Status of the FLUKA project

Application Area meeting

February 18 2004

Alfredo Ferrari

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INFN-Milan, Padova & Frascati, University of Milan and University of Pavia

V.Anderson, A.Empl, K.Lee, L.Pinsky
University of Houston

T.N. Wilson, N. Zapp
NASA/JSC

The INFN-CERN FLUKA Agreement: preliminary

February 2003 *Scientific Agreement* signed by CERN EP and AB - INFN - FLUKA Authors

The purpose of this agreement is to make the FLUKA *Monte Carlo code, fully available to the scientific community, while protecting the scientific rights of the authors and the integrity of the code*

- A (5 member) Coordinating Committee supervises the project
- A full release including source and documentation is foreseen within 12-18 months, starting from the availability of 1 FTE Scientific Associate from EP and 1 FTE Staff from AB
- The Coordinating Committee has also the task of drafting a proper licensing scheme

The INFN-CERN FLUKA Project: Agreement of December 2003

- Approved unanimously by the INFN Council on December 16th
- Signed by the CERN DG on December 17th

The agreement provides the scientific and legal framework for past, present and future work on FLUKA, as well as protection against past/future copyright infringements

"The FLUKA Project is aimed at achieving the goals described in Annex 4 hereto and consists of the continuous maintenance and further development of FLUKA, and of its full release to the scientific community and other interested parties, under licensing conditions which are to be defined in accordance with the terms of this Agreement, whilst acknowledging the work performed by the Authors and protecting the integrity of the FLUKA code"

- The project will last an initial period of three years (2004-2006)
- INFN and CERN share the IP of FLUKA at 70% and 30% level respectively
- A (5 member) FLUKA Coordinating Committee supervises the project (G. Battistoni, E. Chiaveri, J. Harvey, J. Ranft, and P.R. Sala)
- A full release including source and documentation is foreseen within 12-18 months
- The FLUKA Coordinating Committee has the task of drafting the license

The INFN-CERN FLUKA Agreement: licensing conditions

ARTICLE 5 LICENSING CONDITIONS

5.1 Prior to the full release of the FLUKA software to the scientific community and other interested parties and subject to prior review by the FCC, the Parties shall define the licensing conditions which shall apply to such release.

5.2 Except as submitted by the Parties to the FCC and approved by the FCC by unanimous vote (it being understood, in addition, that any proposal for commercial licensing shall also require the approval by the ETT Division Leader at CERN and a person appointed by the President of INFN), the release of FLUKA by the Parties shall be based on, and incorporate the following principles:

i) The licensing conditions shall include the following copyright notice: "This software results from work performed by Alberto Fasso, Alfredo Ferrari, Johannes Ranft and Paola Sala. Copyright Italian National Institute for Nuclear Physics (INFN) and European Organization for Nuclear Research (CERN).";

ii) The licensing conditions shall, in particular in the source code, acknowledge contributions made by other parties and state the conditions applicable to such contributions;

The INFN-CERN FLUKA Agreement: licensing conditions

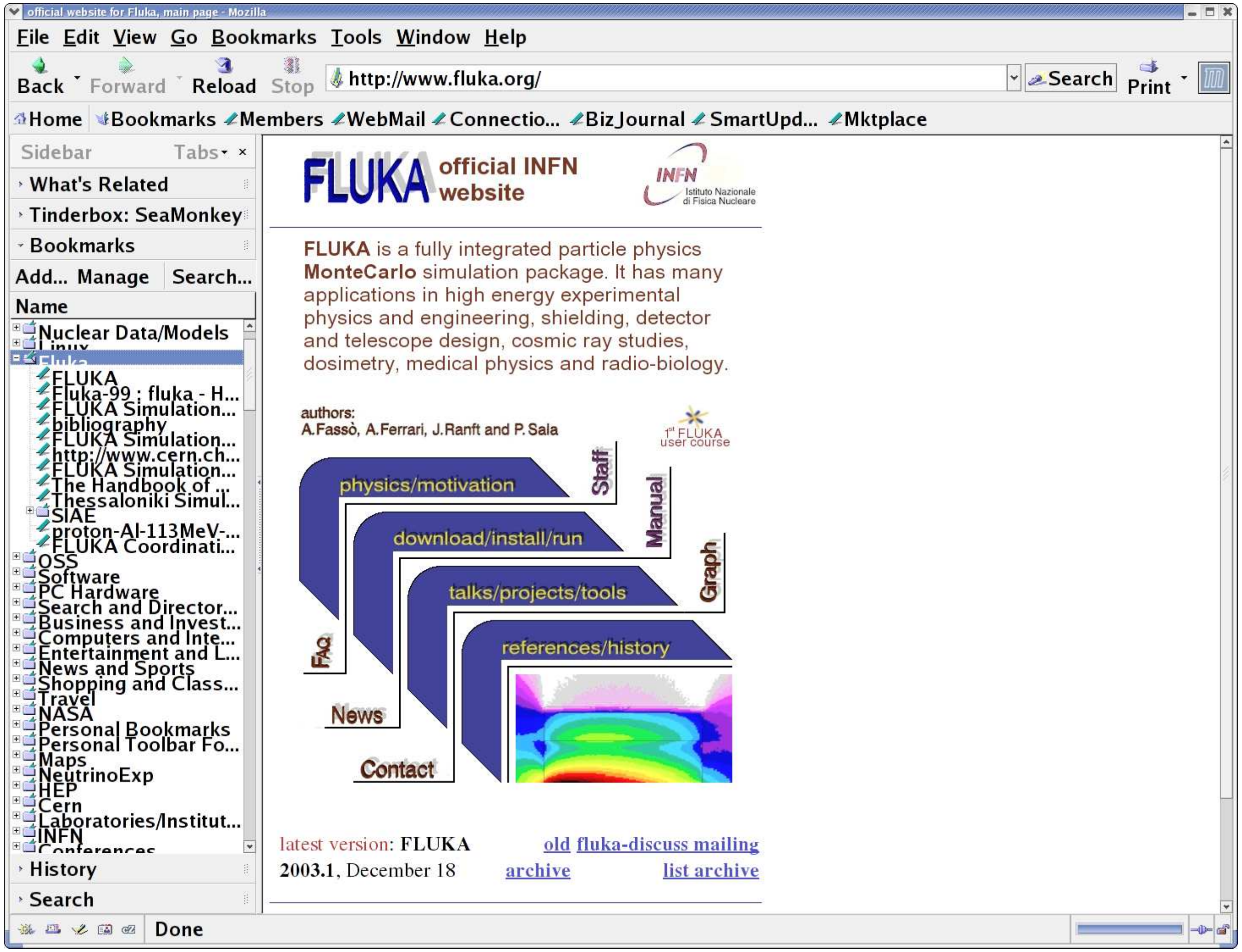
iii) The license conditions shall permit use for scientific, non-commercial purposes of the licensee;

iv) The licensee shall be entitled to modify FLUKA for his own use, but shall not be entitled to release or sub-license FLUKA, whether or not modified by the licensee, to any other party, shall not without prior written permission insert any part of the FLUKA code into other codes, translate it into any other computer language, or, having modified FLUKA, publish any report on such modification if the latter has made a substantial impact on the scientific or technical results so produced by FLUKA;

v) The licensee shall provide the Parties with a license to any modification made by the licensee to FLUKA, including the right for the Parties to incorporate such modification in FLUKA and to sub-license it to other parties;

vi) FLUKA is provided on an as-is basis, without any warranty, and the licensee shall indemnify the Parties for, and hold them free and harmless from, any liability on connection with her or his use of FLUKA.

