FLUKA simulation for a 10 TeV Muon Collider

Daniele Calzolari
CSC24 / 13 Sept 2024

Funded by the European Union

Funded by the European Union (EU). Views and opinions expressed are however those of the author only and do not necessarily reflect those of the EU or European Research Executive Agency (REA). Neither the EU nor the REA can be held responsible for them.

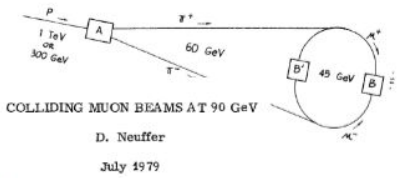
Why a muon collider?

Using muons as colliding particles: simple idea, complex execution:

1. Muon as elementary particle: all the energy is in the collision
2. mμ ≫ me: no limitation from synchrotron radiation
3. Muon lifetime: 2.2 μs

Not a new idea

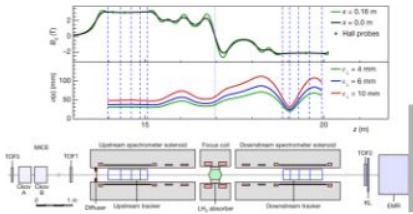
~70s
first proposals



2011 - 2014
MAP

Muon Accelerator Program

2017
MICE demonstrates cooling



2021
European roadmap for accelerators

Here I start working at CERN

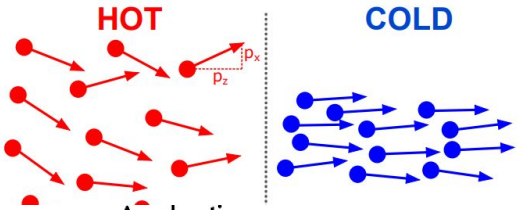
IMCC collaboration enstablished

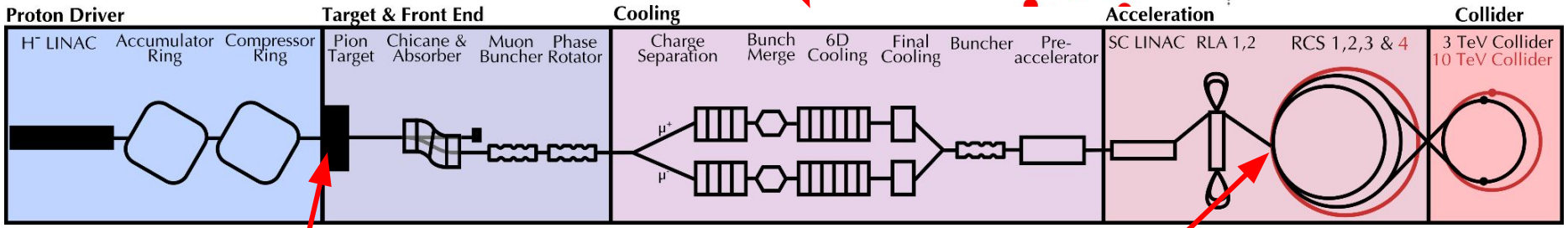
P5 asks for a “muon shot”

Muon collider on the Science cover (with FLUKA data!)

How a muon collider?

Cooling reduces the emittance

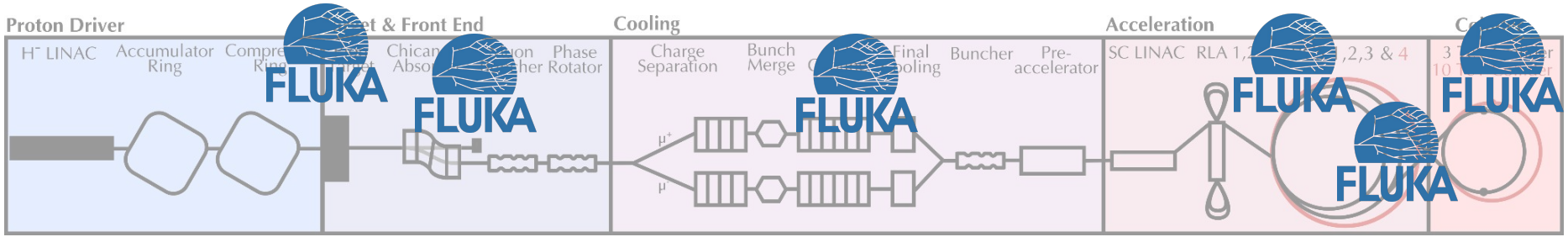




Proton on graphite target: $\pi^{\pm} \rightarrow \mu^{\pm}$

Very fast acceleration

How a muon collider?



