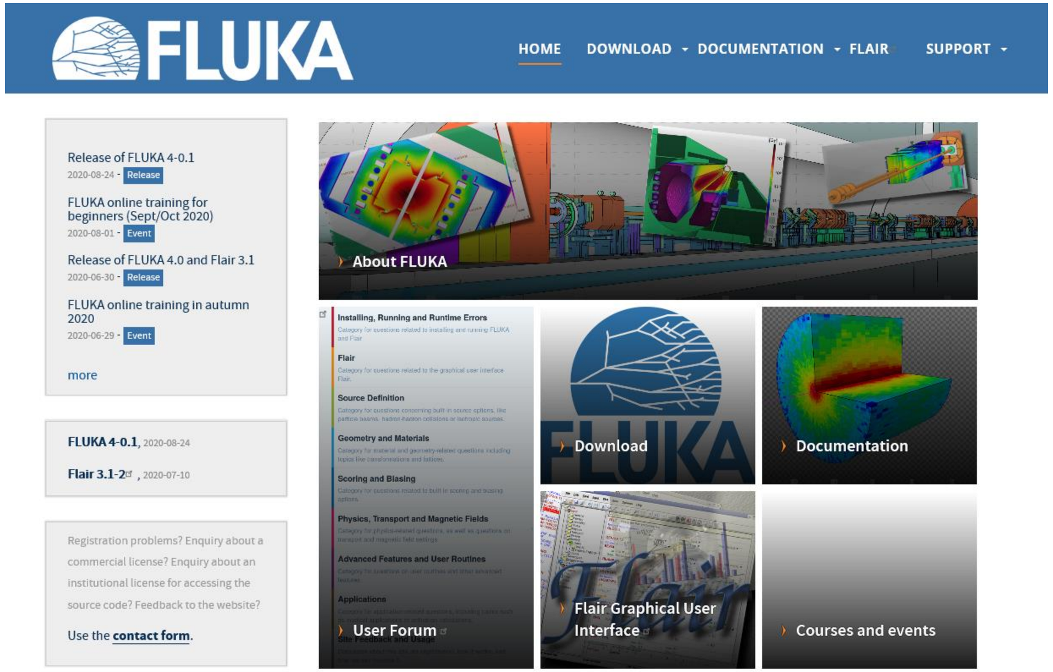
Introduction to FLUKA

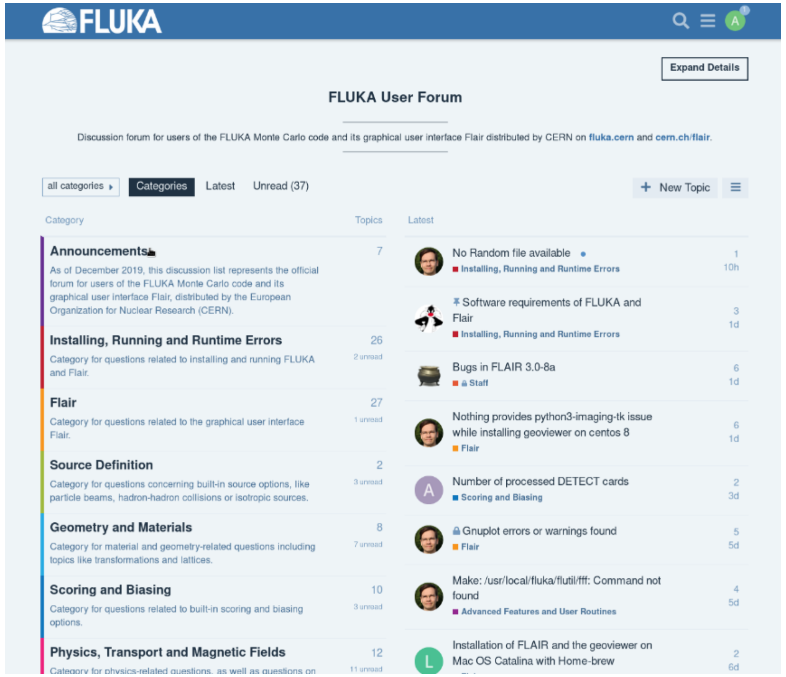
A particle interaction and transport Monte Carlo code

- Born in the 60's at **CERN** with Johannes Ranft
- 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.
- *Presently a joint development & management team including CERN Engineering Department and Radiation Protection Group and ELI-Beamlines (Prague) is in place*

https://fluka.cern



https://cern.ch/fluka-forum



(an independent one time registration is requested to post)

