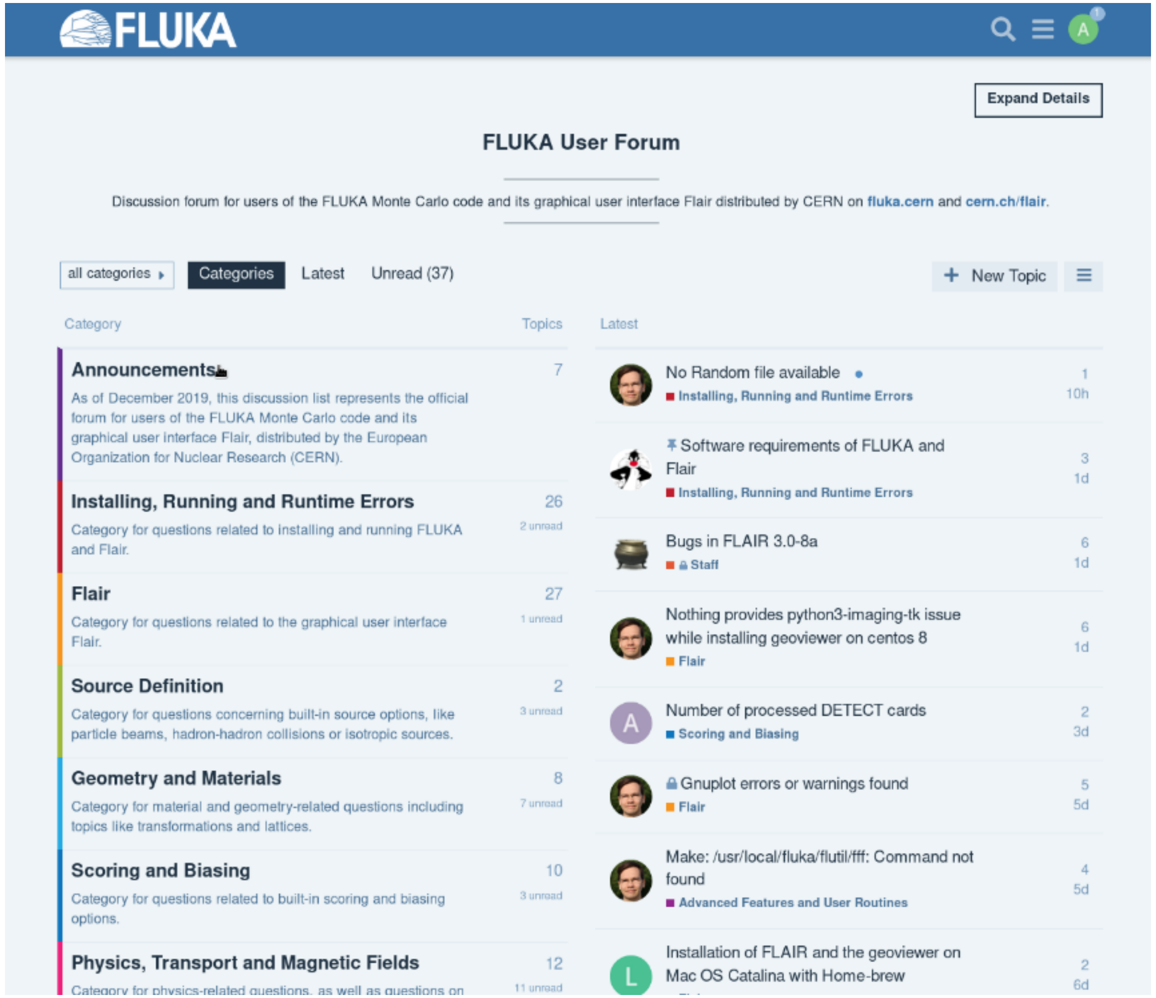
FLUKA User Forum

https://cern.ch/fluka-forum

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

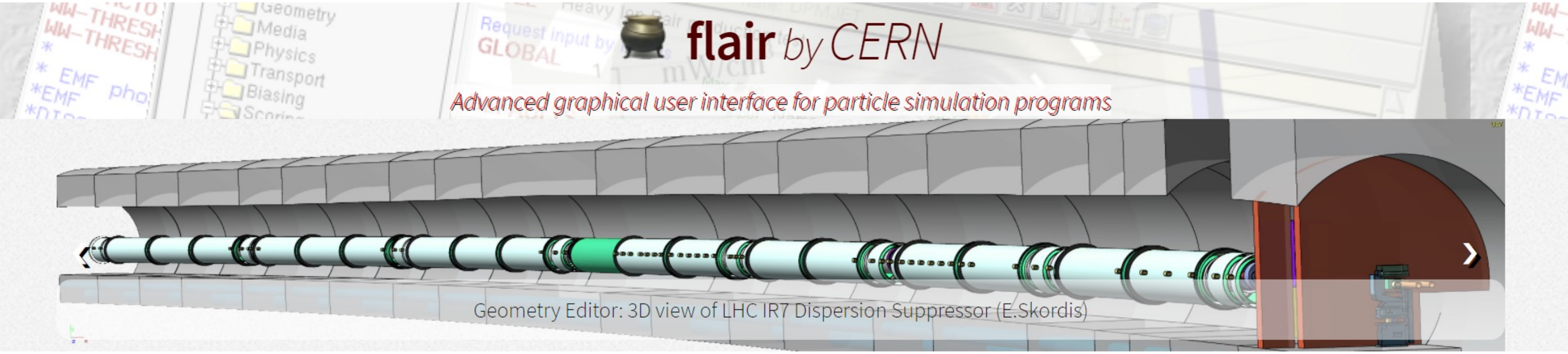
FLUKA Training

- Three Beginner Online Training courses were held in 2020
- One in-person beginner course in 2021, 2022, and 2023
- One advanced course held spring 2023 in person in the US.



FLAIR

https://flair.cern