www



official website for Fluka, main page - Mozilla
File Edit View Go Bookmarks Tools Window Help
Back Forward Reload Stop
http://www.fluka.org/
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http://www.cern.ch...
FLUKA Simulation...
The Handbook of ...
Thessaloniki Simul...
SIAE
proton-Al-113MeV-...
FLUKA Coordinati...
OSS
Software
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News and Sports
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NASA
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Personal Toolbar Fo...
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FLUKA official INFN website
INFN Istituto Nazionale di Fisica Nucleare
FLUKA is a fully integrated particle physics MonteCarlo simulation package. It has many applications in high energy experimental physics and engineering, shielding, detector and telescope design, cosmic ray studies, dosimetry, medical physics and radio-biology.
authors:
A.Fassò, A.Ferrari, J.Ranft and P.Sala
1st FLUKA user course
physics/motivation
download/install/run
talks/projects/tools
references/history
Staff
Manual
Graph
FAQ
News
Contact
latest version: FLUKA 2003.1, December 18
old fluka-discuss mailing archive
list archive

Present Availability and Documentation

Free download from the web server of:

- Libraries, data files, user interface routines, utility scripts and programs for

  1. Linux (RH 9.0, 8.0, and 7.3)
  2. Digital Unix
  3. Sun
  4. HP-UX 10
  5. VMS (on request)

- User manual: included in the distribution, + browsable version

Publications: list on the www server

User Support: mailing list

Latest release: FLUKA2003.1 on december 18th 2003

FLUKA: sponsors

INFN "FLUKA" project established and funded in the framework of the INFN Commissione V, 6.3 FTE's

It is the official MonteCarlo of the ICARUS experiment, as well as for the spallation part of the Energy Amplifier and related studies (all activities chaired by C. Rubbia).

Strong support is coming from the University of Houston and NASA. A three-year (2000-2003) development program for FLUKA has been completed, and a new four-year grant is under way. The final goal is to produce a state-of-the-art tool for space radiation calculations, which will also exploit the ROOT capabilities for the user interface and output analysis (F. Carminati and R. Brun are members of this collaboration).

CERN "FLUKA" project now offical and established for the next three years, 2 FTE's dedicated to the code (1 AB, 1 PH)

The INFN FLUKA project

FLUKA approved as official INFN project in Sept. 2001
(presently 6.35 FTE from Milan, Pavia, Frascati)

INFN project milestones for 2002 and 2003:

- 31/12/2002 Ion (nuclear) interaction model ($E > 5$ GeV/u) (successfully achieved, starting level implementation operational and released)
- 31/12/2002 First (preliminary) integration with radiobiological databases (successfully achieved)
- 30/06/2002 Preliminary "module" for cosmic ray applications (partially achieved, some more work required)
- 30/06/2002 Official WWW server for the code distribution (successfully achieved)
- 31/12/2002 Improvements of the user-friendliness of the code (partially achieved, some work still required)
- 31/12/2002 Release of an interface to the GEANT4 geometry (FLUGG) (successfully achieved)

The INFN FLUKA project II

2003:

- 30/03/2003 FAQ and mailing list services on www.fluka.org (successfully achieved)
- 31/12/2003 Documented examples to be consulted via web (successfully achieved, more examples to come)
- 31/12/2003 Documentation about the new geometry (incl. CT Voxel scans) (successfully achieved, see manual draft)
- 31/12/2003 New radiobiology results about the 3D voxel phantom (successfully achieved)
- 31/12/2003 Upgrade of the DPMJET interface to DPMJET-III (rescheduled for 2004 due to S. Roesler lack of time)

(INFN) project milestones for 2004

- Web site mirrors (SLAC, CERN ?)
- New manual: ready in draft form, it will become a yellow report as soon as finalized
- FLUKA physics description: to become a 300+ page yellow report (unlikely to be finalized by the end of 2004)
- FLUKA courses (see other transparencies)
- Elimination of the preprocessor for (P)EM(F) cross section calculations: work done at 50% as of today, substantial help from the PH associate (D. Ene)
- New geometry abstraction level (names instead of numbers and parentheses in the Boolean operations) (done, see examples)
- Heavy (A>4) fragment evaporation and fragmentation: preliminary implementation working in the development version, still some work to be done
- Residual dose rate temporal evolution, including γ, and $\beta^{+/-}$ emission from calculated residuals: data bases ready for use in the development version, it should be included in the may or in the october/november release

(INFN) project milestones for 2004: cont.

- Preliminary insertion of the BME model (Milan) for low energy ion interactions (¡ 100 MeV/n): still in early stage (see examples)
- Further developments of the FLUKA cosmic ray special package
- Solar particle event simulation (August 1972 particularly)
- Heavy ion electromagnetic dissociation (NASA and LHC)
- Dosimetry and radiobiology of 1 GeV/n Iron beams (NASA and ASI, data taken at Brookhaven)

FLUKA release of december 2003 (FLUKA-2003.1)

The very first time the version with ion capability has been made available to all users!!! A major milestone for the NASA grant

- Ion interaction capability from 100 MeV/n up to the highest cosmic ray energies
- Extensive reworking and improvement in the electro-magnetic part (partially in preparation of PEMF elimination)
- Extensive reworking and cleaning up of commons
- Geometry by “names” and parentheses

The “new” geometry input format: bodies

Free format is used for both body and region input only if requested by a GLOBAL command at the beginning of the input file.

Free format has been introduced only recently and is expected to superseed soon the other formats, which will be kept however for reasons of back compatibility. Its main advantages, in addition to the freedom from strict alignment rules, are the possibility to modify the input sequence without affecting the region description (for instance, by inserting a new body) and the availability of parentheses to perform complex boolean operations in the description of regions.

The input for each body consists of the 3-letter code indicating the body type followed by a unique “body name” (alphanumeric identifier) and a set of geometrical quantities defining the body (their number depends on the body type as explained below). The different items, separated by one or more blanks, or by one of the separators , / ; : can extend over as many lines as needed.

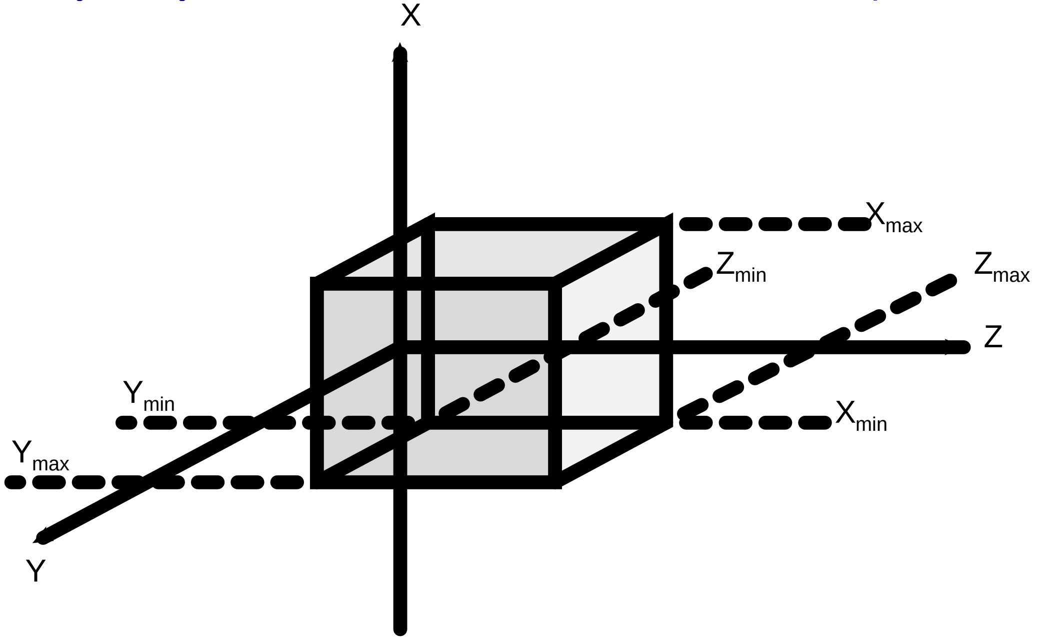
With all input formats, a card having an asterisk (*) in column 1 is treated as a comment card. Such comment cards can be inserted freely at any point of Body and Region input, allowing easier identification.