Presented today: arbitrary selection of results (non exhaustive)

1. Muon production target simulations
2. Collider ring: radiation load to the arcs
3. Machine-detector interface: background from the muon decay

But what is FLUKA?

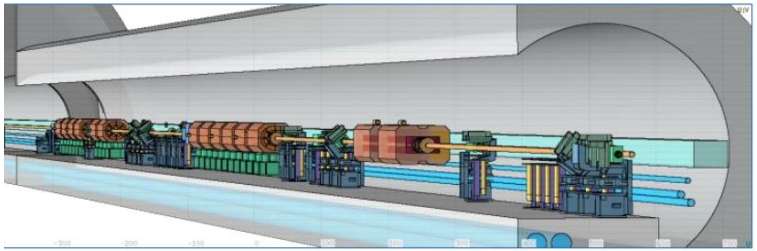
- **FLUKA** was born in the 60's at CERN with Johannes Ranft
- In the 70's to 80's **Leipzig University**, **CERN** and **Helsinki University of Technology**
- Until 2019 under the **CERN & INFN** collaboration
- Until today, where other international partners joined the effort (**CERN RP group** and **Prague ELI beamlines**)

The FLUKA code is a general purpose Monte Carlo code for the interaction and transport of hadrons, leptons, and photons from keV (with the exception of neutrons, tracked down to thermal energies) to cosmic ray energies in any material.

Not a toolkit!

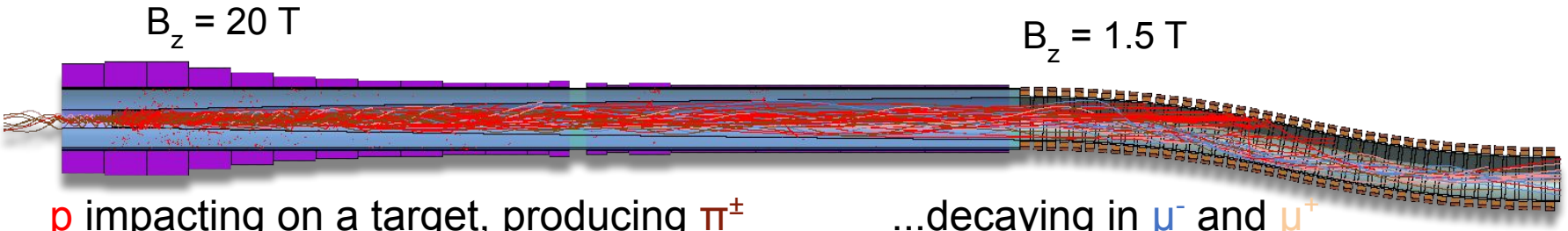
Particularly suited for accelerators

LHC IR7 long straight section



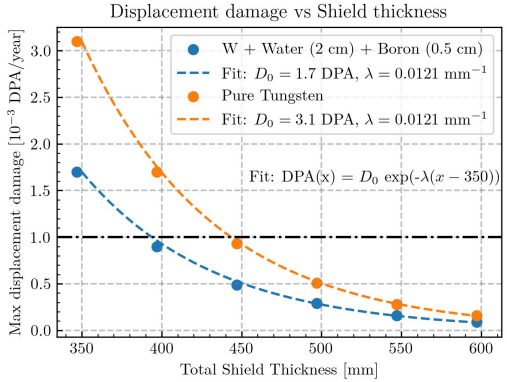
For more details https://indico.cern.ch/event/1352709/contributions/5821996/