Head CT with PET CT dose distribution

Authors

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

Current Version

- Latest version: 3.3-0
- Released on: *Wed Oct 25, 2023*
- 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

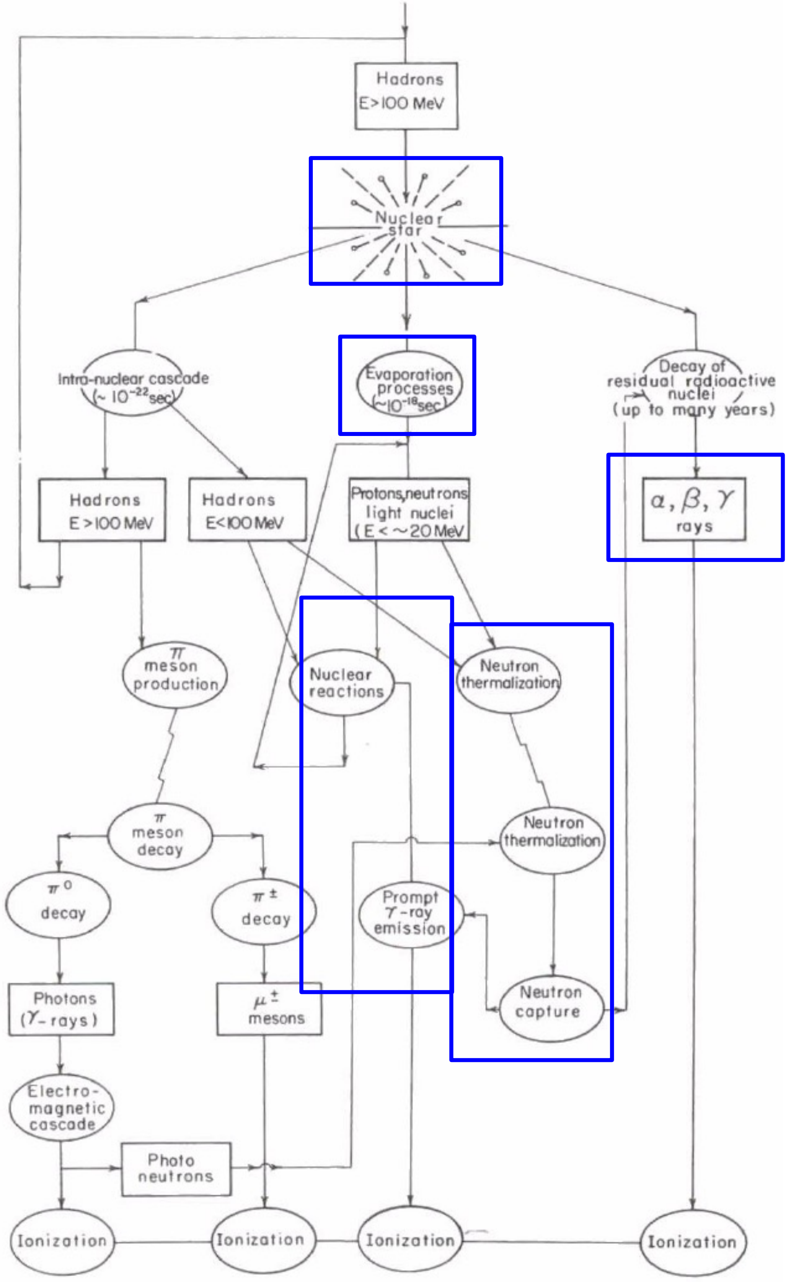
A (hadronic) shower implies a lot of different physics processes, touching a very broad energy [time-space] scale

