MDI - Simulation Studies

F. Collamati - INFN Rome
03-06-2020

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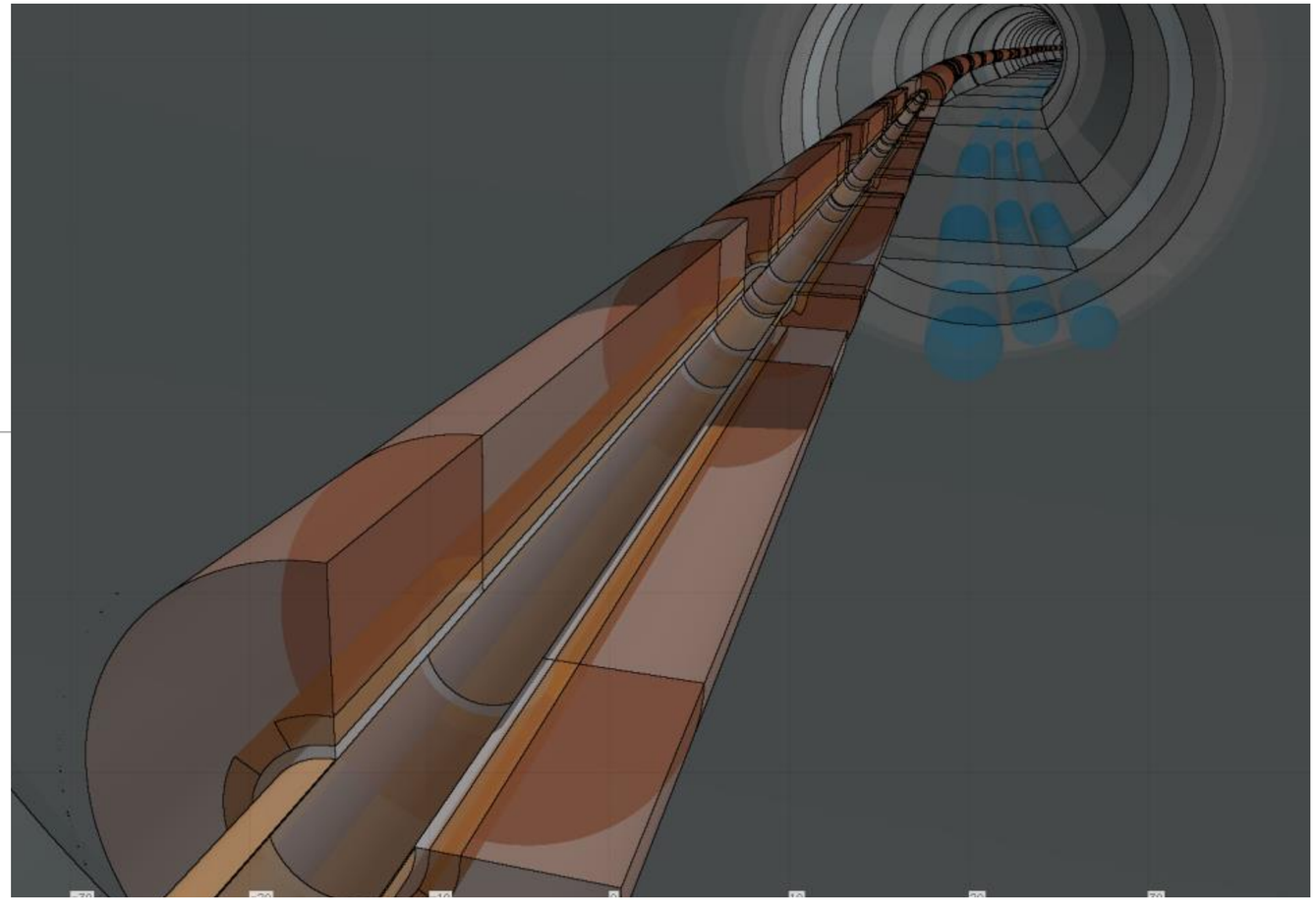


Where are
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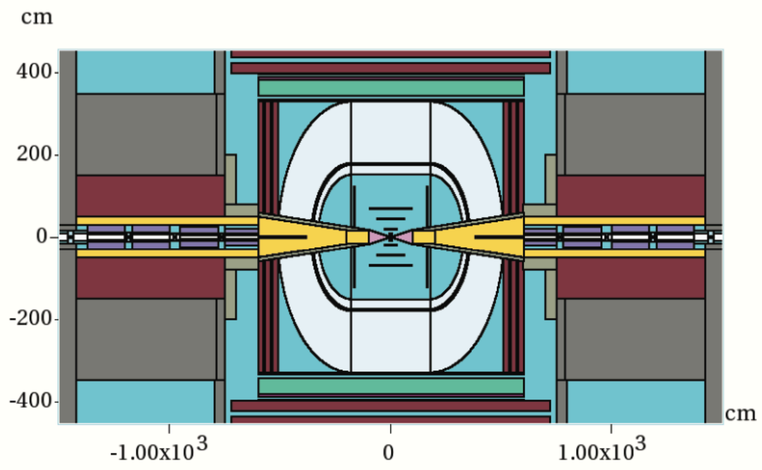
- In the last months, a first study of Beam Induced Background (**BIB**) has been performed exploiting late **MAP** studies:
  - MARS simulation of ±200m f rom IP
  - Tungsten nozzles to mitigate bkg in the IR
  - E_{cm} = 1.5 TeV

  [arXiv:1905.03725]



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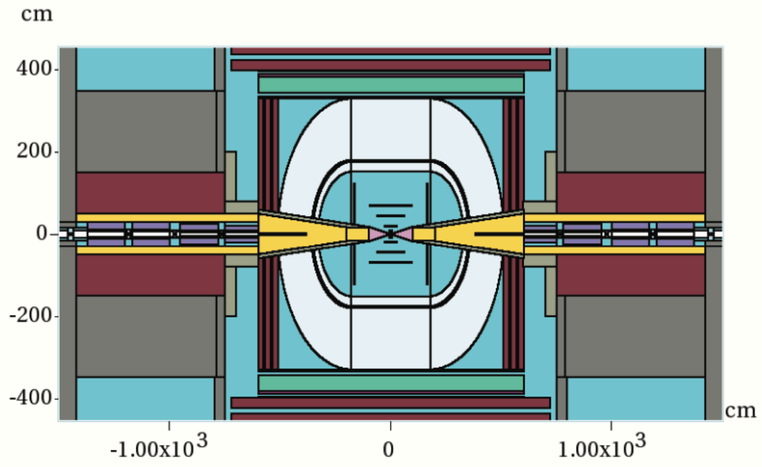