New licensing scheme

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

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

Microscopic process modeling for macroscopic quantity assessment

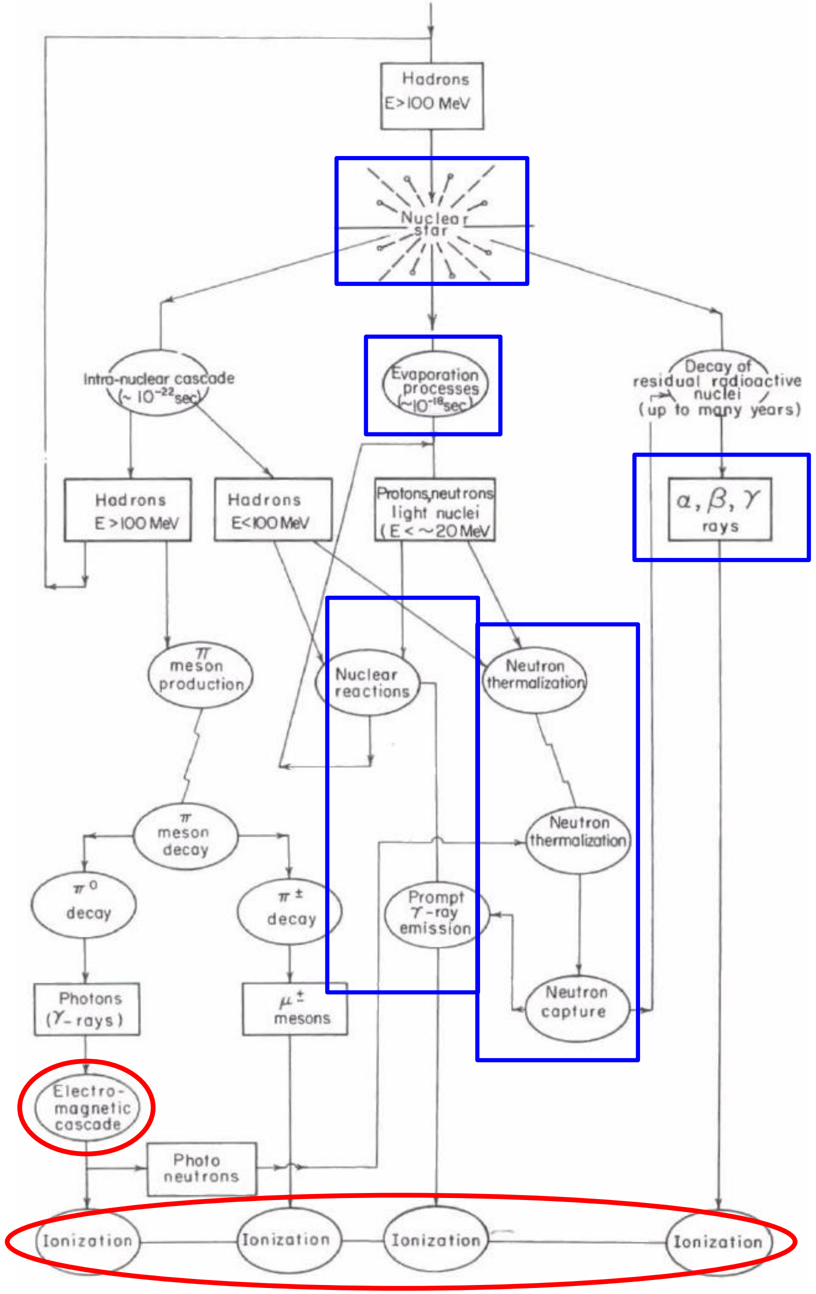
A (hadronic) shower implies a lot of different physics processes, touching a very broad energy [time-space] scale

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, ...



Radiation consequences

	relevant macroscopic quantity
Heating	energy deposition (integral power)
Thermal shock	energy deposition (power density)
Quenching	energy deposition (power density)
Deterioration	energy deposition (dose), particle fluence, DPA
Oxidation, radiolysis, ozone production	energy deposition
Gas production	residual nuclei production
Single event effects in electronic devices	high energy hadron fluence
	[+ neutron fluence, energy deposition (dose)]
Shielding requirements	particle fluence (*prompt* dose equivalent)
Access limitations, radioactive waste, air activation	*residual* dose rate and activity
Beam Loss Monitors (BLM)	energy deposition
Radiation Monitors (RadMon)	thermal neutron and high energy hadron fluence
Tumor cell destruction	energy deposition (dose, biological dose)

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
- particle decay
- low energy (<20 MeV) neutron library