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

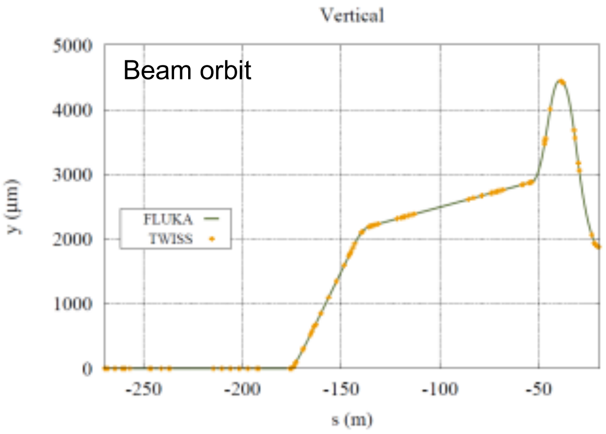
- hadron-hadron and hadron-nucleus interactions
- nucleus-nucleus interactions (including deuterons!)
- photon interactions (>100 eV)
- electron interactions (> 1 keV; including electronuclear)
- muon interactions (including photonuclear)
- neutrino interactions
- low energy (<20 MeV) neutron interactions 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

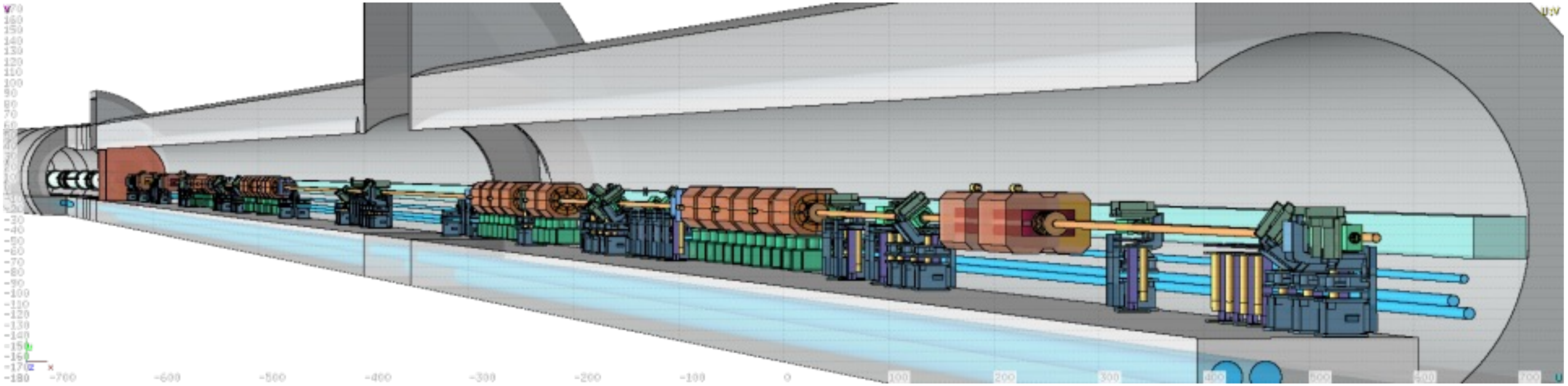
✓Accelerator design
✓Particle physics
✓Cosmic ray physics
✓Neutrino physics
✓Medical applications
✓Radiation protection (shielding design, activation)
✓Dosimetry
✓Radiation damage
✓Radiation to electronics effects
✓ADS systems, waste transmutation
✓Neutronics