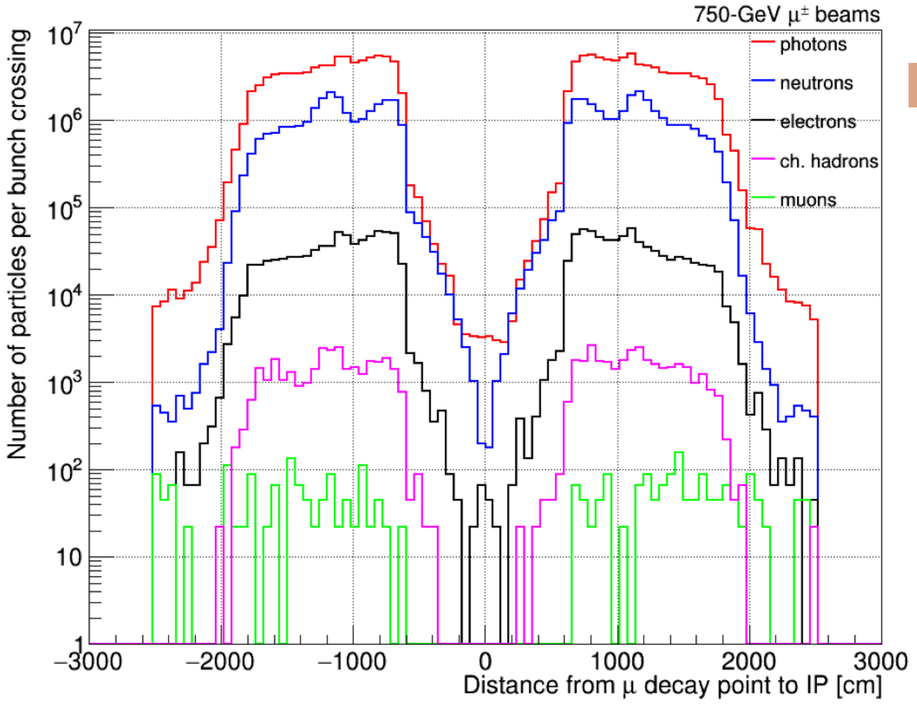

Beam Induced Background comes from 10s-100s meters from the IP

*depending on E_{cm}

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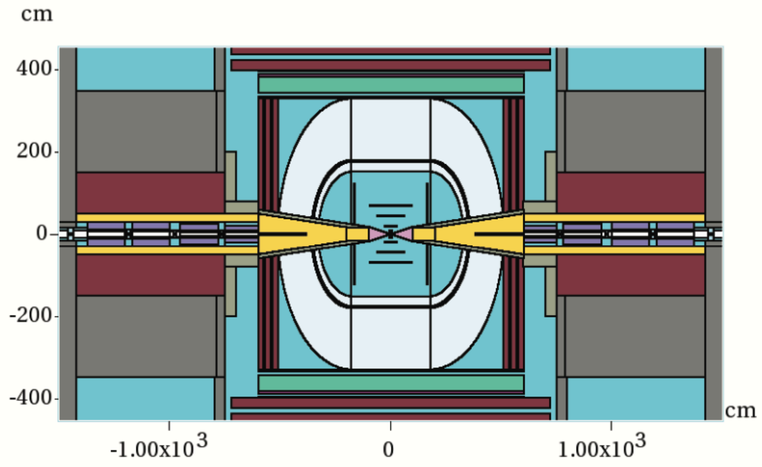

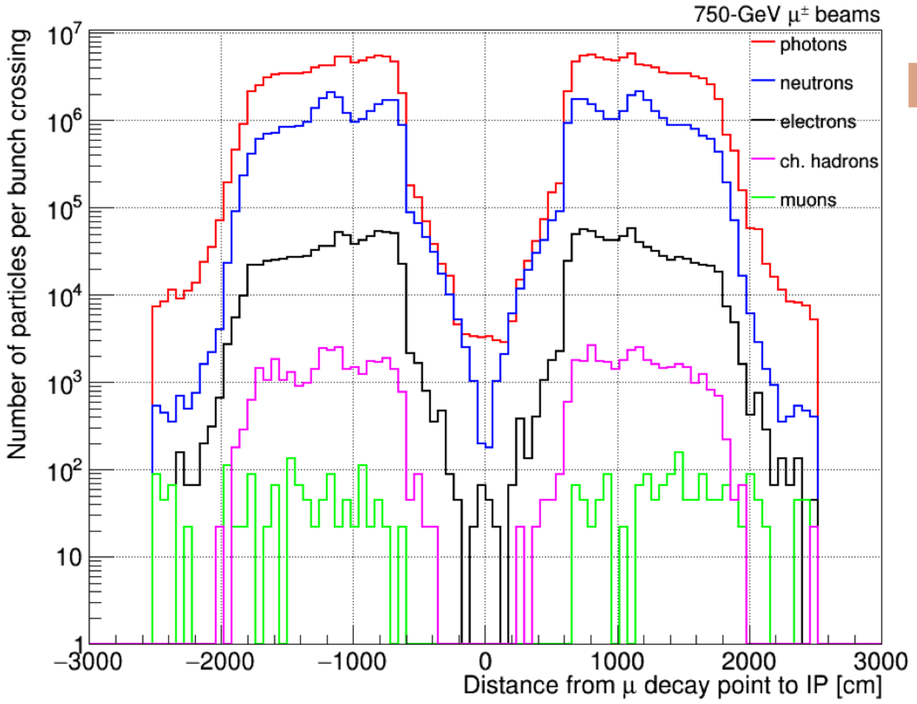

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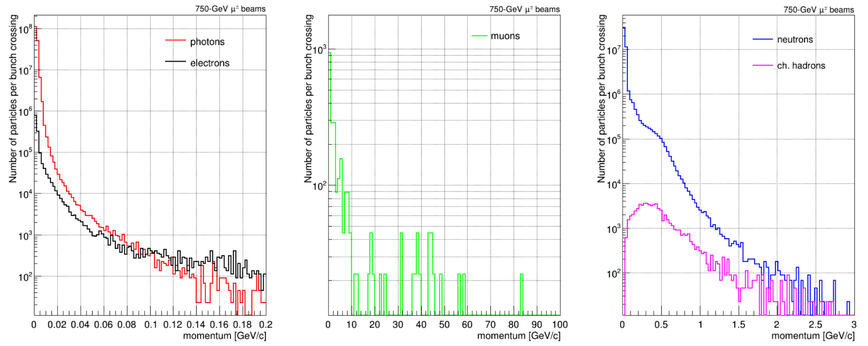

$P_{e/g}$~MeV, $P_{n\,/ch.h}$~500 MeV, P_{mu}~10GeV


WHERE DO WE
WANT TO GO?

- Proceeding in the RD for a possible muon collider, we would like to be able to **test all possible** machine **designs** to compare their BIB
  - ✓ Change beam energy
  - ✓ Change machine optics
  - ✓ MDI optimisation (nozzle..)