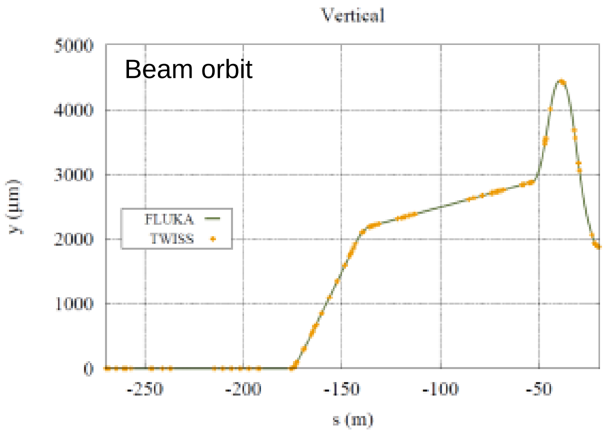
- ionization and multiple (single) scattering (including all ions down to 250 eV/u)
- combinatorial geometry and lattice capabilities
- voxel geometry and DICOM importing
- magnetic field, and electric field in vacuum
- analogue or biased treatment
- on-line buildup and evolution of induced radioactivity and dose

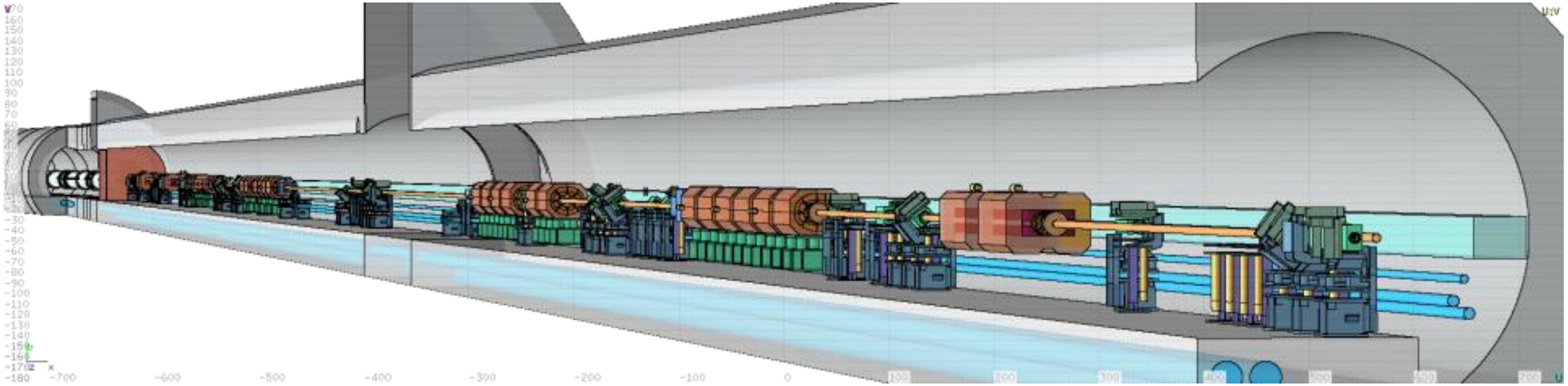
<u>built-in scoring</u> of several quantities (including DPA and dose equivalent)