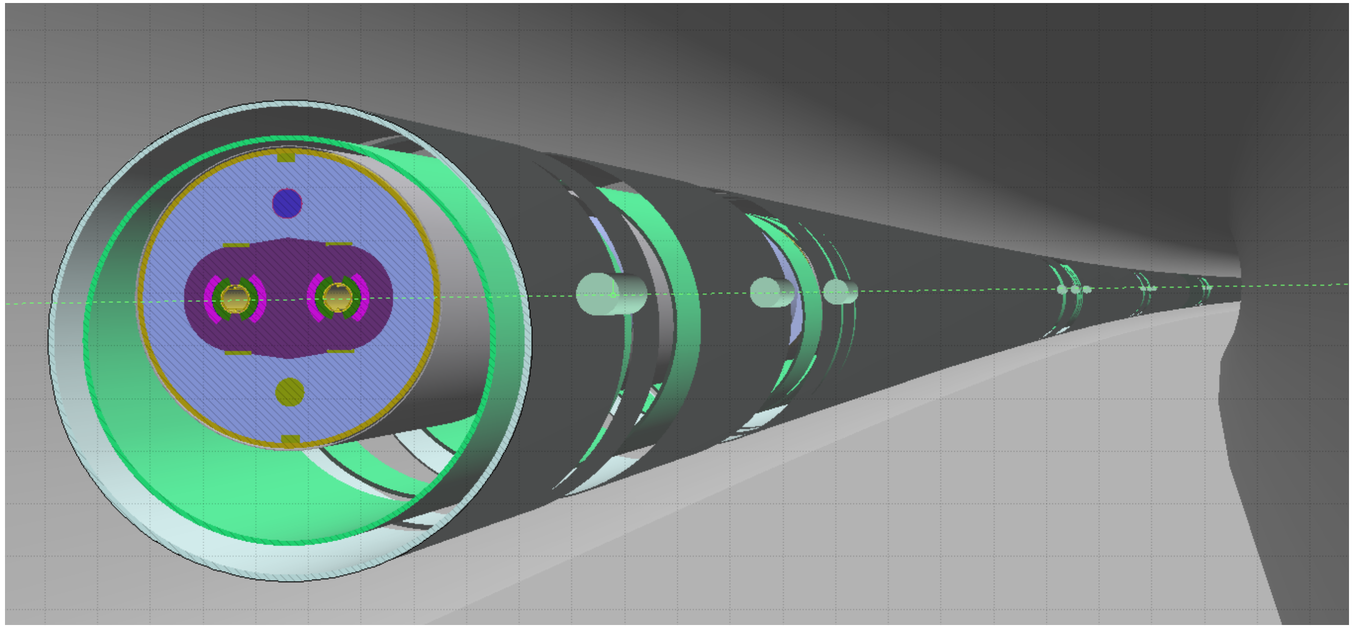
Some examples

Accelerator geometries



LHC IR7 long straight section





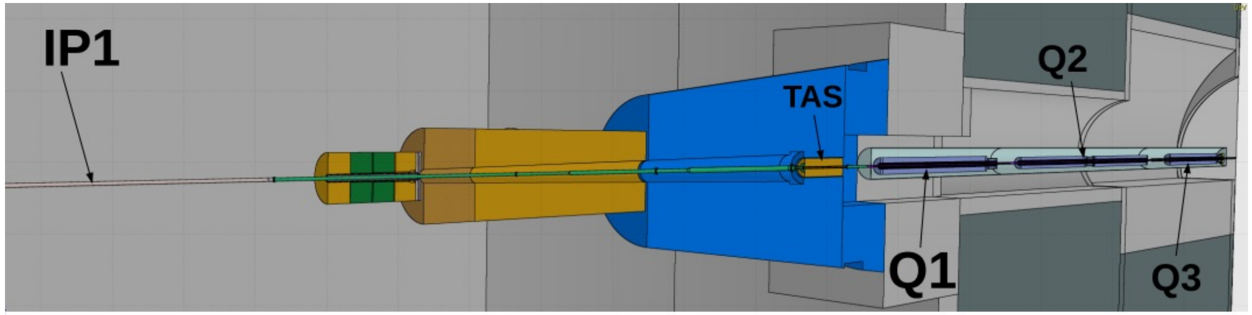
From DETAILED MODELS OF ACCELERATOR COMPONENTS WITH ASSOCIATED SCORING and the ELEMENT SEQUENCE AND RESPECTIVE MAGNETIC STRENGTHS, as given IN THE MACHINE OPTICS (TWISS) FILES,
the **AUTOMATIC CONSTRUCTION OF COMPLEX BEAM LINES**, including collimator settings and element displacement (BLMs), is achievable,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