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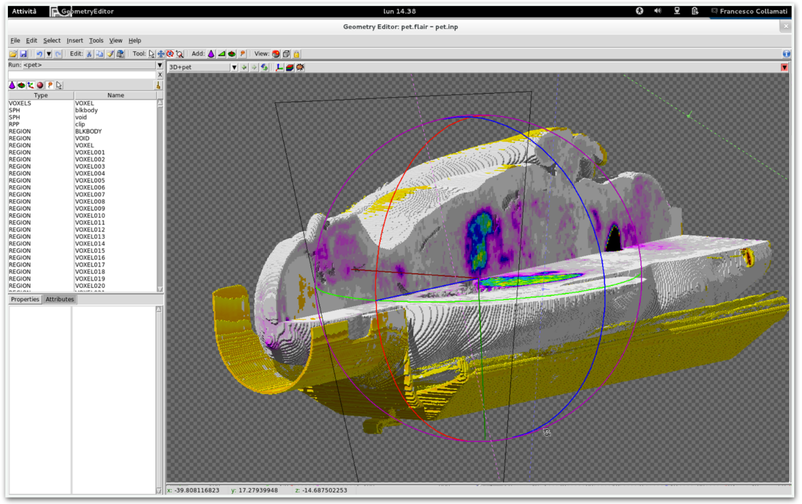
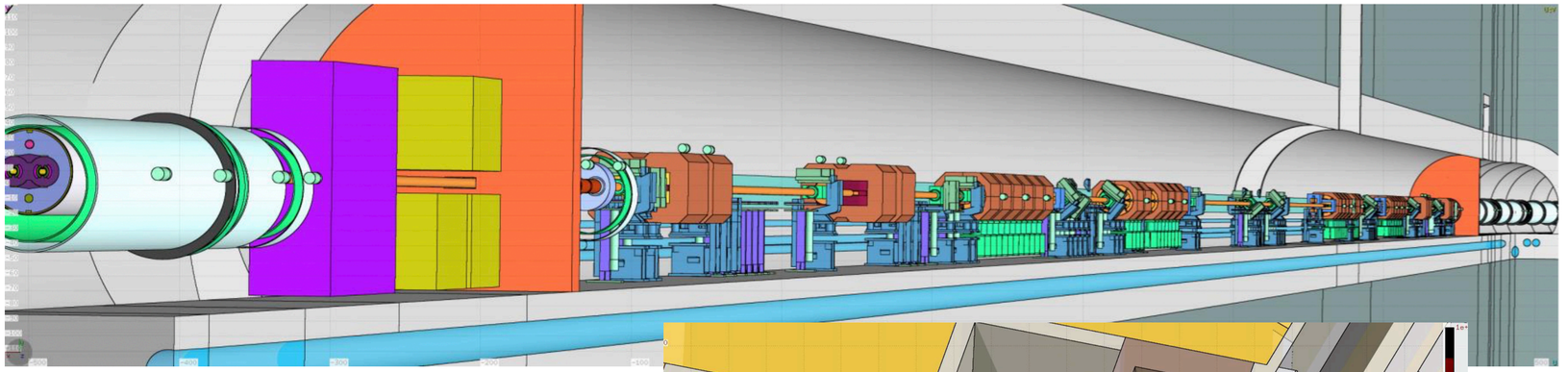
→ We need to become independent!

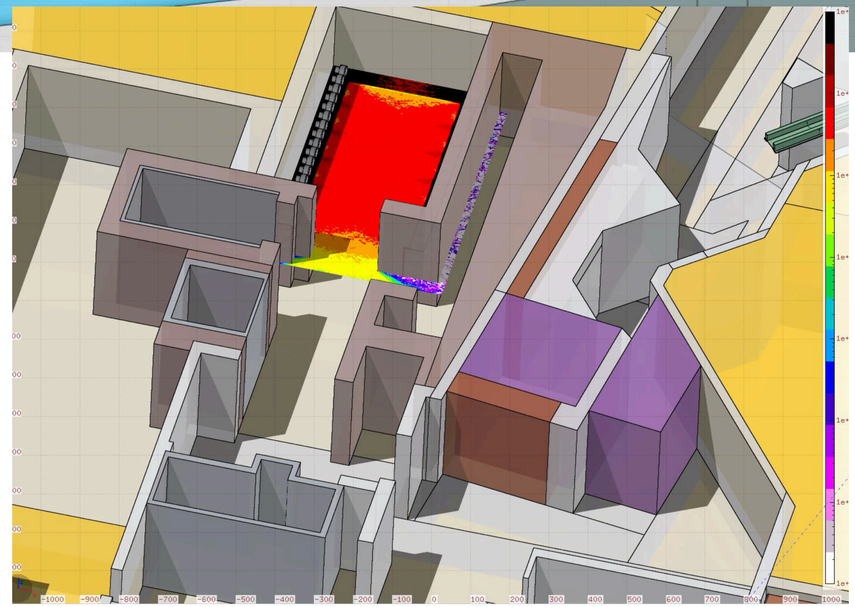
i.e. able to generate ourselves the background distribution in a handy, flexible way

The Tool identification

- **FLUKA** is one of the most common general purpose Monte Carlo software, and is the established standard for example for radio protection studies
  - Natively supports very complicated and detailed geometries







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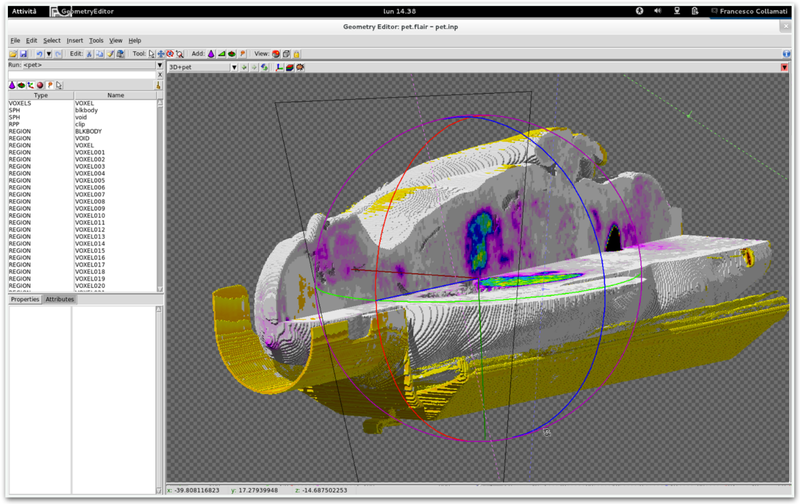
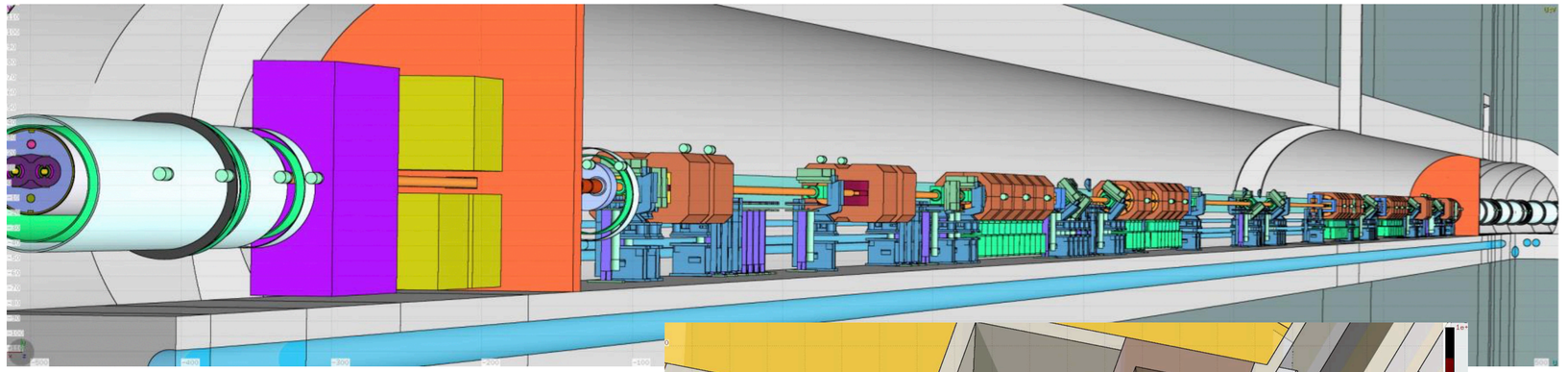
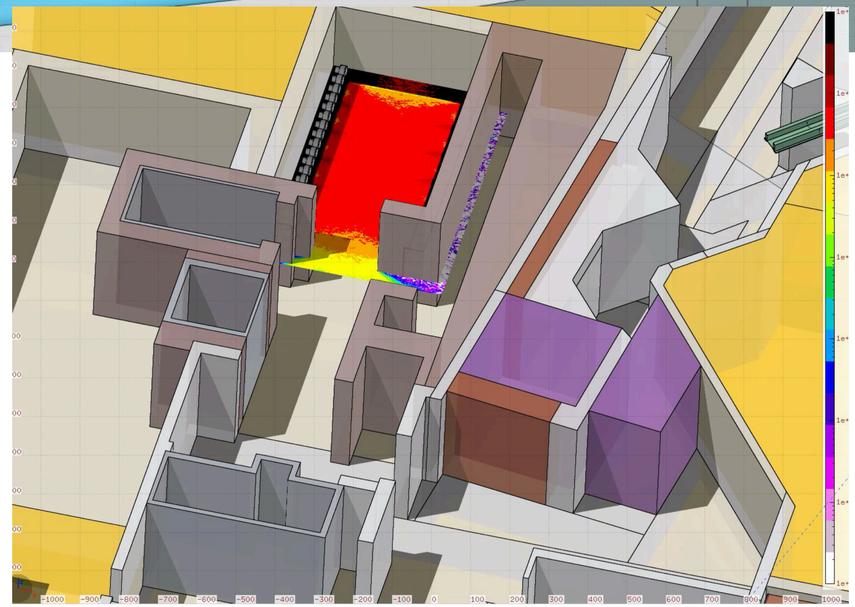