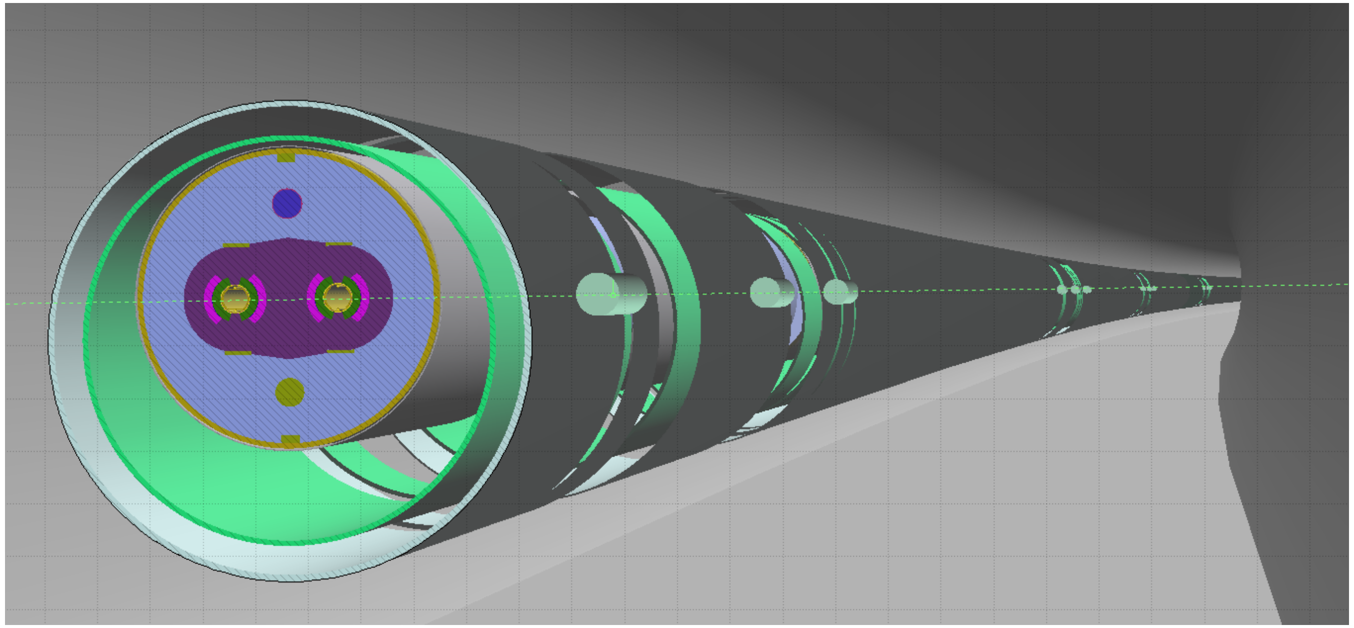
✓ Accelerator design
✓ Shielding design
✓ Radiation protection
✓ Dosimetry
✓ Radiation damage
✓ Radiation to electronics effects
✓ Particle physics (calorimetry, tracking and detector simulation, …)
✓ Cosmic ray physics
✓ Neutrino physics
✓ ADS systems, waste transmutation
✓ Medical applications, hadrontherapy
✓ Neutronics

Some examples

Accelerator geometries







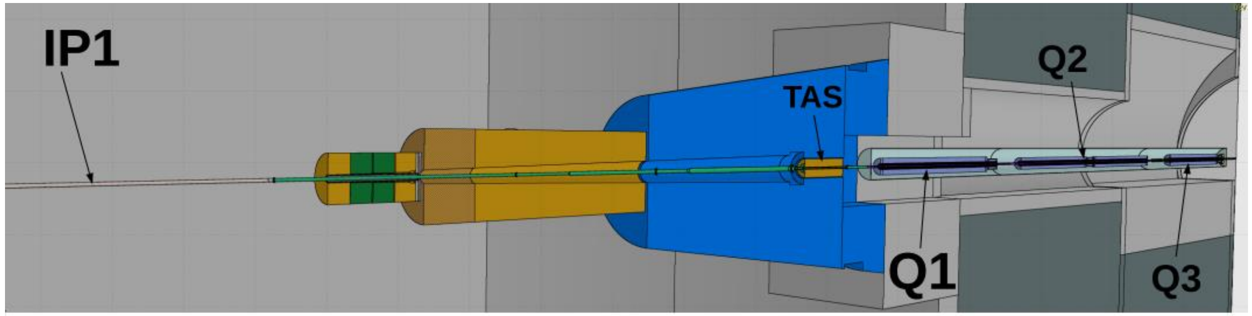
From DETAILED MODELS OF ACCELERATOR COMPONENTS WITH ASSOCIATED SCORING and the ELEMENT SEQUENCE AND RESPECTIVE MAGNETIC STRENGTHS, as given IN THE MACHINE OPTICS (TWISS) FILES,
the **AUTOMATIC CONSTRUCTION OF COMPLEX BEAM LINES**, including collimator settings and element displacement (BLMs), is achievable,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

