Object-Oriented Developments in MARS15 Code

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Outline

- Introduction
- Tools for replacement 32-bit CERNLIB packages FFREAD and HBOOK
- Handling arbitrary size cross section tables
- ROOT-based geometry
- ROOT-based beam line builder

Main Goal

- Add flexibility and overcome the limitations imposed by using single precision for input data and histograms.
- Increase productivity of MARS simulations of beam-induced effects in elements of newly designed or upgraded accelerators.
- Improve reliability of MARS results in above applications.

Base for Implementation

- ROOT - Object-oriented Data Analysis Framework (http://root.cern.ch)
- GNU Scientific Library (GSL)

  (http://www.gnu.org/software/gsl/)
- MAD-X (http://madx.web.cern.ch/madx/)
- Language - C/C++, C++ linker to build MARS applications

Replacement for FFREAD

- Does not depend on computer achitecture
- Allows arbitrary precision for numbers on input
- Does not require changes in input files for existing MARS apllications

Example

```
      CHARACTER*32 A(2)
      INTEGER  IND(40)
      REAL R(6)
      LOGICAL TLOG(4)
      DOUBLE PRECISION DUB(3)
      COMMON/ABRA/ A,IND,R,TLOG,DUB
      CHARACTER (LEN=*), PARAMETER ::
     & fmtline='A[2]/C32:IND[40]/I:R[6]/F:TLOG[4]/O:DUB[3]/D'
......................Default values can be defined here......................
      CALL FMTSET("INP.DAT")                        !  define input file name
      CALL FMTKEY('TEST',A,fmtline,len(fmtline)) !  key definition
      CALL FMTGO()                                  !  processing of the file
```

Content of INP.DAT:

```
First string is task description
C this is a comment
C Strings of arbitrary size can be used for comments
TEST  '7XXXX7' '8UUUUUUUUUUUU8' ! This is another kind of comment
      2   20=-2  42=-4          ! IND(1)=2,  IND(18) = -2, IND(40)=-4
      43.0   44.0   48=48.0    !  R(1)=43, R(2)=44., R(6)=48.
      49=4*T                    !  TLOG = TRUE
```

Replacement for HBOOK Histogramms

- Handler to use ROOT histograms
- Interface functions to book and fill 1,2-D histograms from Fortran programs
- No preliminary inialization required
- Handler takes care of saving histograms to file if program unexpectedly interrupted by signal or by stop operator in Fortran code

Usage Example for ROOT 2D Histograms

Definition of parameters:

```
TYPE(INTEGER), PARAMETER::ID601=601, nbinsx=200, nbinsy=200
TYPE(DOUBLE PRECISION), PARAMETER::xlow= -1.d0, xup = 1.D0
TYPE(DOUBLE PRECISION), PARAMETER::ylow =-1.d0, yup = 1.D0
CHARACTER (LEN=*),PARAMETER::H601_Name='BeamCS0'
CHARACTER (LEN=*),
PARAMETER::H601_Title='Transverse coordinates at IP'
```