- BUT the **manual construction** of such complicated geometries is
  - **Difficult**
  - **Not** scalable-**flexible**
  - Error prone

The Tool identification

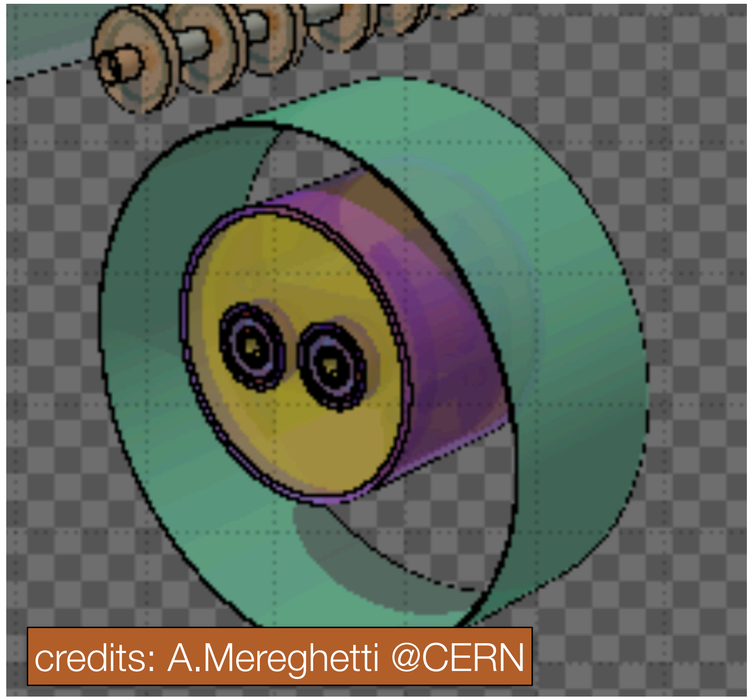
✦**FLUKA LINE BUILDER** is a program aimed at automatically build accelerator geometries, consists of 2 parts:

Fluka Element DataBase

```
 > tree fedb/
fedb/
├── [4.0K]  assemblies
├── [4.0K]  bodies
│   ├── [ 787]  myacc_MBS.bodies
│   ├── [ 254]  myacc_MBSORI.bodies
│   └── [ 103]  myacc_MQBODY.bodies
├── [4.0K]  materials
│   ├── [2.3K]  materials.inp
│   ├── [ 251]  myacc_MBS.assignmat
│   ├── [ 135]  myacc_MBSORI.assignmat
│   └── [  96]  myacc_MQBODY.assignmat
├── [4.0K]  regions
│   ├── [ 404]  myacc_MBSORI.regions
│   ├── [1.8K]  myacc_MBS.regions
│   └── [  90]  myacc_MQBODY.regions
├── [4.0K]  stepsizes
├── [2.1K]  structure.py
├── [1.3K]  structure.pyc
├── [4.0K]  test
│   ├── [  18]  expand.sh -> ../tools/expand.sh
│   ├── [2.1K]  flair-autosave.pickle
│   ├── [4.1K]  myacc_MB.inp
│   ├── [1.5K]  myacc_MBorig.inp
│   ├── [1000]  myacc_MQ.inp
│   ├── [ 193]  pippo.inp
│   ├── [  21]  template.inp -> ../tools/template.inp
│   ├── [3.8K]  TestElement_exp.inp
│   ├── [ 865]  TestElement.inp
│   └── [  23]  TestElement.sh -> ../tools/TestElement.sh
└── [4.0K]  tools
    ├── [6.9K]  cut.py
    ├── [ 679]  display_elem.inp.template
    ├── [3.0K]  display_elem.sh
    ├── [1.1K]  expand.sh
    ├── [2.0K]  find_paths.py
    ├── [1.2K]  find_paths.pyc
    ├── [6.0K]  roto_traslate.py
    ├── [6.3K]  scan-fedb.py
    ├── [1.1K]  split.py
    ├── [ 796]  template.inp
    ├── [ 13K]  test_assembly.py
    └── [2.1K]  TestElement.sh

7 directories, 34 files
```

Collection of models of single accelerator devices in Ascii files



credits: A.Mereghetti @CERN

Line Builder

myacc_MBSORI.regions - emacs@pcbe16165

File Edit Options Buffers Tools Help

Save Undo

```
*
*    . yoke
RPP dipyoke     -200.0 20. -10.0 10.0 -200.0 30.0
YCC MBSORIKo    -200.0 -200.0 210.0
YCC MBSORIKi    -200.0 -200.0 190.0
*    . pipe
XZP MBSObpu     1.5
XZP MBSObpd     -1.5
YCC MBSObpo     -200.0 -200.0 203.0
YCC MBSObpi     -200.0 -200.0 197.0
*
-:---  myacc_MBSORI.bodies   All (8,0)      (FLUKA Ovwrt)
*
*    . yoke
MBSOYOKE      5 | +dipyoke +MBSORIKo -MBSORIKi -MBSObpu
                | +dipyoke +MBSObpu  -MBSObpd  +MBSORIKo -MBSObpo
                | +dipyoke +MBSObpu  -MBSObpd  +MBSObpi  -MBSORIKi
                | +dipyoke +MBSORIKo -MBSORIKi +MBSObpd
*    . pipe
MBSOBPVC      5 +dipyoke +MBSObpu -MBSObpd +MBSObpo -MBSObpi
*    . out
MBSOOUT_      5 | +dipyoke -MBSORIKo
                | +dipyoke +MBSORIKi
*
-:---  myacc_MBSORI.regions   All (4,14)     (FLUKA)
* dipole:
* ..+....1....+....2....+....3....+....4....+....5....+....6....+....7..
ASSIGNMA         IRON  MBSOYOKE
ASSIGNMA       VACUUM  MBSOBPVC                          1.0
ASSIGNMA       VACUUM  MBSOOUT_
*
-:---  myacc_MBSORI.assignmat   All (5,14)     (FLUKA)
```