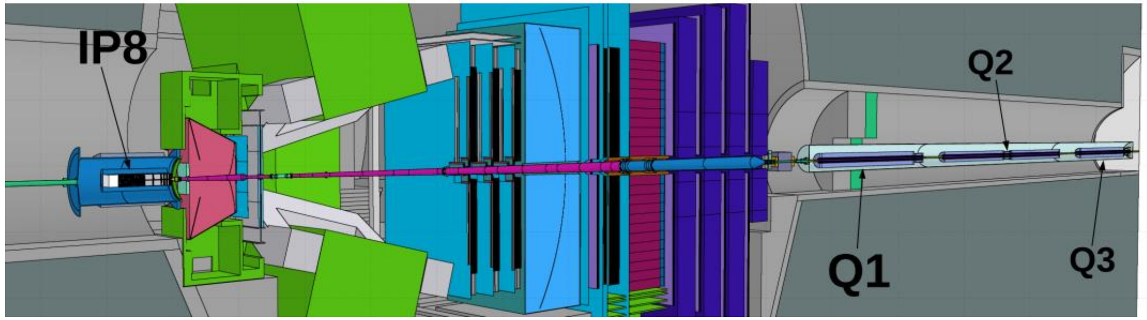
LINE BUILDER

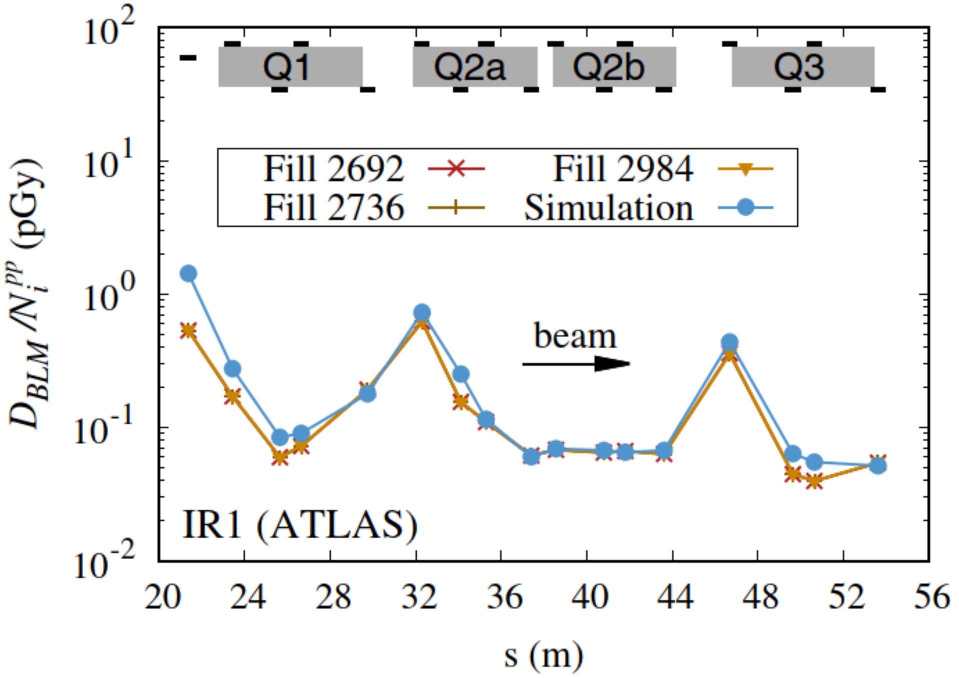
[A. Mereghetti et al., IPAC2012, WEPPD071, 2687]