Rectangular Parallelepiped: `RPP`

An `RPP` has its edges parallel to the coordinate axes.

It is defined by 6 numbers in the following order: X_{min}, X_{max}, Y_{min}, Y_{max}, Z_{min}, Z_{max} (minimum and maximum coordinates which bound the parallelepiped).

An `RPP` definition extends over one single card in default fixed format, or over two cards in high-accuracy body fixed format 4 kinds of infinite half-spaces.



Rectangular Parallelepiped (RPP)

Rectangular Parallelepiped: `RPP`

Example in default fixed format (the comment lines shown are allowed input lines):

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7..
  RPP     4     -20.0     +20.0     -50.0     +50.0     -38.5     +38.5
* (a parallelepiped centered on the origin)
```

The same input, in high-accuracy fixed format:

```
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7....+.
  RPP     4                 -20.0                 +20.0                 -50.0
                            +50.0                 -38.5                 +38.5
```

The same example in free format:

```
RPP SmlBrick  -20.0  +20.0  -50.0  +50.0  -38.5  +38.5
```

The "new" geometry input format: regions

Free format is based on mnemonic "names" instead of sequential numerical identifiers and allows the use of parentheses to perform more complex boolean operations.

Each region is described as a combination of one or more bodies, by means of the three operator symbols:

$$\boxed{-}\ \boxed{+}\ \text{and}\ \boxed{|}$$

where | is used instead of `OR`.

Each body is referred to by its "name" (an alphanumeric string of up to 8 characters, the first character being alphabetical) in the body description table. Input for each region starts on a new line and extends on as many continuation lines as are needed. It is of the form:

REGNAME NAZ boolean-zone-expression

or

REGNAME NAZ | boolean-zone-expression | boolean zone expression | . . .

where *REGNAME*, *NAZ* and the remaining part are separated by one or more blanks.

The “new” geometry input format: regions

REGNAME is the region “name” (an arbitrary unique alphanumeric character string chosen by the user). The region name must begin by an alphabetical character and must not be longer than 8 characters.

NAZ as the same meaning as for the fixed format

“boolean-zone-expression” is a sequence of one or more body names preceded by the operators + (intersection) or − (complement or substraction). A zone expression can be contained inside one set of left and right parentheses. Several zone expressions can be combined by the union operator | (corresponding to `OR` in fixed format input).
When | operators are used there are always two or more of them, and they refer to all bodies following them until the next | or the end of the region description, each body being preceded by its + or − sign.
In evaluating the expressions, the highest operator precedence is given to parentheses, followed by the | operator. In each zone expression, at least one body name preceded by + must be present. If one line is not sufficient, any number of continuation lines can be added. Blanks are ignored.

The “new” geometry input format: examples of regions

Examples of regions consisting of a single zone:

```
lastlayr   4  +bigball  +slab
* Region "lastlayr" is the part of space common to body "bigball" and body
* "slab"

MidVacuu  7 +cylind2   -slit  -sqrhole +Plane1
* Region "MidVacuu" is the part of space common to bodies "cylind2" and
* "Plane1", excluding however that which is inside body "slit" and that which
* is inside body "sqrhole"

H2Osphere   5   +marble
* Region "H2Osphere" coincides entirely with body "marble"
```

The "new" geometry input format: examples of regions

Examples of regions consisting of the union of several zones, possibly (but not necessarily) partially overlapping:

```
Corners  6 | +dice +topNorth | +dice +topEast | +dice +topSouth |
+dice +topWest | +dice +botNorth | +dice +botEast | +dice +botSouth | +dice
+botWest
* Region "Corners" is made of the 8 corners of a cube, each of which is
* obtained by the intersection of a cubic body "dice" and a tilted plane
* described by vector pointing to the center of the cube

twoparts 0 | +leftpart -outerbox | +rghtpart +topplane
* Region "twoparts" is the sum of two parts of space: the space points which
* are inside body "leftpart" but not inside body "outerbox", plus those which
* are common to bodies "rghtpart" and "topplane"
```

Example of a region defined as a single zone by means of parentheses:

```
AirAroun 5  + tunnel + Column - (+outrpipe-innrpipe)
* Region "AirAroun" contains the space points located inside the intersection
* of body "tunnel" and body "Column", with the exception of those which are
* inside body "outrpipe" but not inside body "innrpipe"
```

The "new" geometry input format: examples of regions

Example of a region defined as multiple zones by means of parentheses:

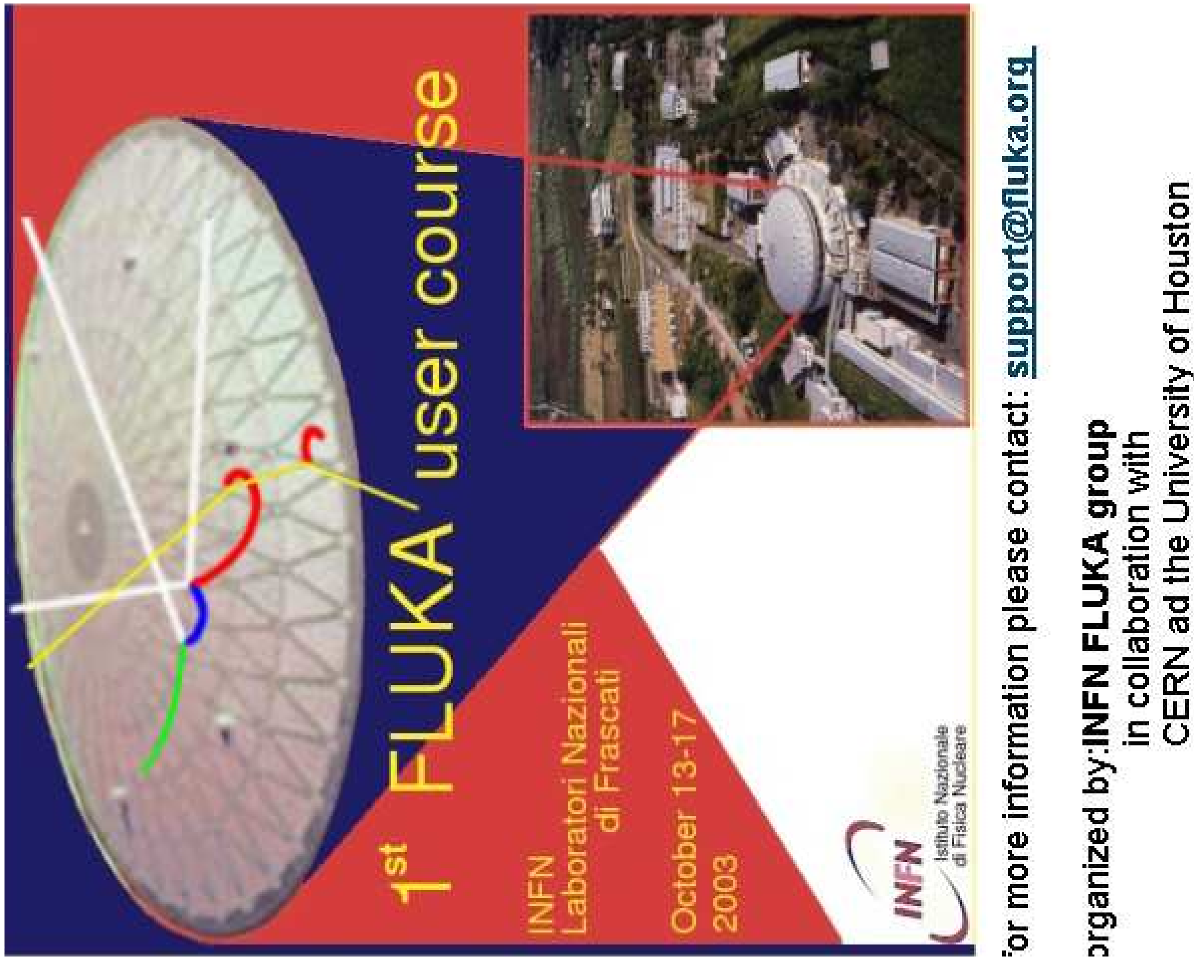
```
CmplexRg | +longcyl + (+shortcyl +vertPla1 -vertPla2) | (+Brick | + ceeling
- floor)
* Region CmplexRg is the union of two zones. The first zone is the
* intersection of body "longcyl" with a portion of space contained inside
* both bodies "shortcyl" and "vertPla1" but not inside body "vertPla2".
* The second zone is the union of the space points inside body "Brick"
* and the space points contained by body  "ceeling" but located outside
* body "floor".
```

Planning for next releases

!!! The following schedule is purely tentative !!!

- An intermediate release in mid 2004 containing (hopefully):
  - Full "name" like input
  - PEMF out (?)
  - Experimental ion electromagnetic dissociation
  - Radioactive products decay
- A full release including source and the final manual within 2004 including:
  - New neutron xsec library (D. Ene)
  - 12-C and 16-O pointwise xsec for neutrons below 20 MeV
  - "Heavy" evaporation/fragmentation model
  - General cleanup

FLUKA Courses: Frascati 13–17 October, CERN 1–3 December



Next Courses

Due to the surprising success of the 2003 Courses, we were forced to refuse quite a number of applications. There are plans for holding other Courses in 2004, however the exact schedule, as well as the compatibility with the many tasks of this year has still to be verified