Bending Dipole Prototype

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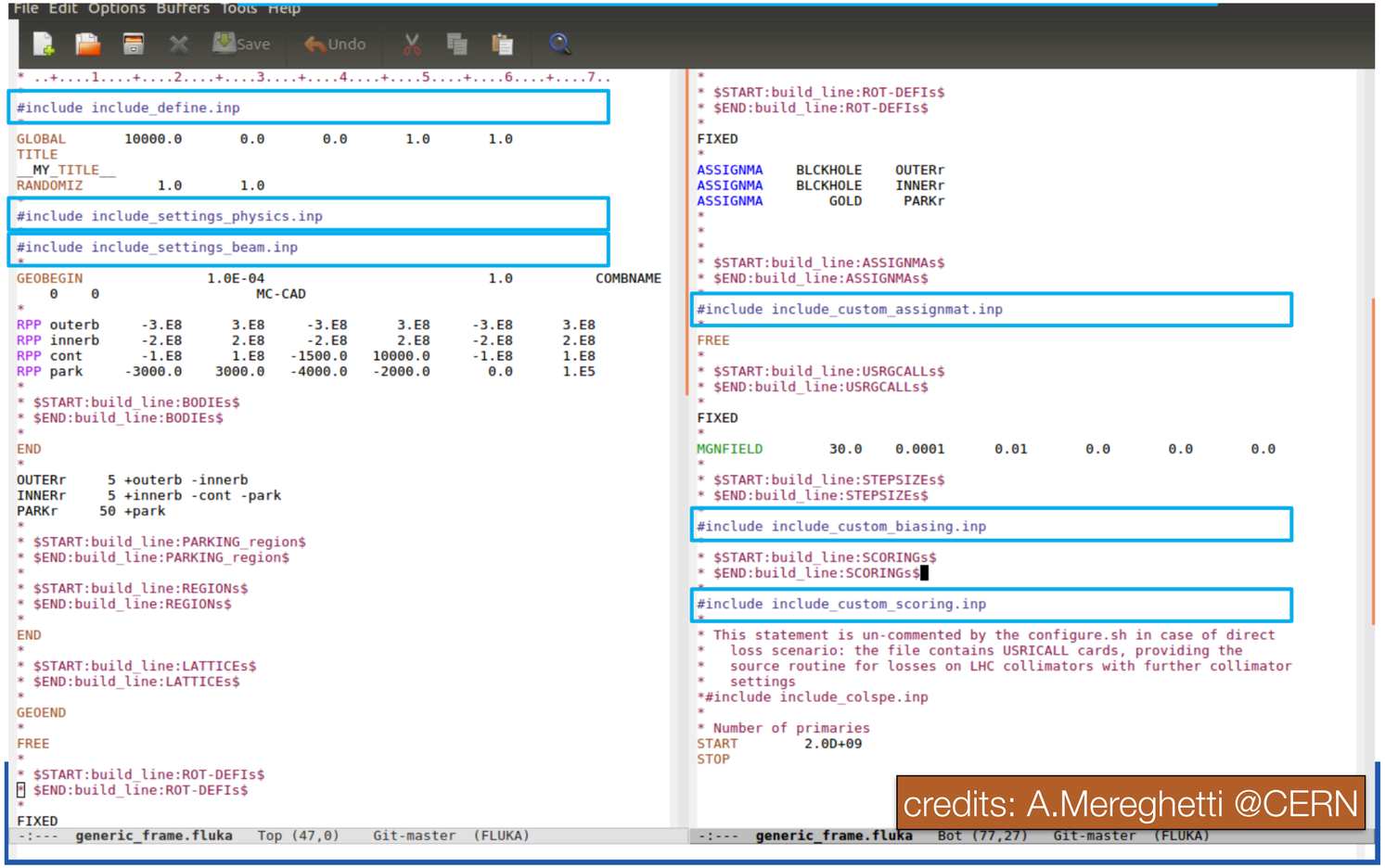
Line Builder



credits: A.Mereghetti @CERN

Python (v2.7) program that inserts the needed magnetic elements in a pre-existent “template geometry” based on machine optics

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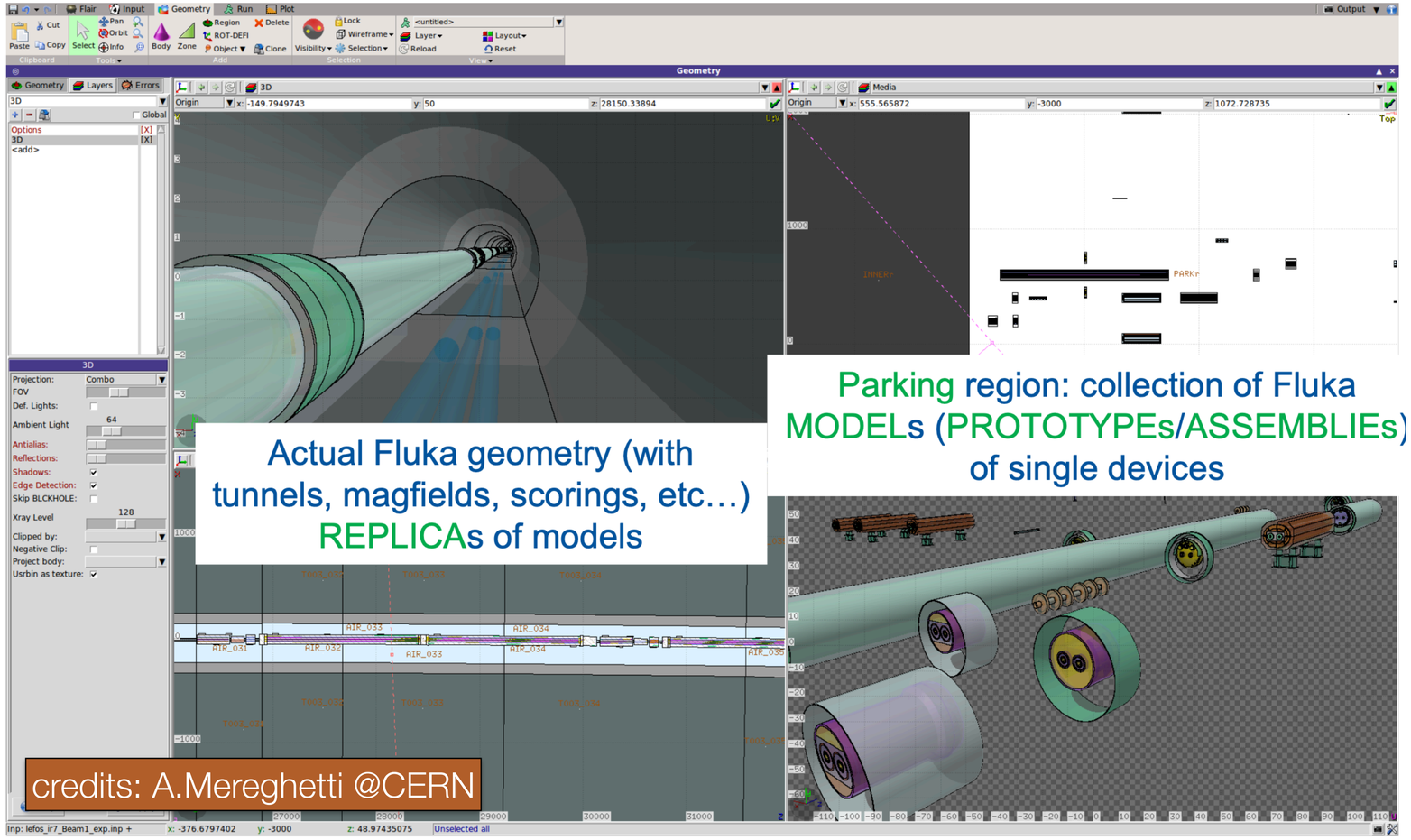