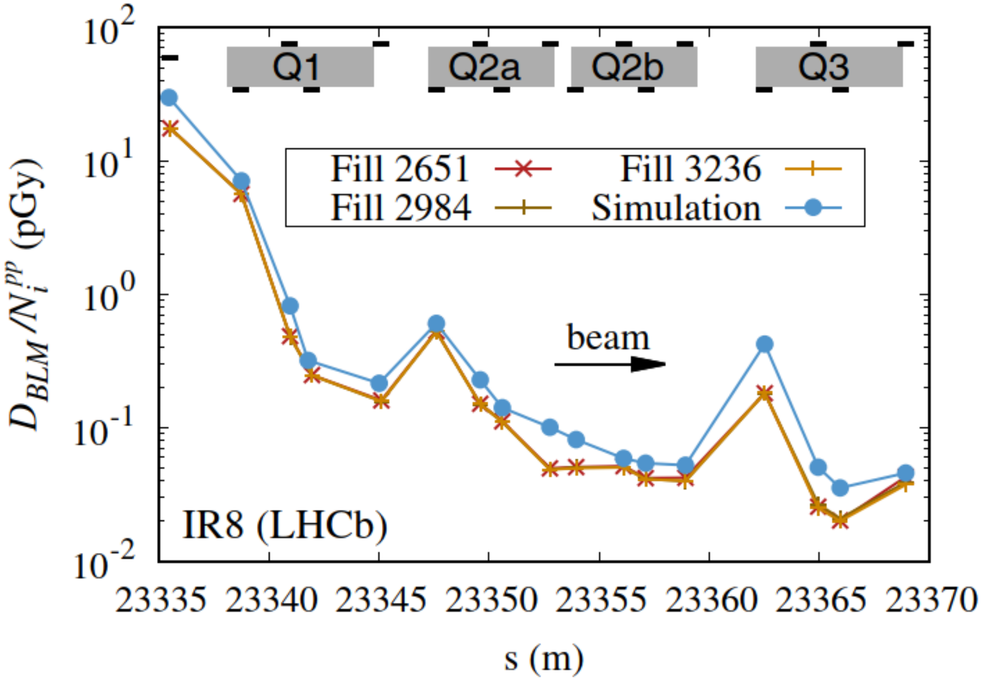
Beam loss description at the LHC

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









Activation benchmarking

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

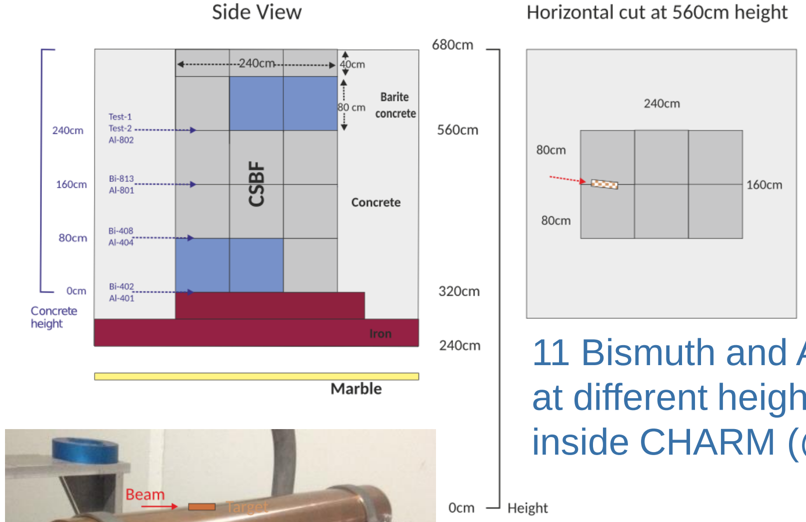
[E. Iliopoulou and R. Froeschl]

Situated laterally above the CHARM target

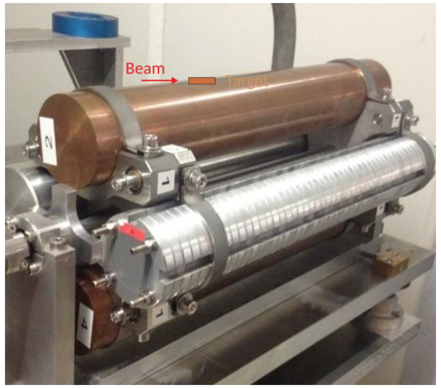
for deep shielding penetration studies (Detector calibration, Detector inter-comparison, Activation)