- Possible 2004 course in China (as requested by some chinese Universities): main organization by A. Fassò (SLAC)
- Possible 2004 course in Houston: strong push from our american colleagues within the NASA Grant. Houston would take care of all the logistics, a possible date could be just after the Nuclear Data 2004 Conference (Santa Fe') at the beginning of October, however it clashes with the work required for the full release

Monte Carlo BME

Monte Carlo approach based on the **B**oltzmann **M**aster **E**quation theory

Heavy ion reactions at incident energies of a few tens of MeV/amu

BME:statistical evolution of the composite nucleus through a sequence of two body interactions and emission of unbound particles, also in the form of light clusters. Mean field effects are taken into account

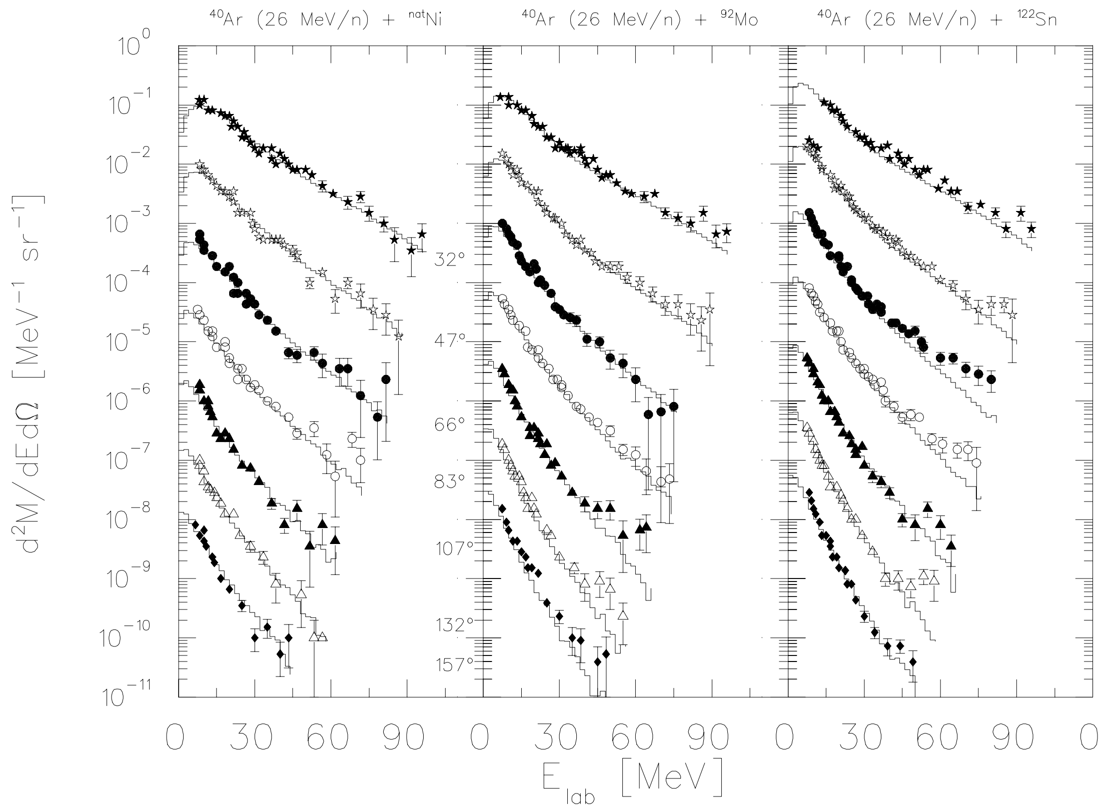
BME is inclusive, but:

Milan:Monte Carlo code (exclusive) evaluates the probability of any complex event as the joint probability of a sequence of elementary emissions, whose probabilities are assumed to be equal to corresponding multiplicities (given by BME) in very short time intervals. Up to ^{16}O, incomplete fusion processes following the projectile break-up are included.

M. Cavinato et al., Nucl. Phys. A 679 (2001) 753, Phys. Lett. B 382 (1996) 1

E. Gadioli et al., Nucl. Phys. A 708 (2002) 391

Monte Carlo BME: examples I, from Nucl. Phys. A 679 (2001) 753

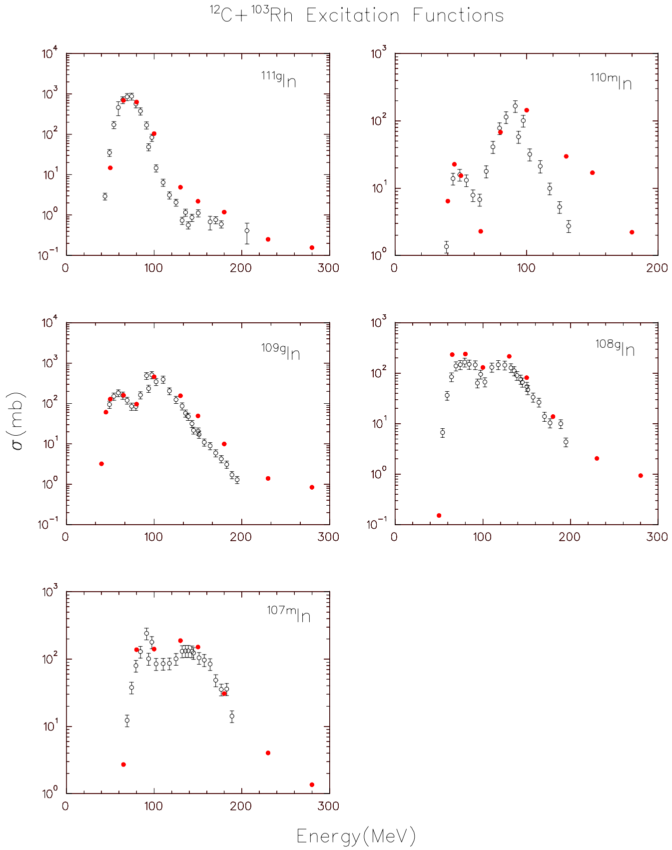


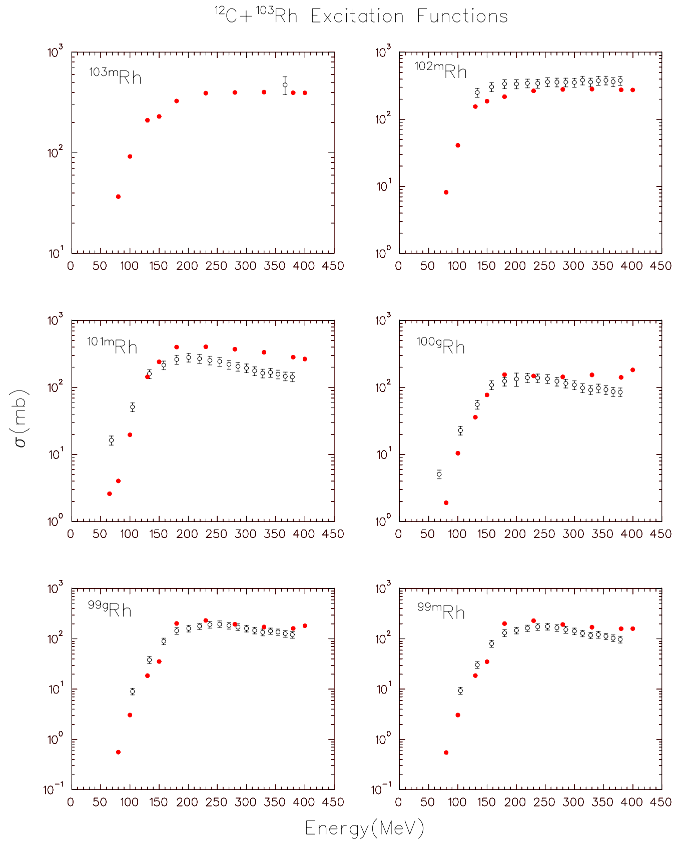
Spectra of neutrons emitted in central collisions of ^{40} Ar with Ni, ^{92}Mo and ^{122}Sn at 26 MeV/amu. Symbols are exp. data, histograms are simulation results. Starting from top the spectra are progressively scaled down by a factor ten