FINAL RESULT

Once the geometry has been built in FLUKA, we can simulate whatever we want..!

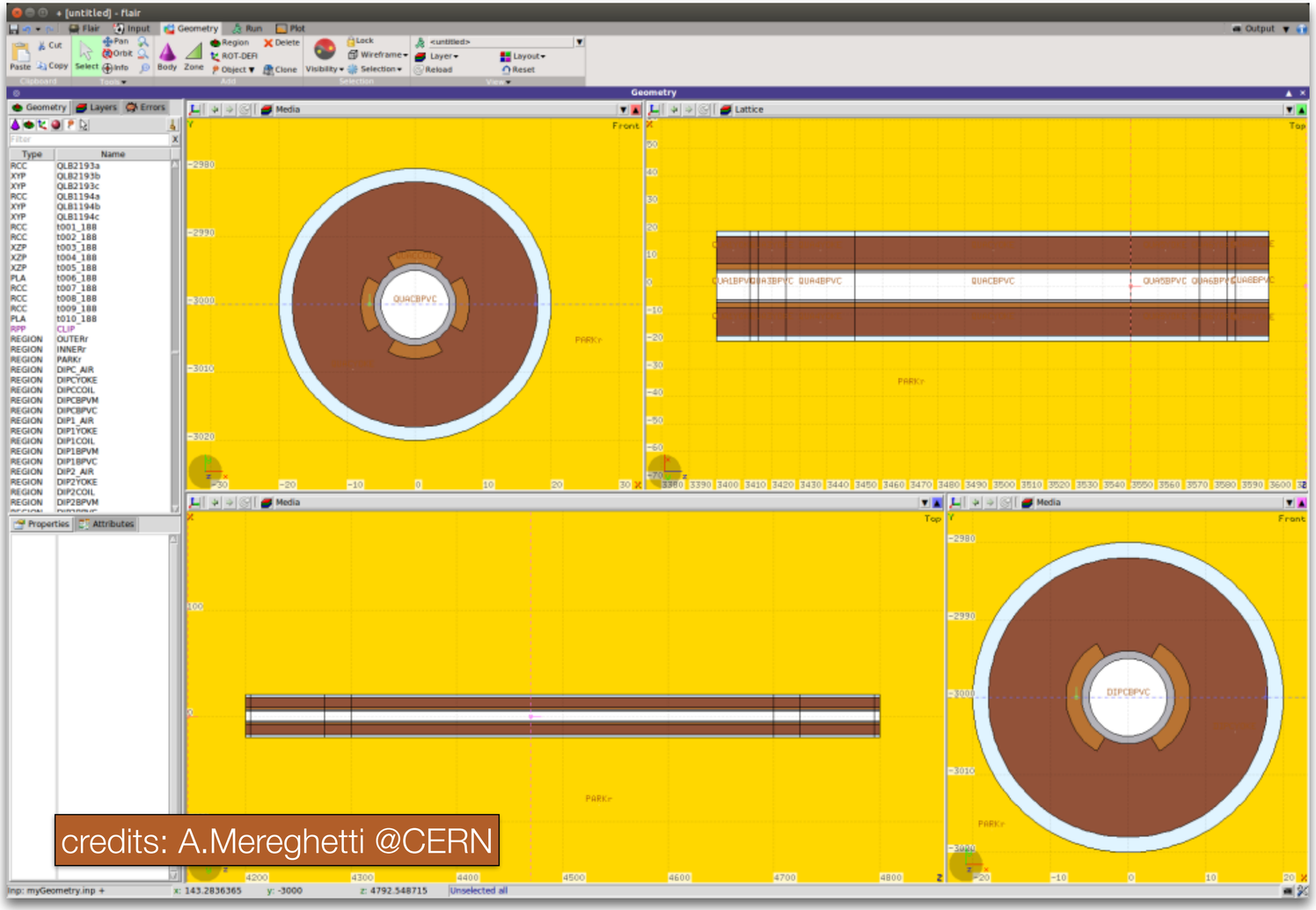
The Procedure

```
@ TYPE             %05s "TWISS"
@ SEQUENCE         %07s "MYACCEL"
@ PARTICLE         %06s "PROTON"
@ MASS             %le           0.9382720812999995
@ CHARGE           %le           1.0000000000000000
@ ENERGY           %le           1.3712601863056616
@ PC               %le           1.0000000000000000
@ GAMMA            %le           1.4614739025458472
@ KBUNCH           %le           1.0000000000000000
@ BCURRENT         %le           0.11463416918410078
@ SIGE             %le           0.00045000000000000
@ SIGT             %le           0.07550000000000000
@ NPART            %le  199999999999.99996948242187500
@ EX               %le           0.00000171060184396
@ EY               %le           0.00000171060184396
@ ET               %le           0.00100000000000000
@ BV_FLAG          %le           1.0000000000000000
@ LENGTH           %le          44.56637061435915115
@ ALFA             %le           0.02452735406345014
@ ORBIT5           %le          -0.0000000000000000
@ GAMMATR          %le           6.38520212960327616
@ Q1               %le           2.23430396971649170
@ Q2               %le           2.39886628492304776
@ DQ1              %le         -13.15027500931211080
@ DQ2              %le         -12.03854917694575200
@ DXMAX            %le           3.72418111948598485
@ DYMAX            %le          -0.0000000000000000
@ XCOMAX           %le           0.0000000000000000
@ YCOMAX           %le           0.0000000000000000
@ BETXMAX          %le          56.74023186627047721
@ BETYMAX          %le          30.53217555627889368
@ XCORMS           %le           0.0000000000000000
@ YCORMS           %le           0.0000000000000000
@ DXRMS            %le           1.95163328969153160
@ DYRMS            %le           0.0000000000000000
@ DELTAP           %le           0.0000000000000000
@ SYNCH_1          %le           0.0000000000000000
@ SYNCH_2          %le           0.0000000000000000
@ SYNCH_3          %le           0.0000000000000000
@ SYNCH_4          %le           0.0000000000000000
@ SYNCH_5          %le           0.0000000000000000
@ TITLE            %08s "no-title"
@ ORIGIN           %16s "5.05.01 Linux 64"
@ DATE             %08s "11/06/19"
@ TIME             %08s "14.17.20"
* NAME              KEYWORD                    S                    L                 TILT                 KICK                HKICK                VKICK                ANGLE
$ %s                %s                       %le                  %le                 %le                  %le                  %le                  %le                  %le
 "MYACCEL$START"    "MARKER"    0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "DRIFT_0"          "DRIFT"     0.19999999999999996  0.39999999999999991  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "S.ARC.12"         "MARKER"    0.39999999999999991  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "DRIFT_1"          "DRIFT"     0.44999999999999996  0.10000000000000009  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "MB.1T2"           "SBEND"     2.07079632679489656  3.14159265358979312  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  1.57079632679489656
 "DRIFT_2"          "DRIFT"     3.69159265358979294  0.10000000000000009  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "E.ARC.12"         "MARKER"    3.74159265358979320  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "DRIFT_3"          "DRIFT"     4.14909265358979340  0.81499999999999995  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "MQ.1X2"           "QUADRUPOLE" 4.64159265358979312  0.17000000000000001  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "DRIFT_4"          "DRIFT"     5.64159265358979312  1.83000000000000007  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "MQ.2X2"           "QUADRUPOLE" 6.64159265358979312  0.17000000000000001  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "DRIFT_5"          "DRIFT"     6.77659265358979290  0.10000000000000053  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "BPM.2X2"          "MONITOR"   7.07659265358979361  0.50000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "DRIFT_6"          "DRIFT"     7.94159265358979294  1.22999999999999865  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "MQ.3X2"           "QUADRUPOLE" 8.64159265358979312  0.17000000000000001  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "DRIFT_7"          "DRIFT"     9.64159265358979134  1.82999999999999829  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "MQ.4X2"           "QUADRUPOLE" 10.64159265358979134  0.17000000000000001  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "DRIFT_8"          "DRIFT"     11.13409265358978928  0.81499999999999950  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "S.ARC.23"         "MARKER"    11.54159265358978992  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "DRIFT_9"          "DRIFT"     11.59159265358978885  0.09999999999999964  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "MB.2T3"           "SBEND"     13.21238898038468612  3.14159265358979312  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  1.57079632679489656
 "DRIFT_10"         "DRIFT"     14.83318530717958339  0.09999999999999964  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "E.ARC.23"         "MARKER"    14.88318530717958232  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "DRIFT_11"         "DRIFT"     15.29068530717958296  0.81499999999999950  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
 "MQ.1X3"           "QUADRUPOLE" 15.78318530717958268  0.17000000000000001  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000  0.00000000000000000
```