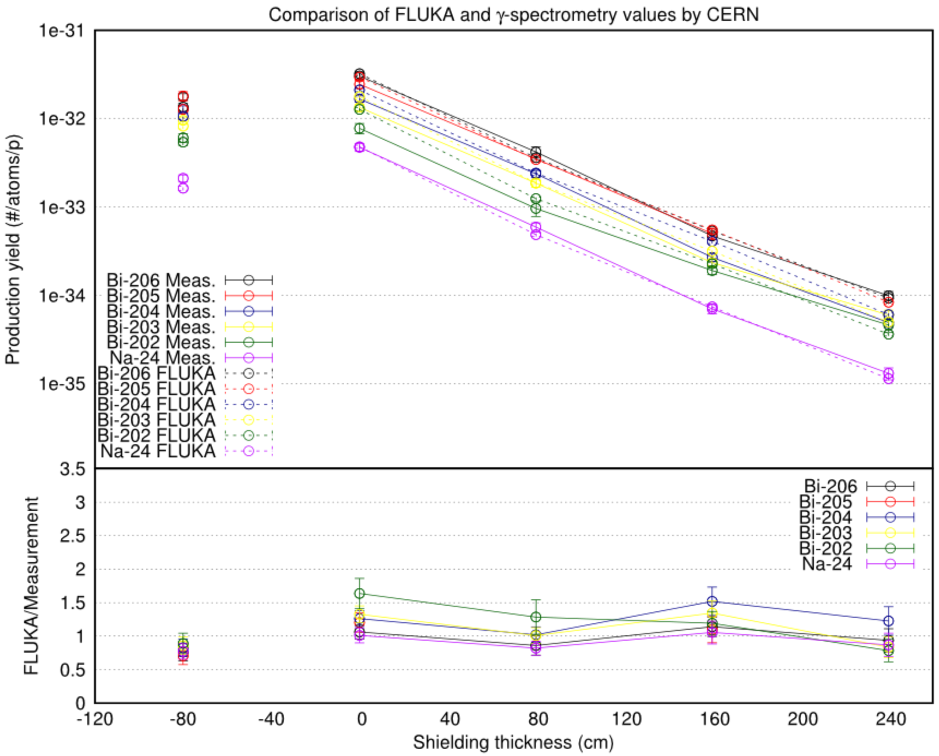
360cm of concrete and barite concrete

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,

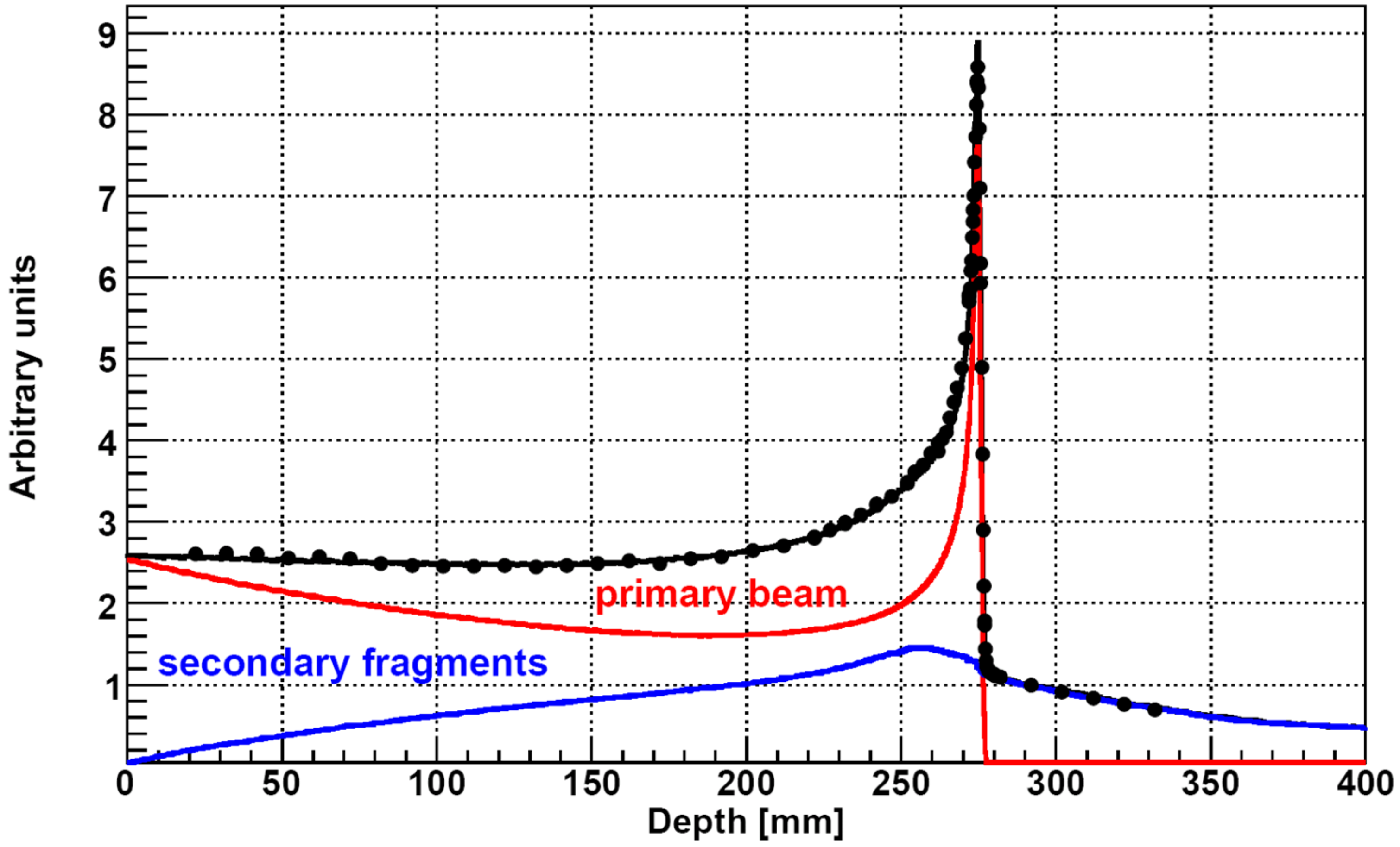
to study radiation effects on electronic components)