Monte Carlo BME: examples II, unpublished

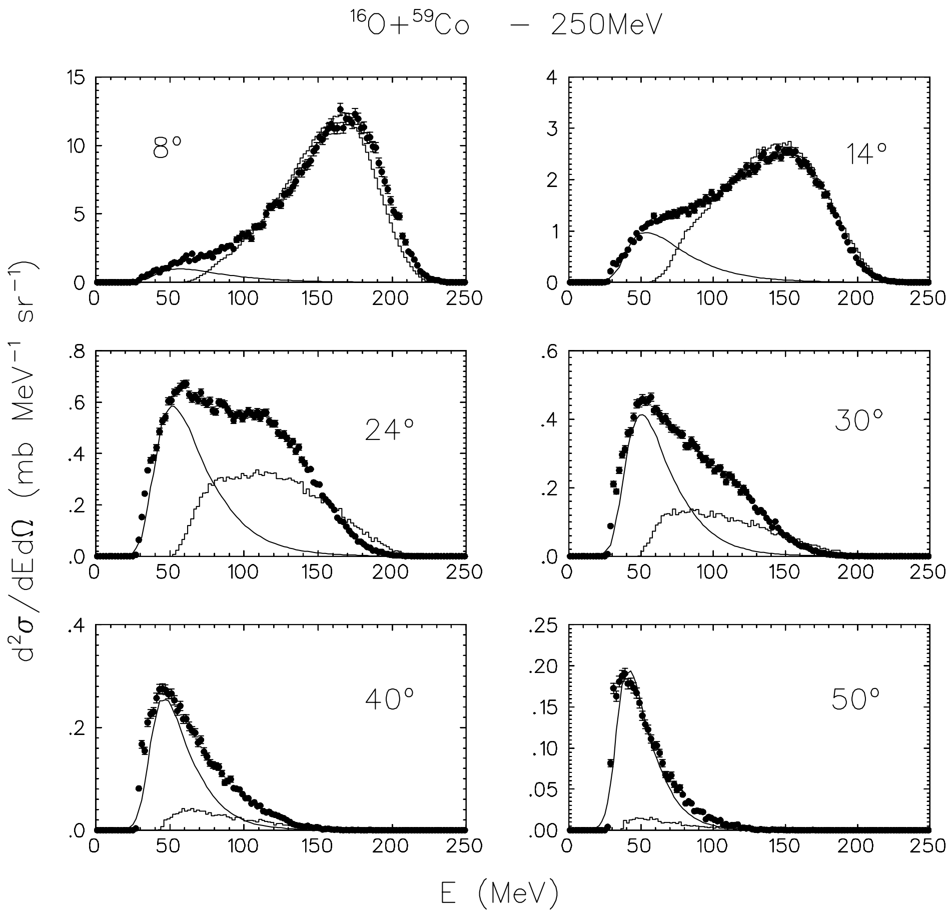
Residual In and Rh excitation functions following ^{12}C+^{103}Rh.

Red: simulation results, black: exp. data





Monte Carlo BME: examples III (NPA 708 (2002) 391)



Spectra of carbon fragments emitted in ^{16}O on ^{59}Co at 250 MeV.

Exp. spectra: solid points

Theoretical predictions by BME (lines)

projectile break-up (histo)

The FLUKA - RQMD-2.4 interface

Refs: H. Sorge PRC52 3291 (1995), H.Sorge, H.Stocker, W.Greiner, Ann. Phys. 192 266 (1989), NPA498 567c (1989)

Relativistic QMD model applicable from $\approx$ 0.1 GeV/n up to several hundreds of GeV/n, successfully applied to relativistic A-A particle production over a wide energy range

Limitations:

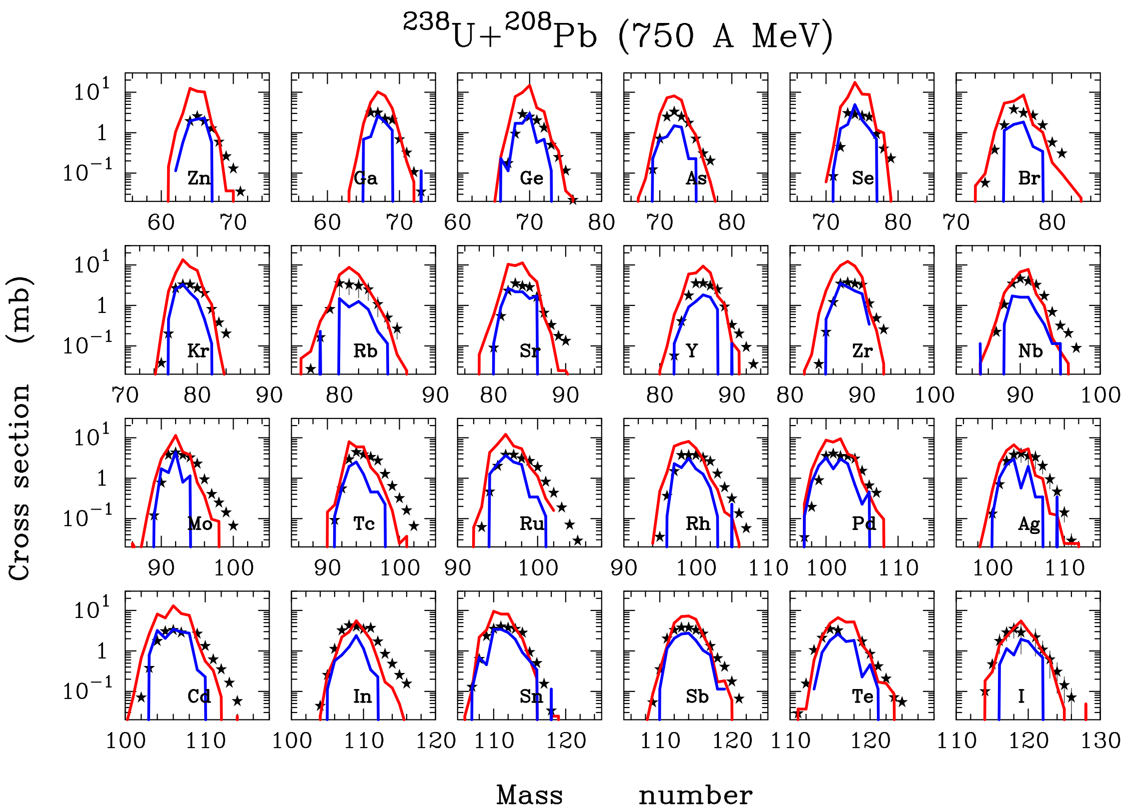
- No evaporation/fragmentation/fission/deexcitation of residuals and fragments
- Energy non-conservation issues, particularly when run in full QMD mode
- No meaningful excitation energy calculation implemented or possible
- Apparently no longer maintained

Solutions: *ALREADY IMPLEMENTED IN FLUKA-RQMD*

- Rework from scratch the nuclear final state out of the available info on spectators, correlating the excitation energy to the actual hole depth of hit nucleons
- Fix the remaining energy-momentum conservation issues taking into account exp. binding energies as well
- Use the FLUKA evaporation/fragmentation/fission/deexcitation module

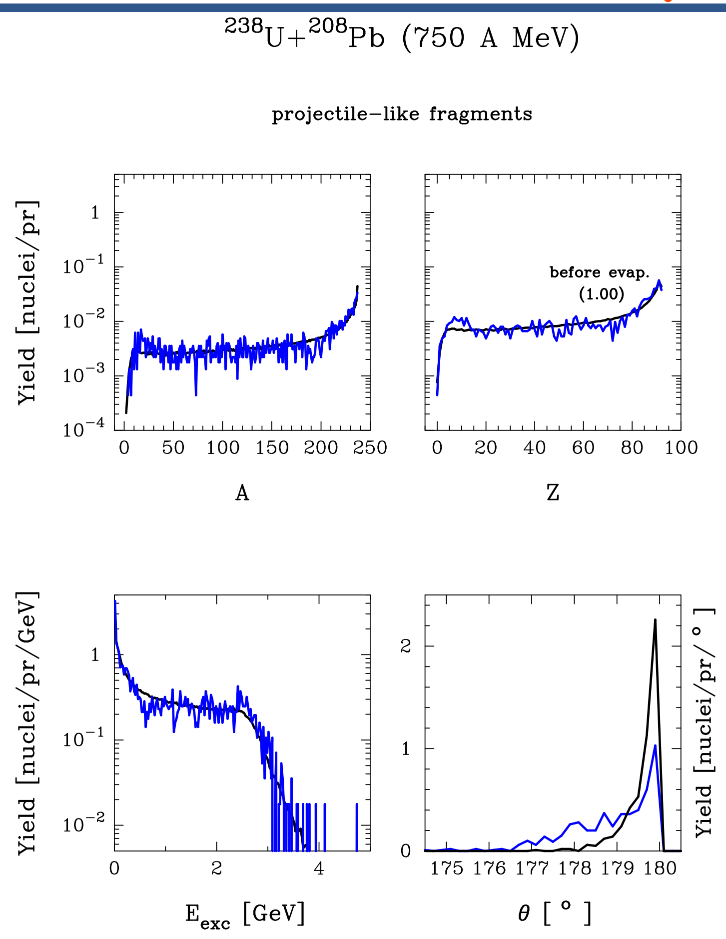
Current solution for A-A interactions below few GeV/n, waiting for an in-house developed model

FLUKA with modified RQMD-2.4 (cascade mode vs QMD mode)