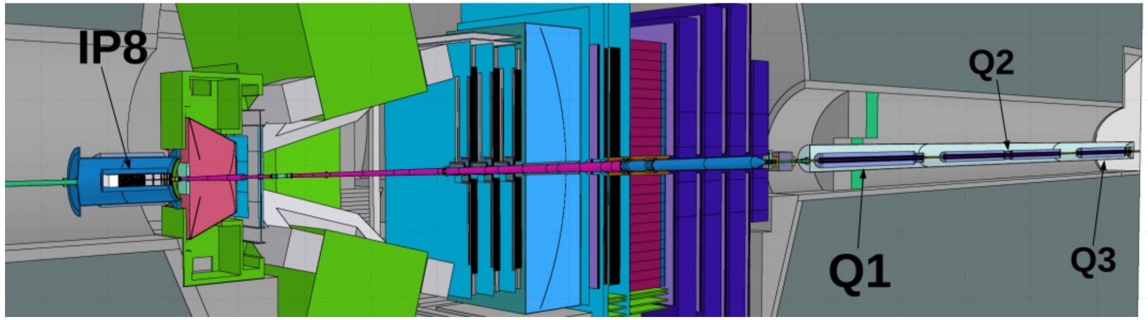
LINE BUILDER

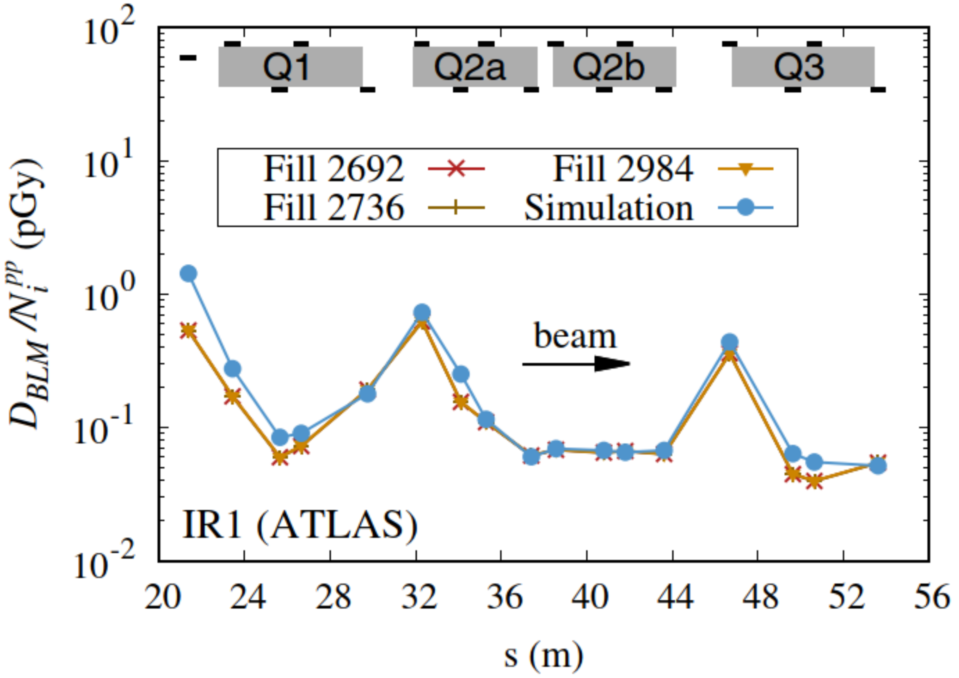
[A. Mereghetti et al., IPAC2012, WEPPD071, 2687]