5×10^{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

R2E

Medical physics: radiotherapy



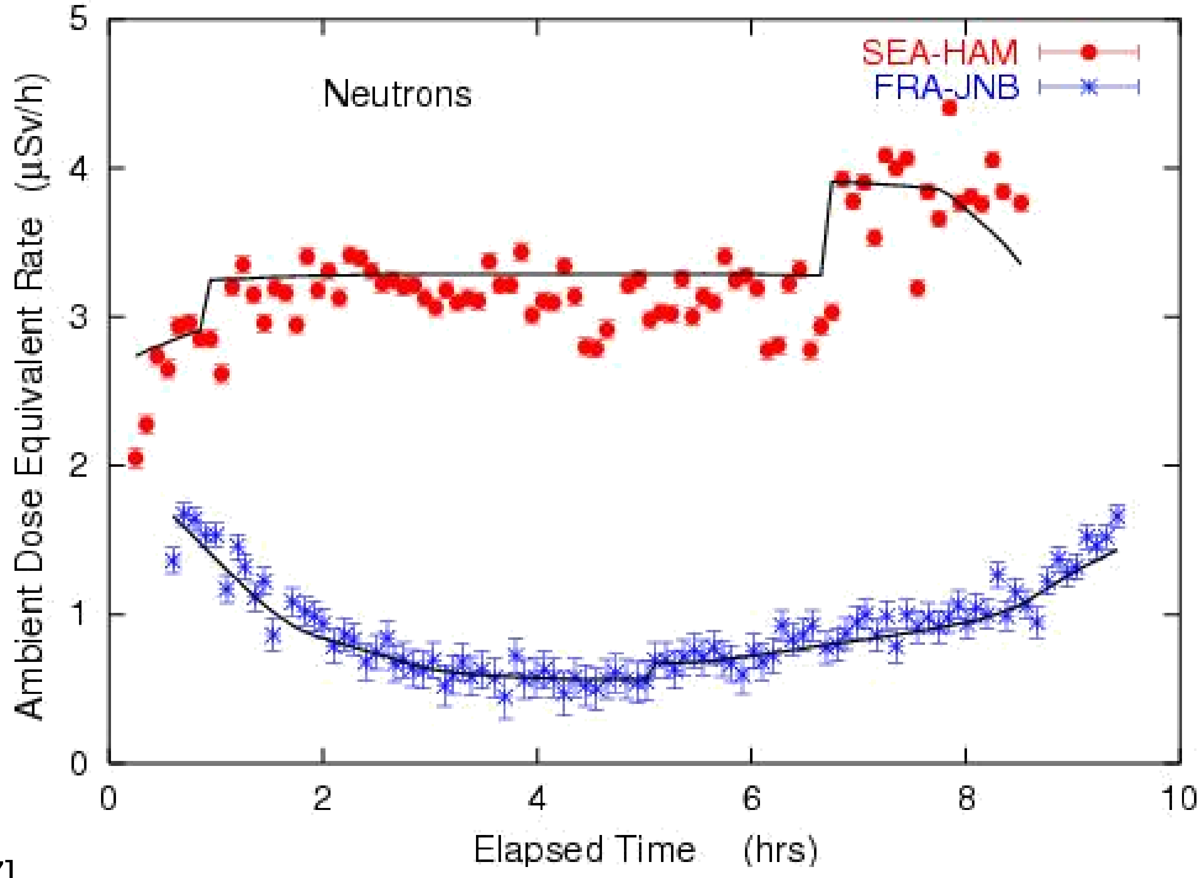
Bragg peak in a water phantom
400 MeV/A C beam:
The importance of fragmentation

[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

3 – 7 PM CEST every day:
featuring lectures, demos, on-line exercises, and multiple-choice questionnaires

Day 1	Welcome; Introduction to FLUKA	Monte Carlo basics	BREAK	Basic input & Flair introduction	Hands-on
Day 2	Geometry - Basic	Exercise	BREAK	Materials	Exercise
Day 3	Geometry editor	Exercise	BREAK	Simple sources/ Preprocessor	Exercise
Day 4	Scoring: intro & USRBIN	Exercise	BREAK	EM & thresholds + AUXSCORE	Exercise
Day 5	Scoring: USRTRACK, USRBDX, USRYIELD & R2E	Exercise	BREAK	Flair - Advanced	Hands-on
Day 6	Geometry - Advanced	Exercise	BREAK	Magnetic & electric fields	Exercise
Day 7	Biasing	Exercise	BREAK	Activation	Exercise
Day 8	Source routine	Hands-on	BREAK	Standard output	Common errors/mistakes
Day 9	Advanced sources	Medical applications	BREAK	Hands-on	Physics
Day 10	Secondary beam exercise		BREAK	Advanced topics	Course evaluation; Conclusion

FLUKA