Fragment charge cross sections for 750 MeV/n U ions on Pb for "fast cascade" and "full QMD" modes. Data (stars) from J. Benlliure, P. Armbruster et al. Eur. Phys. J A 2, 193-198 (1998)). Fission products have been excluded like in the experimental analysis.

FLUKA with modified RQMD-2.4 (cascade vs QMD mode) II



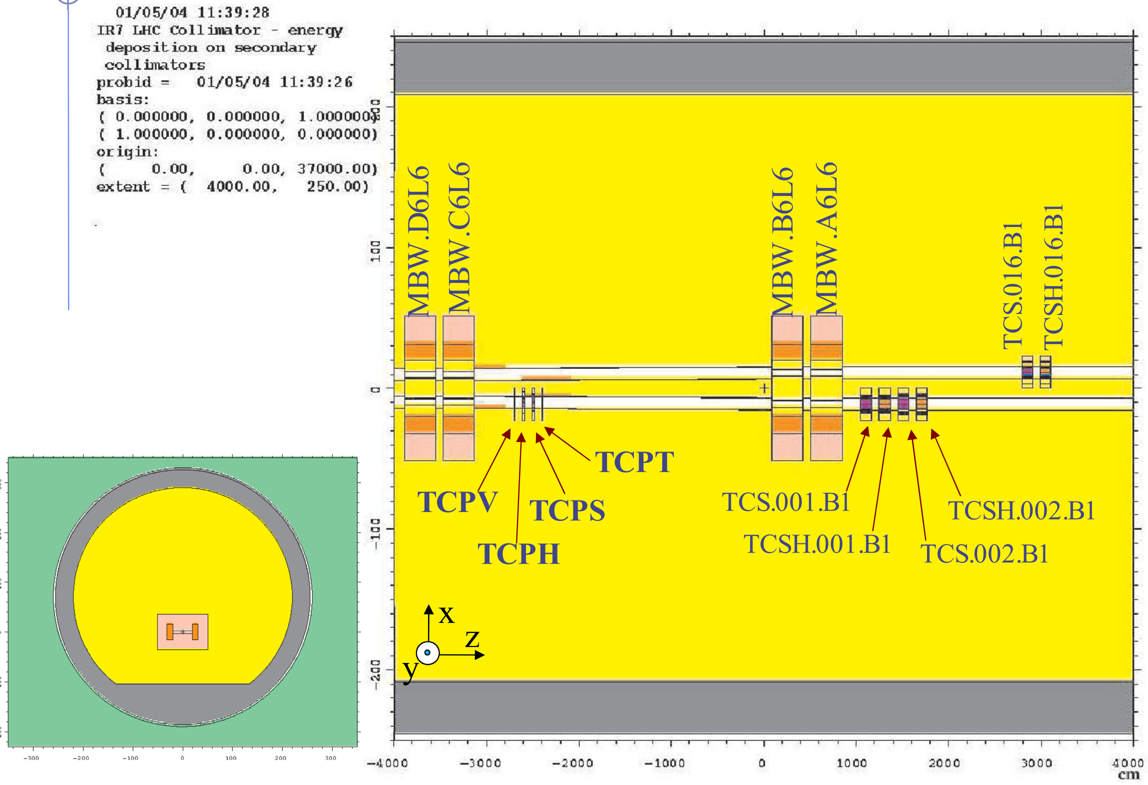
Same problem as before, mass distribution, excitation energy distribution and fragment angular distribution for "fast cascade" and "full QMD" modes.

FLUKA unit in AB

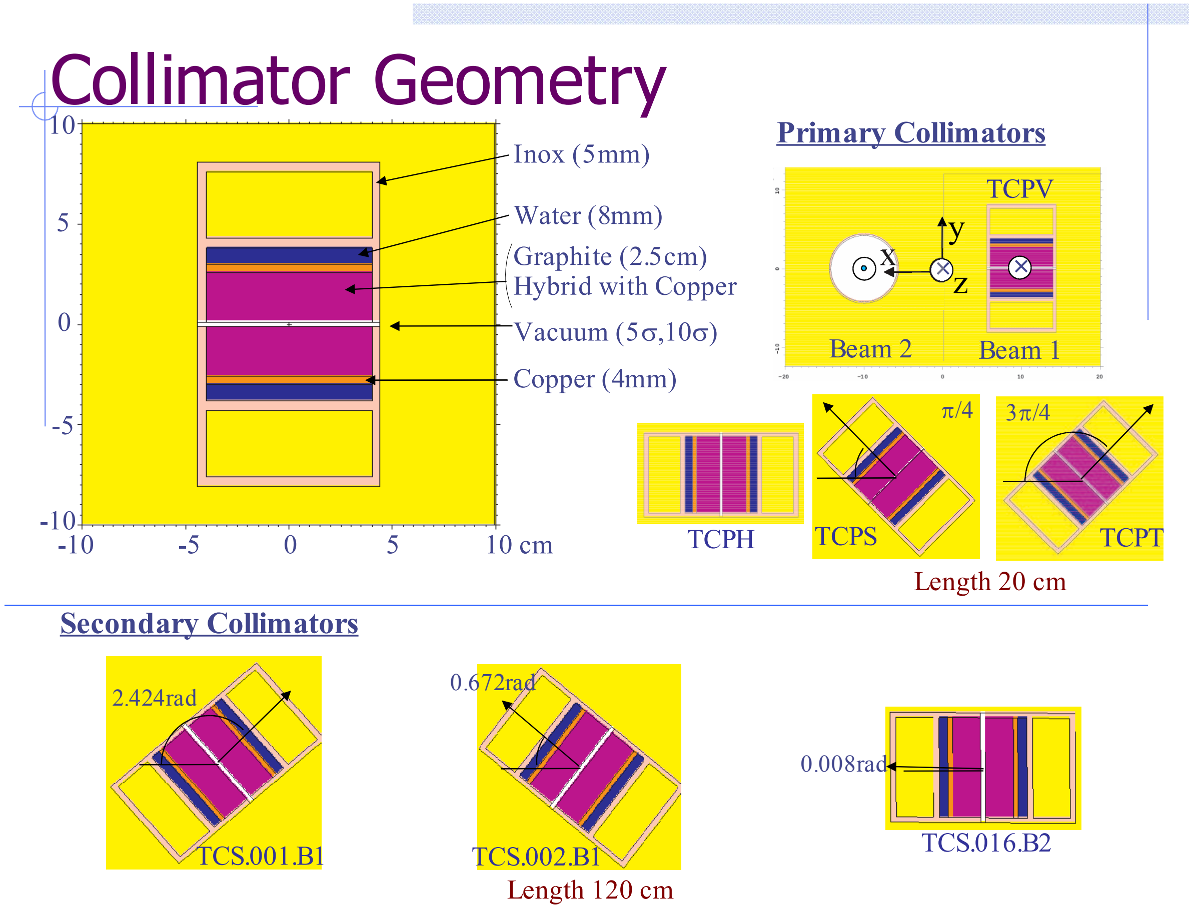
Main goal: supervise and coordinate all (FLUKA) LHC and CNGS related calculations for AB, make the most efficient use of the available manpower, (A. Ferrari), prioritize the request coming from the various groups/activities (E. Chiaveri, S. Myers)

- Manpower: A. Ferrari (coordinator), V. Vlachoudis (ATB/EET section leader), M. Lorenzo-Sentis (fellow, february 2004 →), M. Magistris (fellow, august 2003 →), A. Presland (fellow, september 2003 →), M. Sans-Merce (fellow, → march 2004), L. Santana-Leitner (fellow, april 2004 →), K. Tsoulou (fellow, → july 2004)
- LHC related calculations:
  - LHC Collimator system (beam heating, engineering, machine protection)
  - Radiation damage to electronics
  - Beam dumps and protection elements
- CNGS related calculations:
  - Physics (ν beam, beam monitors...)
  - Engineering (target, windows, beam heating...)
  - INB (together with RP)

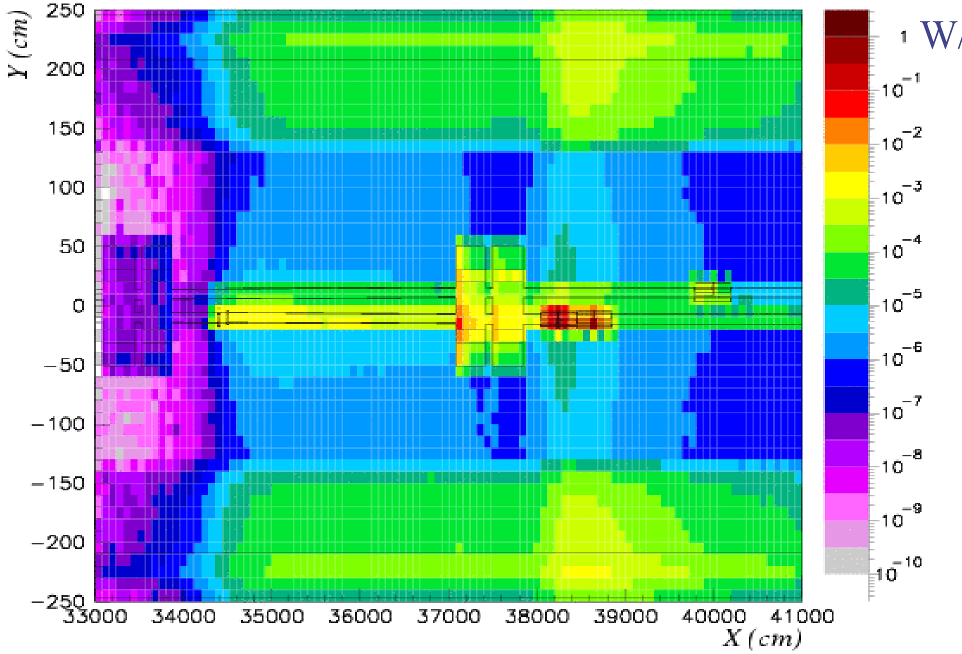
IR7 Geometry



FLUKA tasks for LHC and CNGS: LHC coll. II



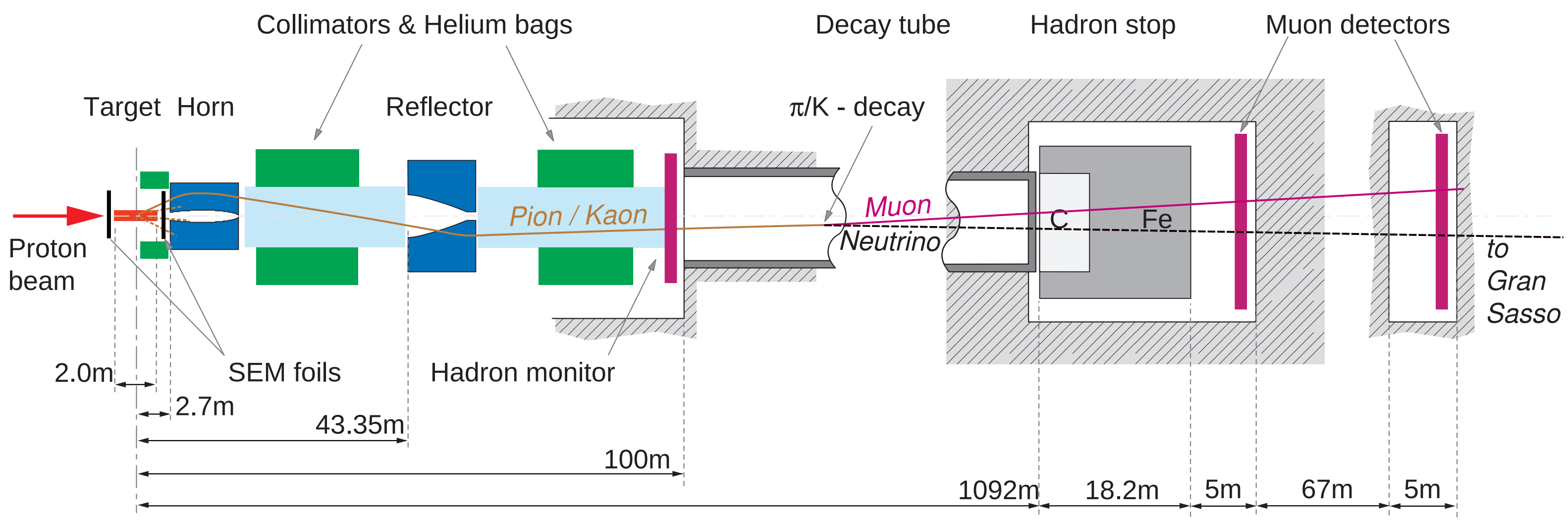
TCPV - Energy deposition



W/cm^3

Average energy deposition per 4 10^{11}p/s on tunnel and beam elements for -1 < Y < 1m