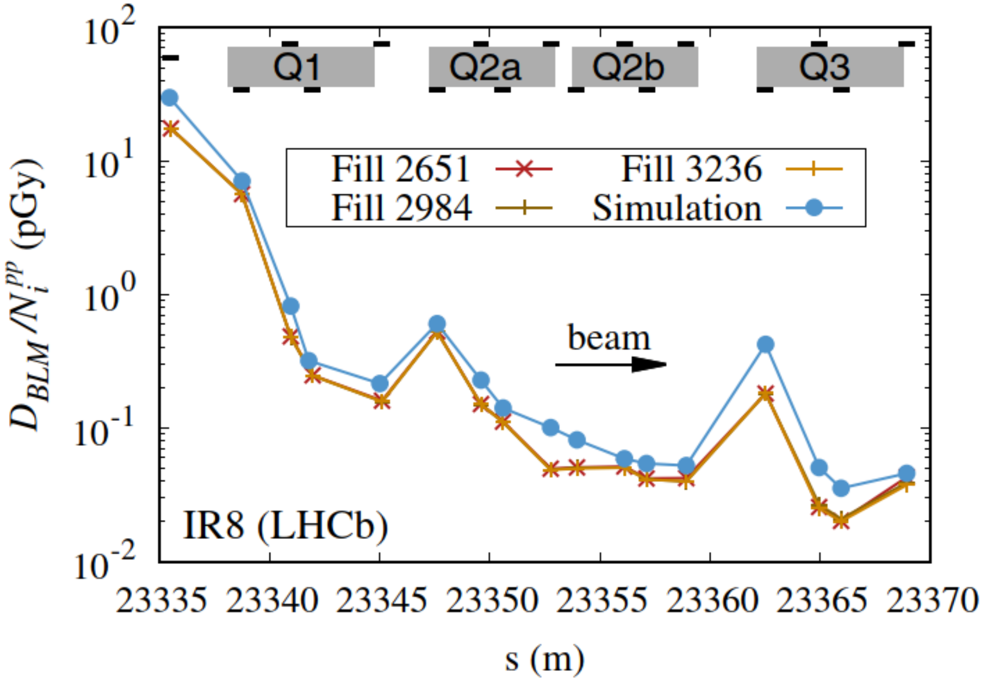
Beam loss description at the LHC

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









Activation benchmarking

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

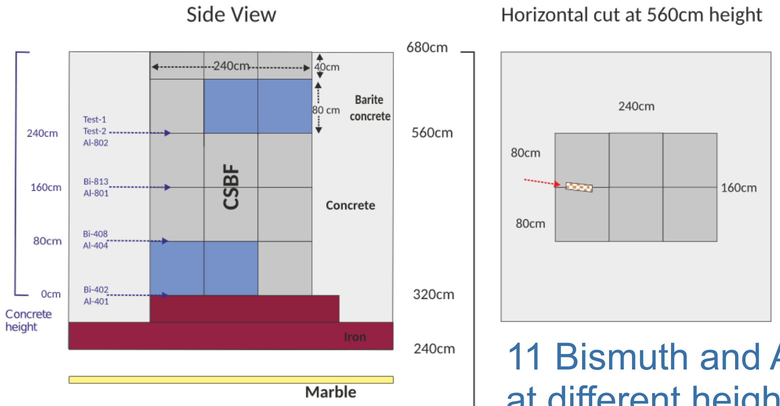
[E. Iliopoulou and R. Froeschl]

Situated laterally above the CHARM target

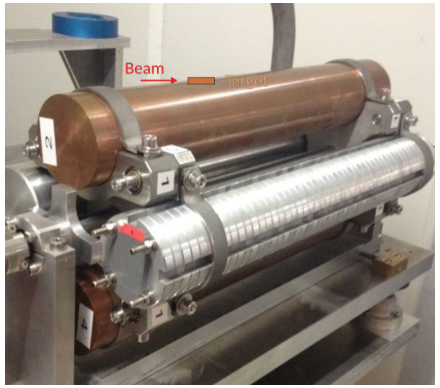
for deep shielding penetration studies (Detector calibration, Detector inter-comparison, Activation)