- We started from the muon collider **machine optics** from **MAP** Studies @ 1.5TeV CM
  - ➡ Old optics format! (Mad-8)
  - ➡ Different conventions from LHC studies
  - ➡ Very limited use of markers

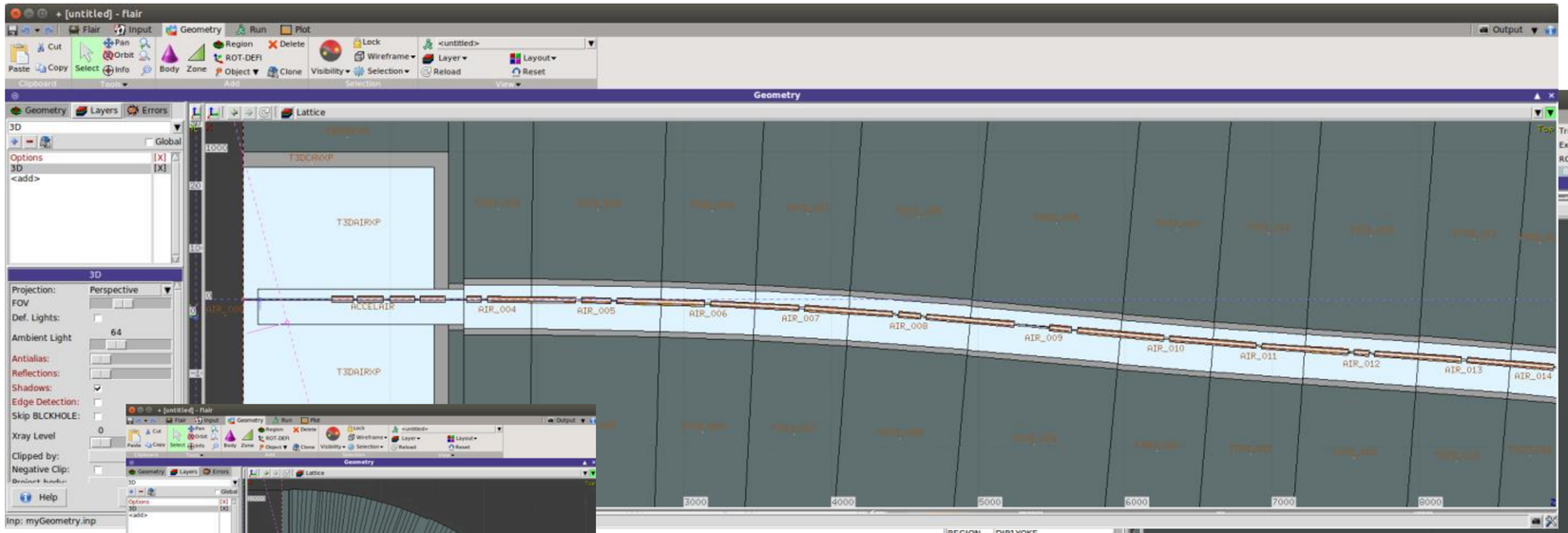
The Procedure

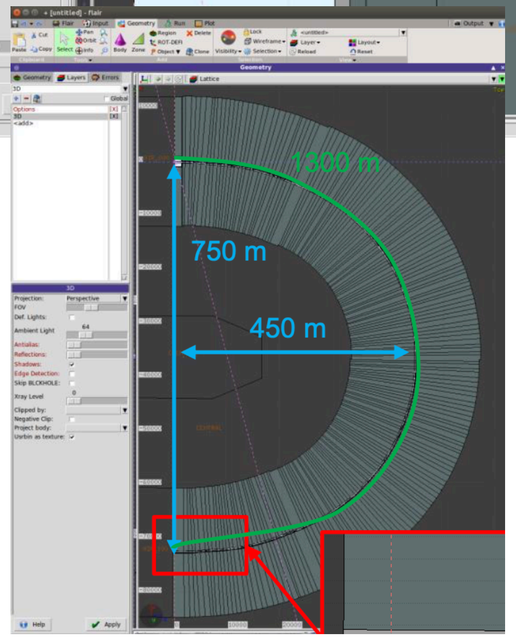
- A first **Fluka Elements Data Base** has been developed with some “First order” magnetic elements geometries: *Dipoles* and *Quadrupoles*