Muon collider production target

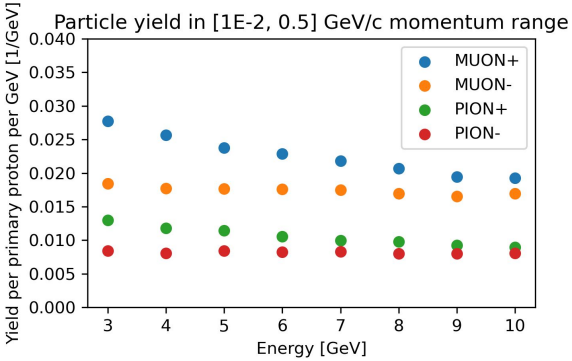


p impacting on a target, producing $\pi^{\pm}$ ...decaying in μ^- and μ^+

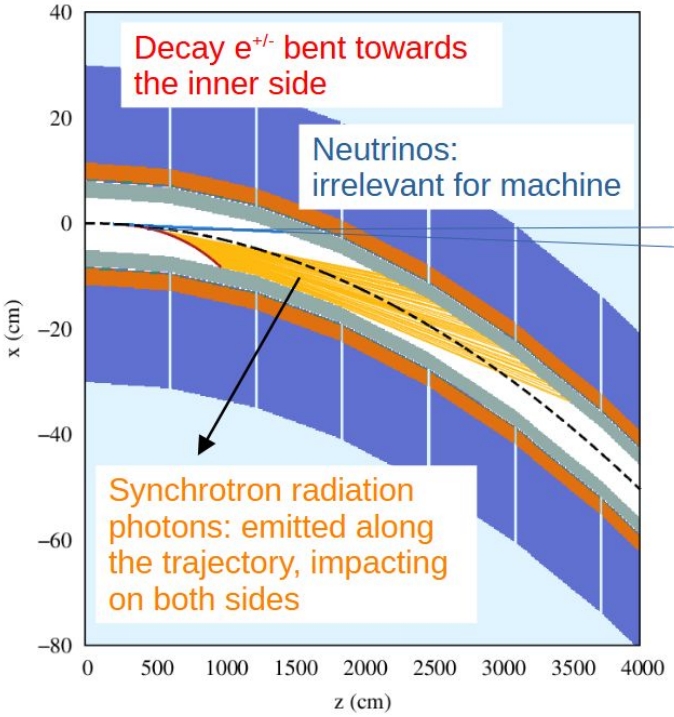
Shielding design to mitigate radiation load