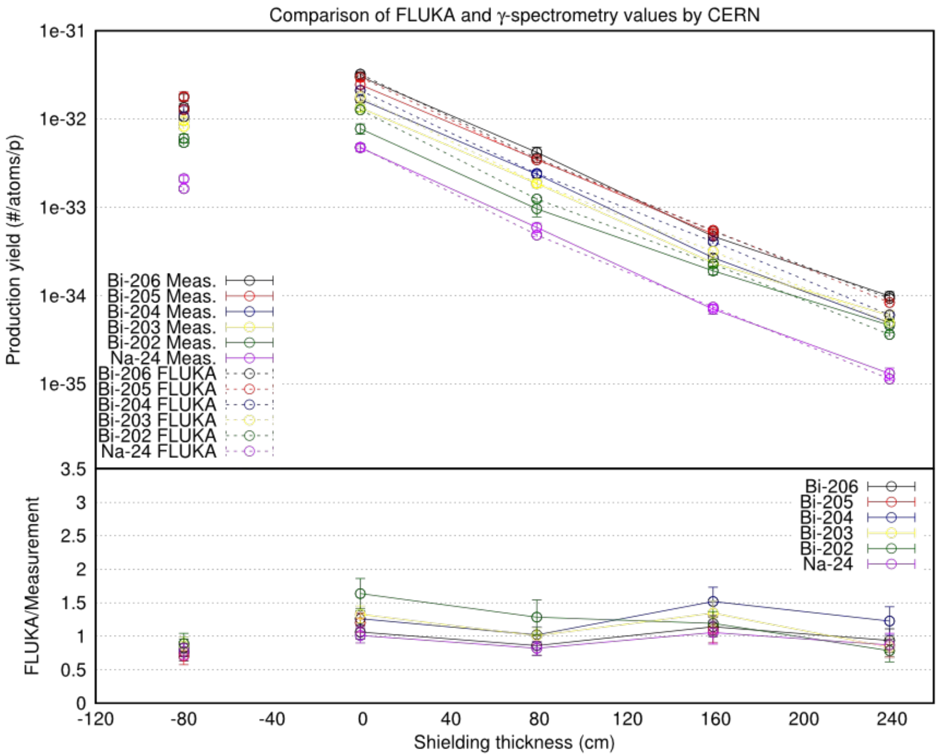
360cm of concrete and barite concrete

plus 80cm of cast iron



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





R2E

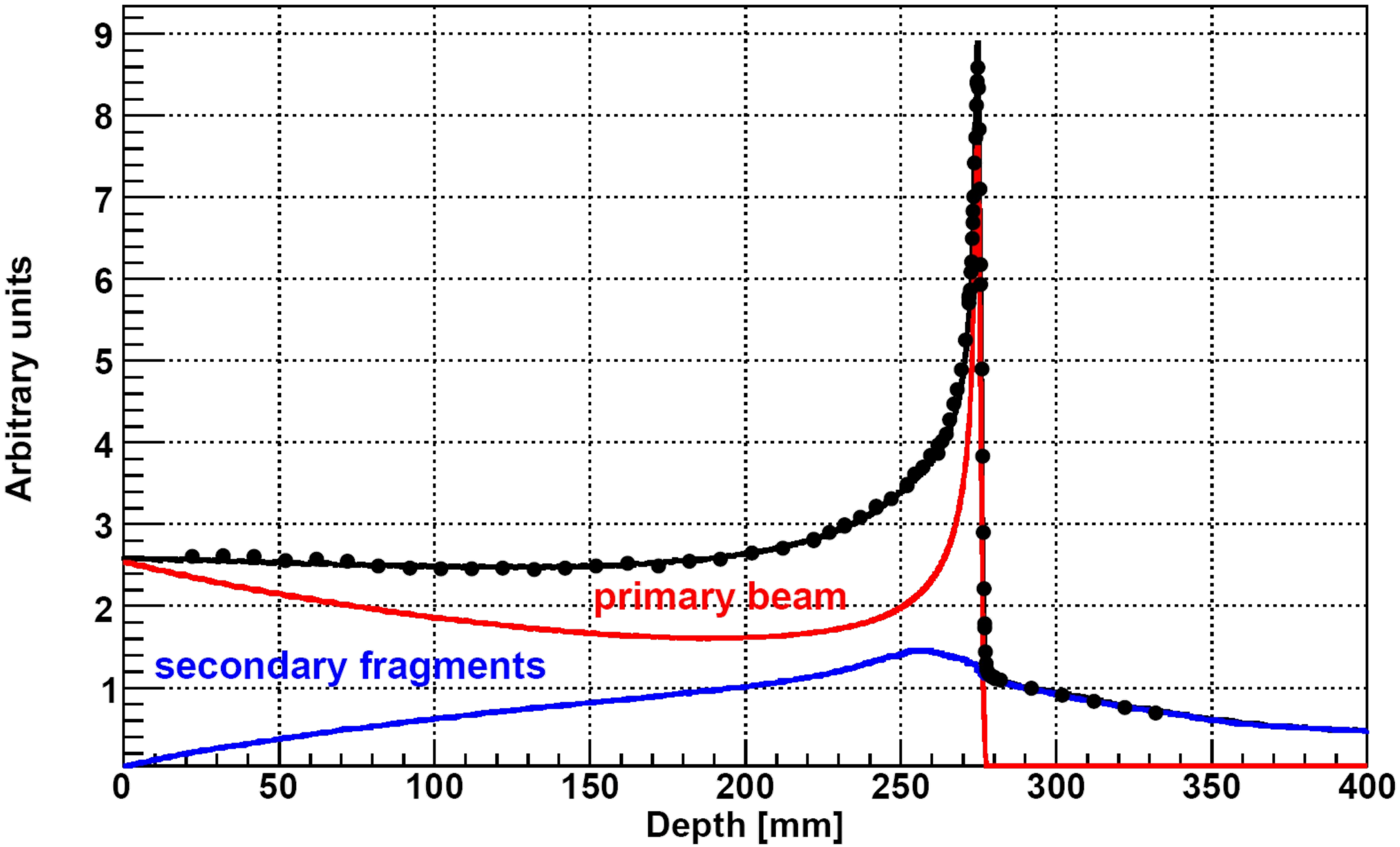
@ CHARM (CERN High energy AcceleRator Mixed field facility,