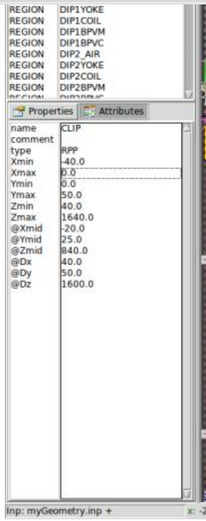


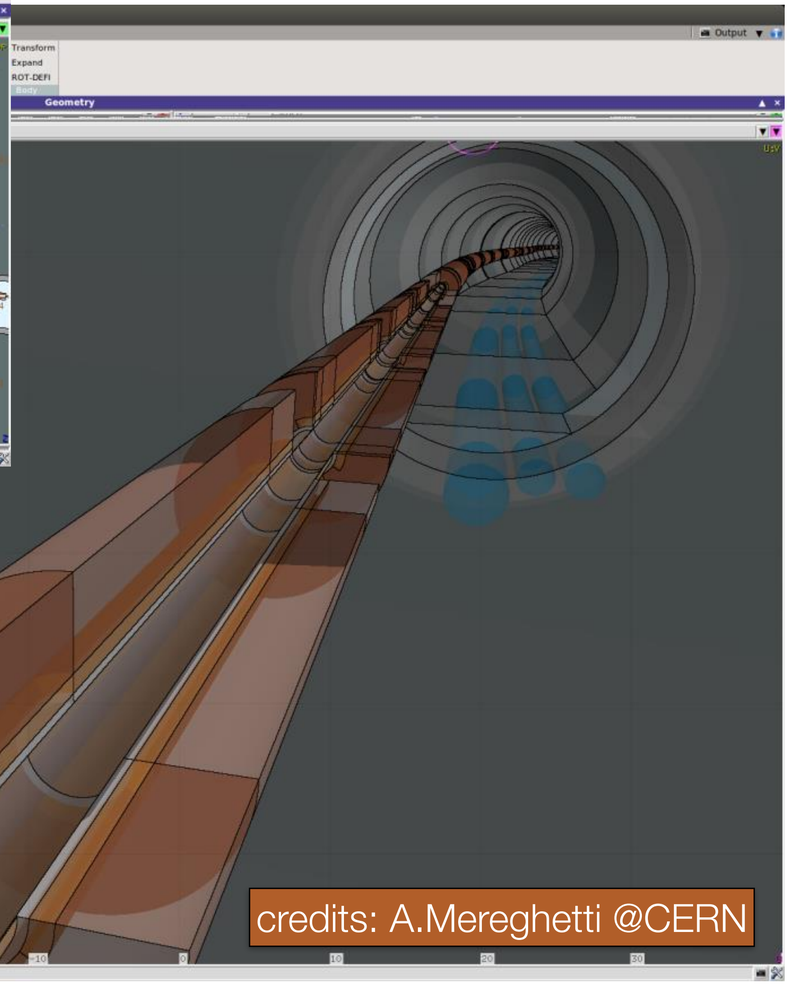
The Procedure

- A very first geometry of the whole muon collider (half ring) has been produced…





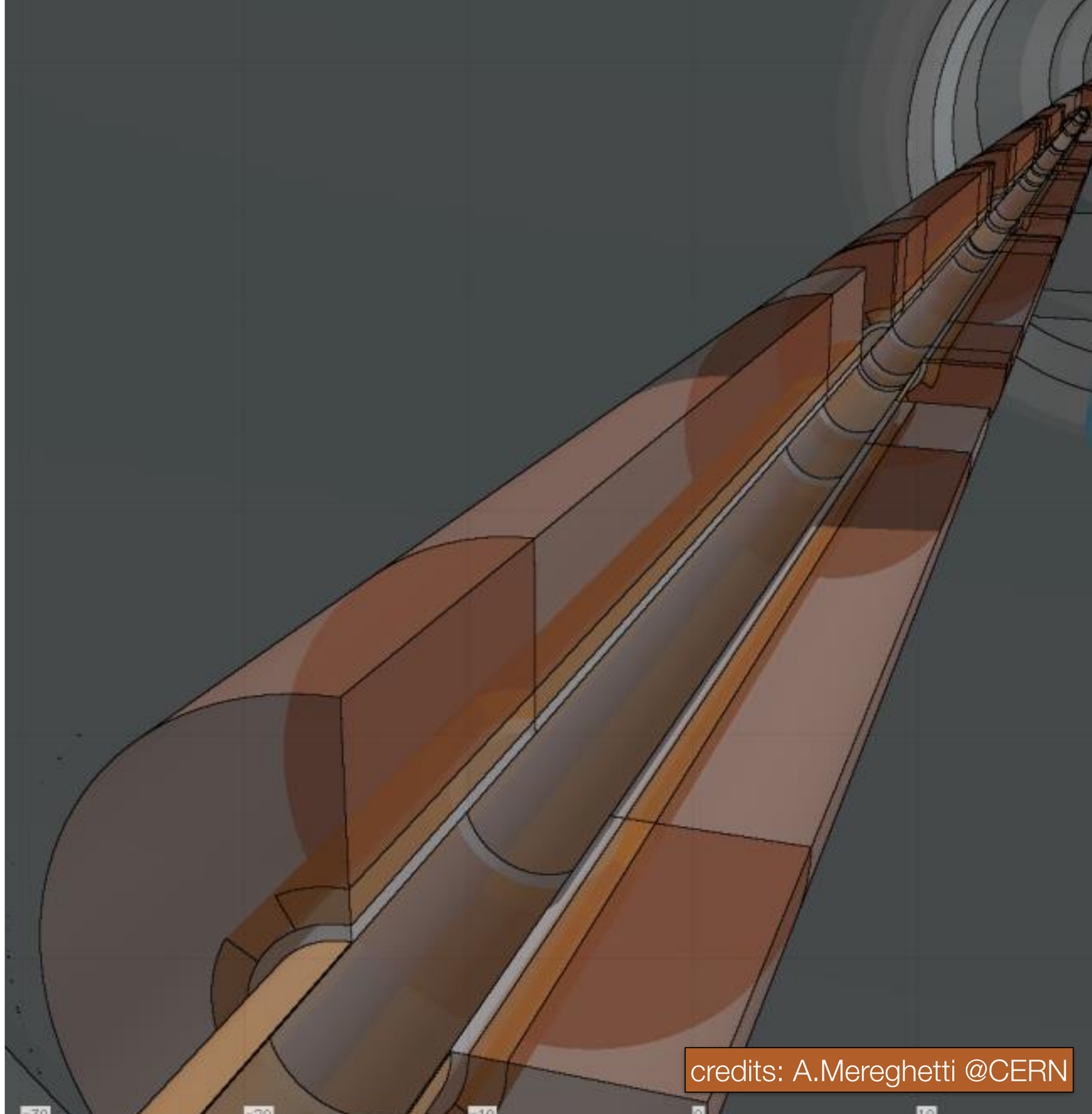




credits: A.Mereghetti @CERN

To Sum Up

- **Beam Induced Background** in the experimental area of a Muon Collider is mainly due to **muon decays** from 10-100m from the IP
- A powerful **flexible tool** for **simulating** such sections of the machine starting from the optics is needed
- **FLUKA Line Builder** has been chosen and started to use
  - First magnetic elements and geometries developed



credits: A.Mereghetti @CERN

Next Steps and Help Needed

- Geometry:
  - Add missing models for Super Conducting **magnets** (*sextupoles*)
  - Verify that the reconstructed optics is closed
  - Build the external shell of the **detector** inside the experimental cavern
- Physics:
  - Setup all the relevant physics cards
- Scoring:
  - Setup scoring of BIB
- **Machine Detector Interface design and optimisation**

Currently involved people:
- F. Collamati - INFN Rome
- C. Curatolo - INFN Padova
- A. Mereghetti - CERN
- P. Sala - INFN Milano