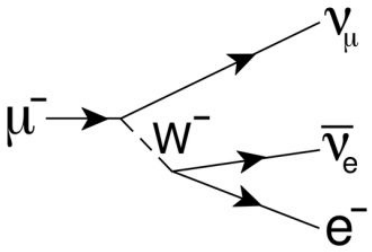


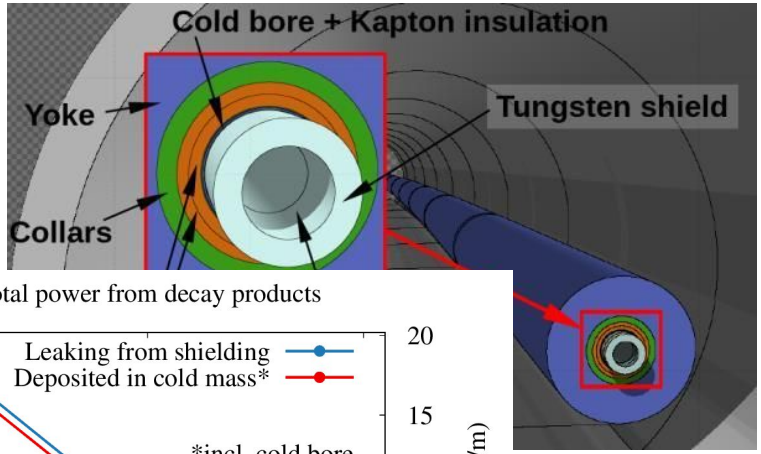
Optimization of the muon yield

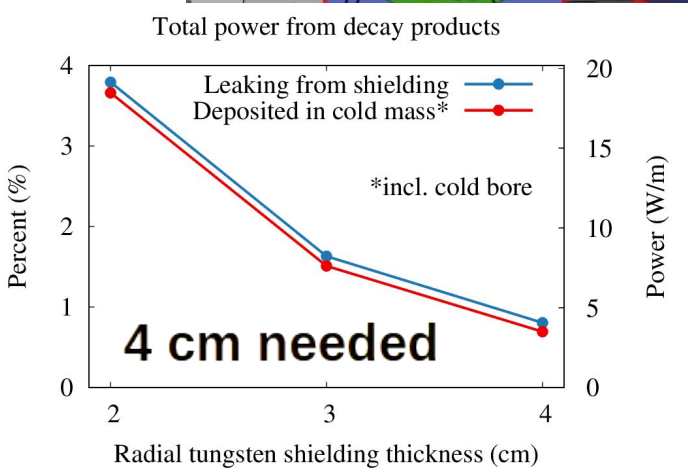


Muon decay: radiation load to arcs

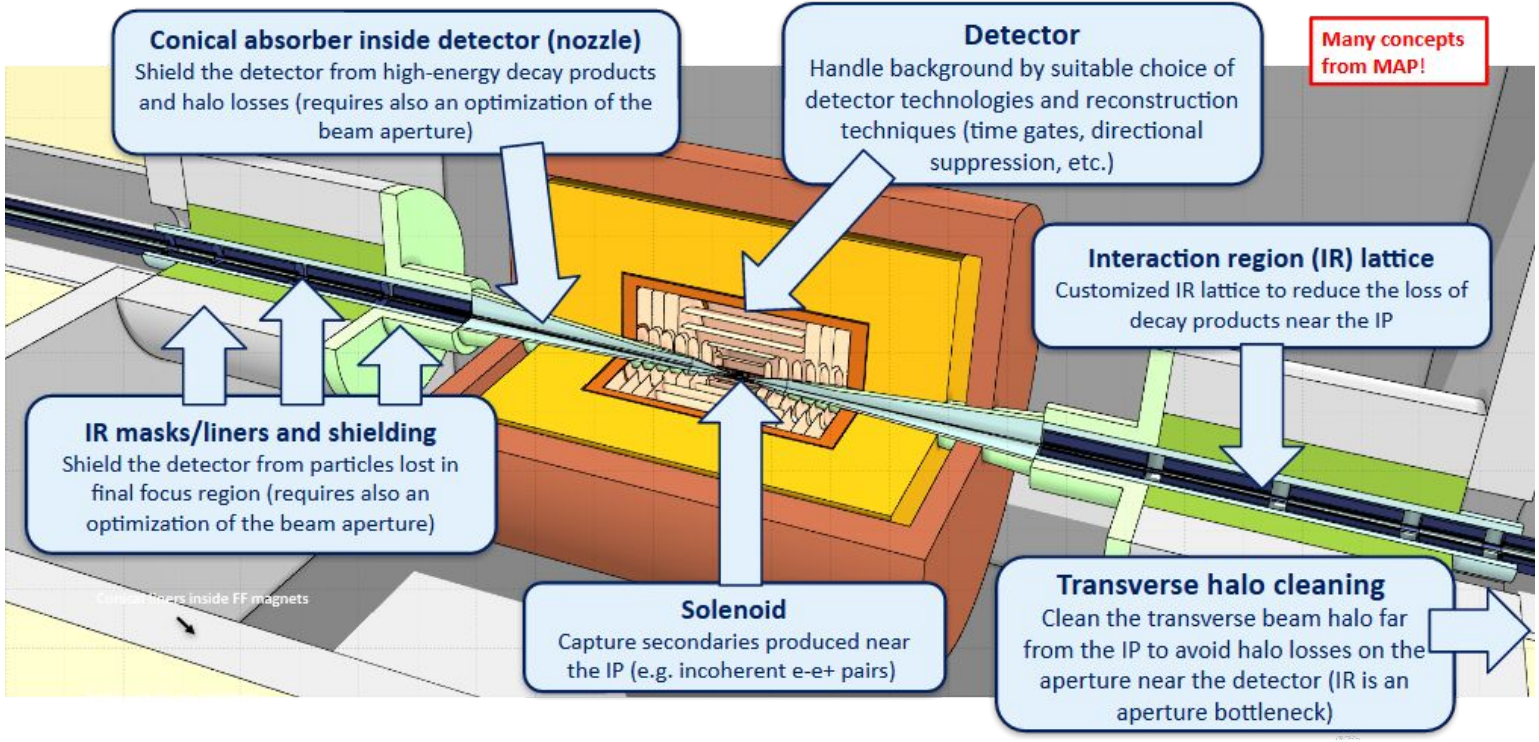




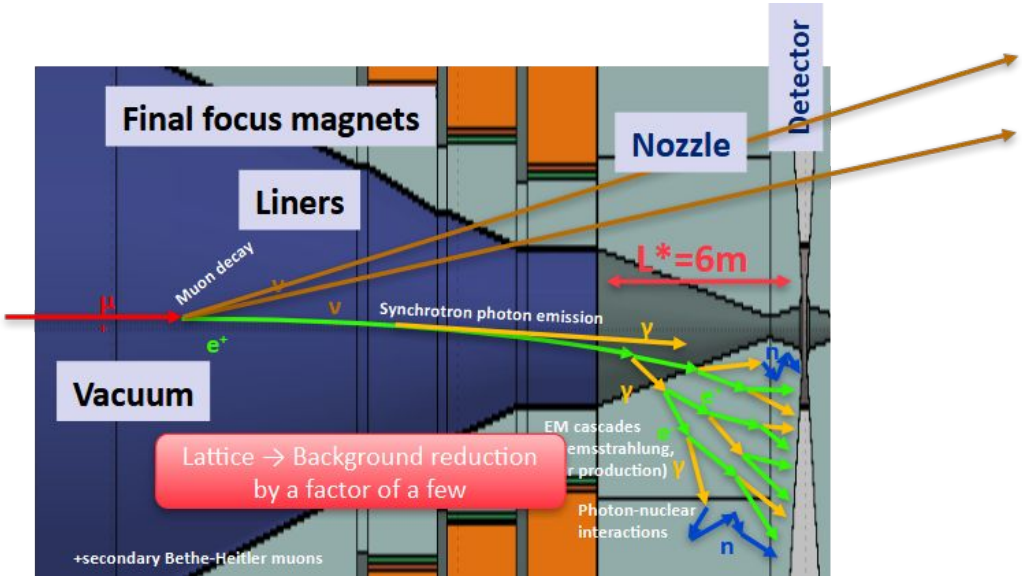




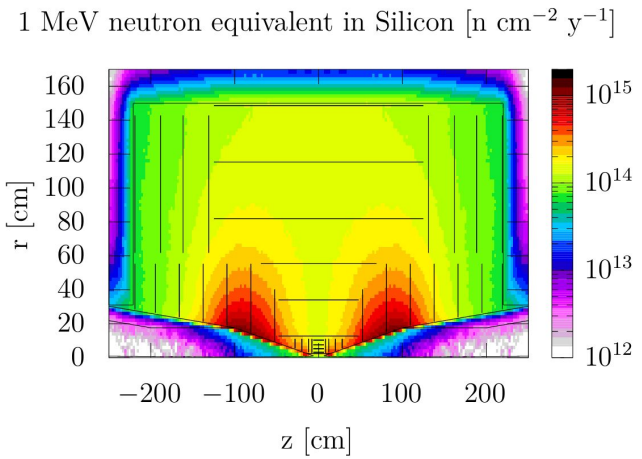
Muon decay: machine detector interface



Muon decay: beam induced background



Muon decay generate secondaries which are the most important source of background!



Cute muonic cats:
@qftoons, aka Gaia Fontana

Thank you

International MUON Collider Collaboration

MuCol

Funded by the European Union

Funded by the European Union (EU). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the EU or European Research Executive Agency (REA). Neither the EU nor the REA can be held responsible for them.

Muon decay: beam induced background

Background particles (from decay) entering detector per bunch crossing (with time cut [-1:15] ns):

- O(10^8) γ (>100 keV),
- O(10^7) n (>10^{-5} eV)
- O(10^6) e+ & e- (>100 keV)