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



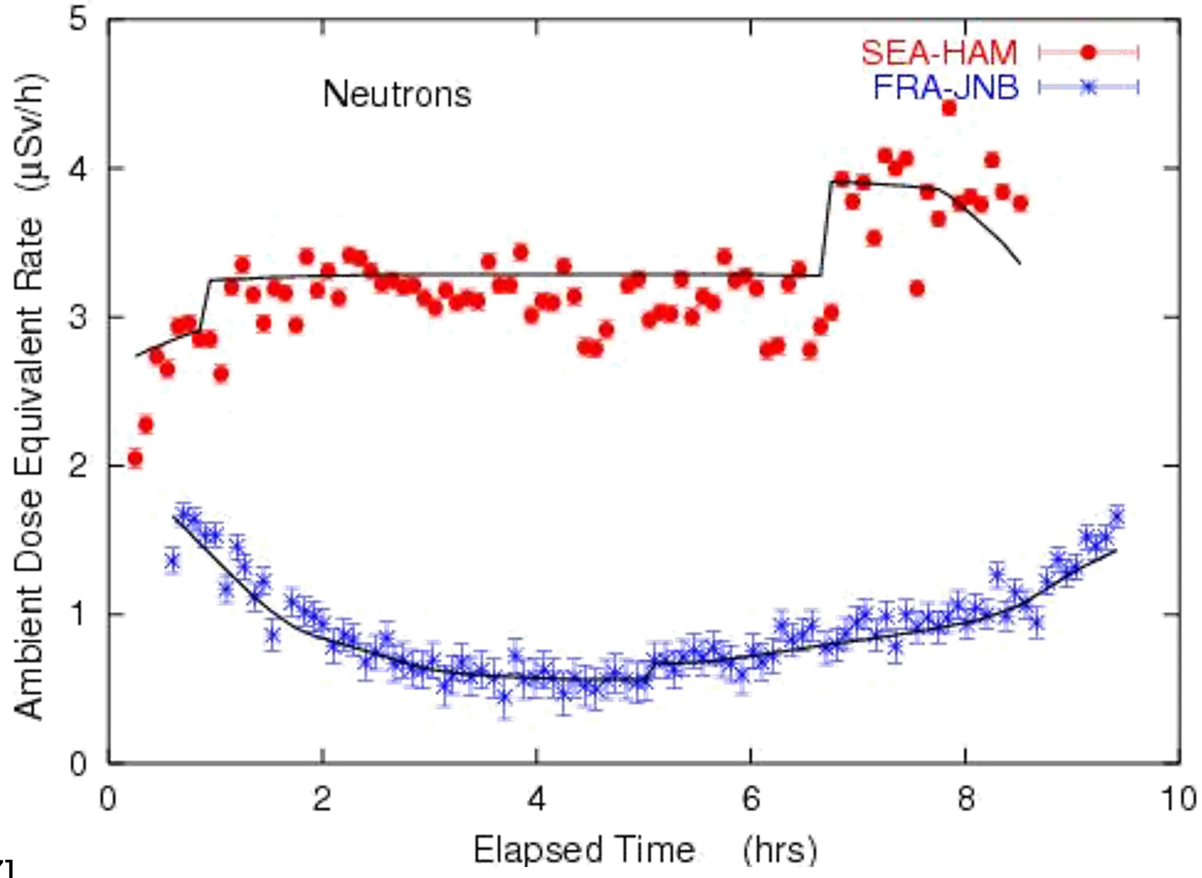
Bragg peak in a water phantom
400 MeV/A C beam:
The importance of fragmentation

[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]

Programme of this course

Schedule of the week

9:00 Registration	9:00 Geometry editor	9:00 Simple sources & Preprocessor	9:00 Neutrons	9:00 RP
9:30 Introduction to FLUKA	9:45 Exercise Geometry editor	10:00 Exercise Simple sources & Preprocessor	9:45 Exercise Neutrons	10:00 Exercise RP
10:15 Teachers & students introduction	10:45 Coffee break	11:00 Coffee break	10:45 Coffee break	11:00 Coffee break
10:45 Coffee break	11:10 Materials	11:25 EM fields	11:10 Biasing	11:25 Wrap-up exercise
11:10 MC Basics	11:40 Exercise Materials	12:10 Exercise EM fields	11:55 Exercise Biasing	12:55 Lunch
12:10 Basic input & Flair intro	12:40 Lunch	13:10 Lunch	12:55 Lunch	13:55 Evaluation
13:10 Lunch	13:40 Scoring I	14:10 Scoring II	13:55 Hadron Physics	14:25 Wrap-up exercise solution
14:10 Basic input & Flair intro hands-on	14:40 Exercise Scoring I	14:55 Exercise Scoring II	14:40 Geometry adv.	14:55 Advanced topics
15:25 Geometry	15:40 Coffee break	15:55 Coffee break	15:25 Coffee break	15:55 Coffee break
16:25 Coffee break	16:05 EM & thresholds	16:20 Source routine	15:50 Ex. Geometry adv.	16:15 **END**
16:50 Exercise Geometry	16:50 Exercise EM & thresholds	16:50 Exercise Source routine	16:50 Standard output & errors	
18:05 **END**	17:50 **END**	17:50 **END**	17:35 **END**	

SOCIAL DINNER

Schedule of the week

9:00 Registration	9:00 Geometry editor	9:00 Simple sources & Preprocessor	9:00 Neutrons	9:00 RP
9:30 Introduction to FLUKA	9:45 Exercise Geometry editor	10:00 Exercise Simple sources & Preprocessor	9:45 Exercise Neutrons	10:00 Exercise RP
10:15 Teachers & students introduction	10:45 Coffee break	11:00 Coffee break	10:45 Coffee break	11:00 Coffee break
10:45 Coffee break	11:10 Materials	11:25 EM fields	11:10 Biasing	11:25 Wrap-up exercise
11:10 MC Basics	11:40 Exercise Materials	12:10 Exercise EM fields	11:55 Exercise Biasing	12:55 Lunch
12:10 Basic input & Flair intro	12:40 Lunch	13:10 Lunch	12:55 Lunch	13:55 Evaluation
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16:25 Coffee break	16:05 EM & thresholds	16:20 Source routine	15:50 Ex. Geometry adv.	16:15 **END**
16:50 Exercise Geometry	16:50 Exercise EM & thresholds	16:50 Exercise Source routine	16:50 Standard output & errors	
18:05 **END**	17:50 **END**	17:50 **END**	17:35 **END**	

FLUKA