CERN Neutrino to GranSasso



400 GeV/c protons, double fast extraction, $5\ 10^{13}$ protons every 6 s

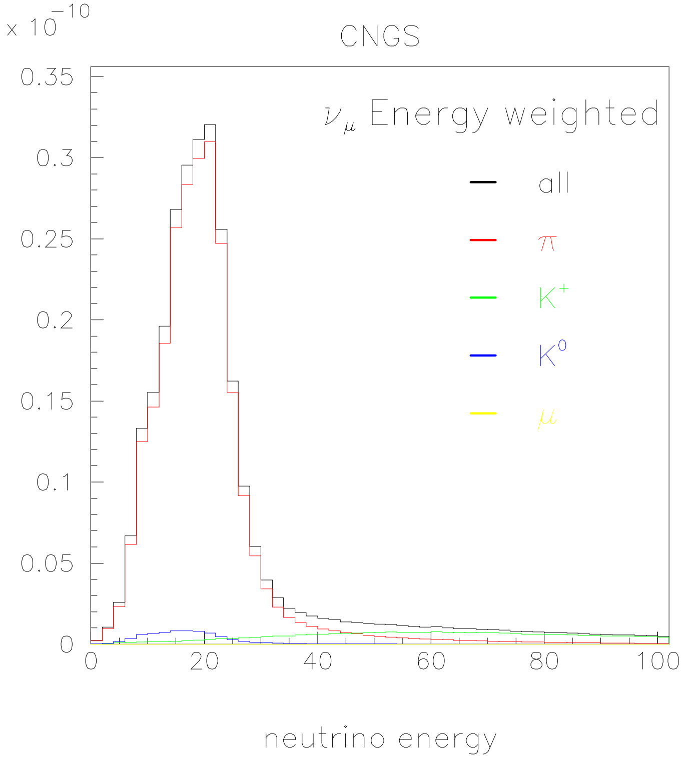
Thin graphite target (⌀5/4 mm, 13 bars 100 mm each)

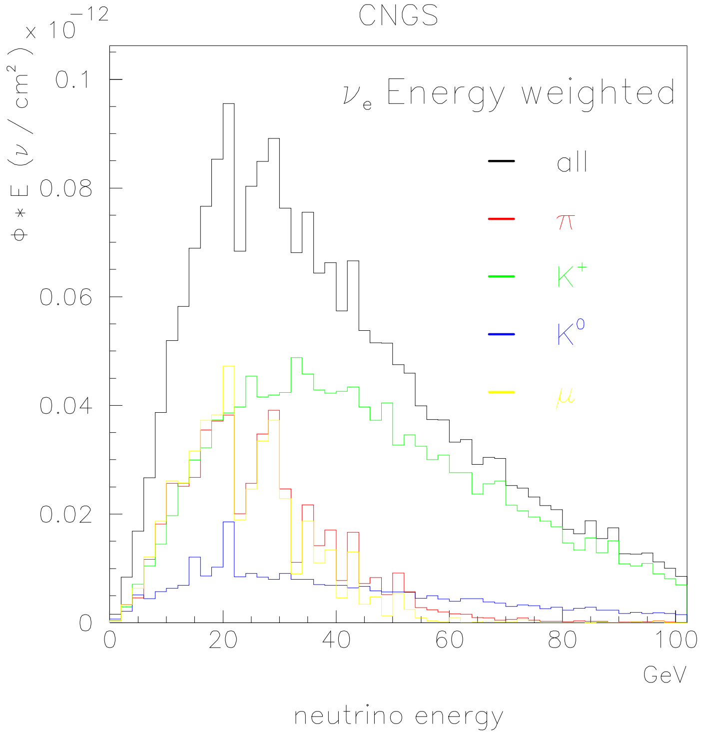
Two magnetic lenses focalize 35 and 50 GeV positive

1 Km decay tube

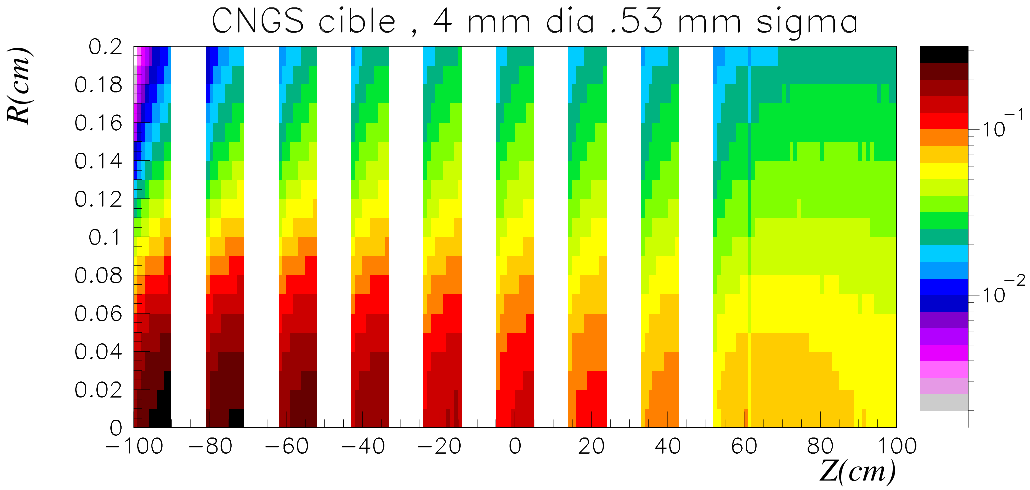
730 Km to Gran Sasso

Nice agreement with experiment $\rightarrow$ confidence in prediction for CNGS





Baseline CNGS target : 13 Graphite rods, $\varnothing$=5(x2) 4(x11) mm, total length 2000 mm, Carbon length 1280 mm



Energy deposition in the standard CNGS target, in GeV/cm^3/primary, for a 400 GeV proton beam with σ=0.53mm

Conclusions

- Solid framework for the next years through the official establishment of a joint CERN-INFN FLUKA project. All issues with unauthorized versions cleaned up once forever
- 2002 and 2003 milestones largely achieved, many critical milestones for 2004, including (crossing fingers) the first full public release of the code under the licensing conditions defined in the CERN-INFN agreement
- New AB FLUKA unit established in an attempt to tackle efficiently urgent LHC (and CNGS) beam-machine interaction problems. Possible interferences with the milestone and release work, due to the conflicting requirements for some key players. Careful planning/prioritazion required
- Ion shower capabilities now available to the generic users: major achievement for a) Space radiation studies, b) Therapy problems (particularly when coupled with the CT scan → voxel geometry features), c) LHC ions beam-machine interaction studies

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