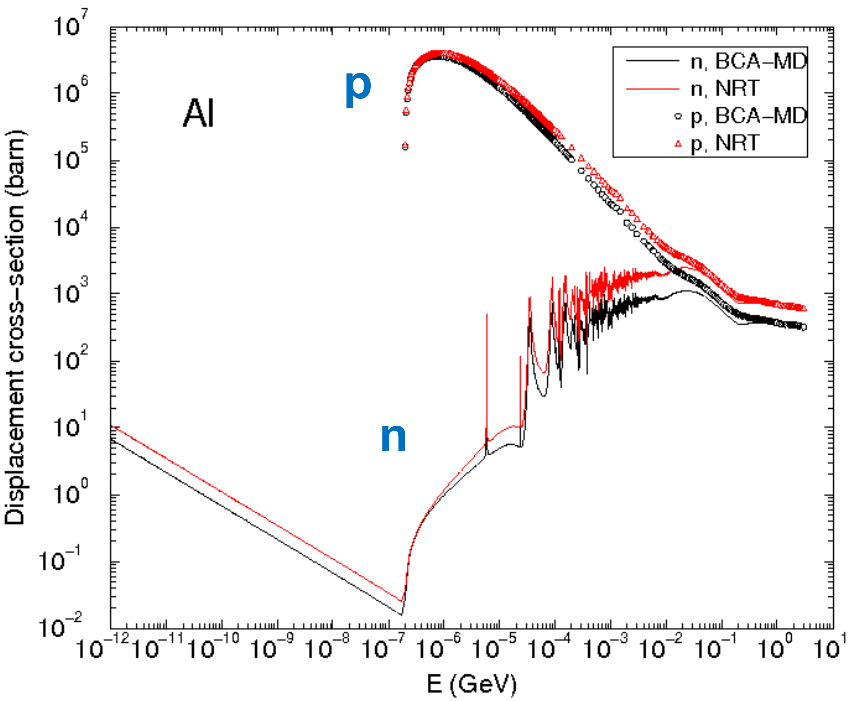
Booking 2D histogram:

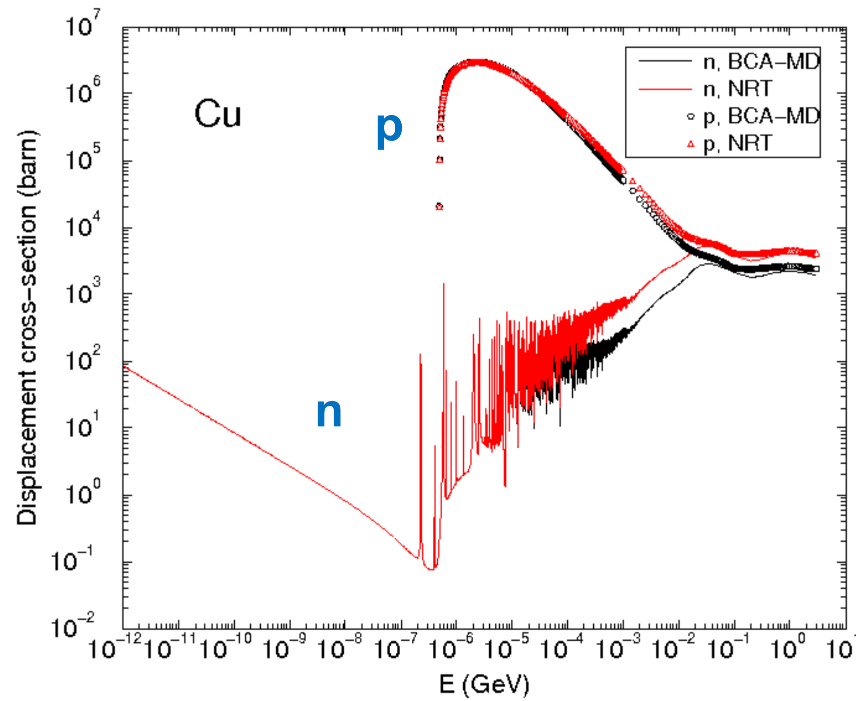
```
CALL book_h2d(ID601,H601_Name,H601_Title, nbinsx,xlow,xup, nbinsy, ylow,yup)
```

Filling 2D histogram:

```
IDH=601
call  fill_h2d(IDH,x,y,w)
```

Handling DPA x-sections





For neutrons from 10-5 eV to 200 MeV: NJOY99+ENDF-VII database, for **393 nuclides**: NRT (industry standard) corrected for experimental defect production efficiency.

Individual energy grid for each nuclide: 400 to 25,000 entries

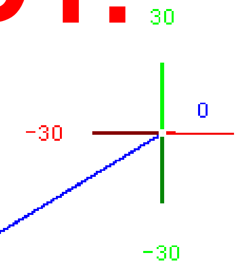
Handling Large Cross Section Tables

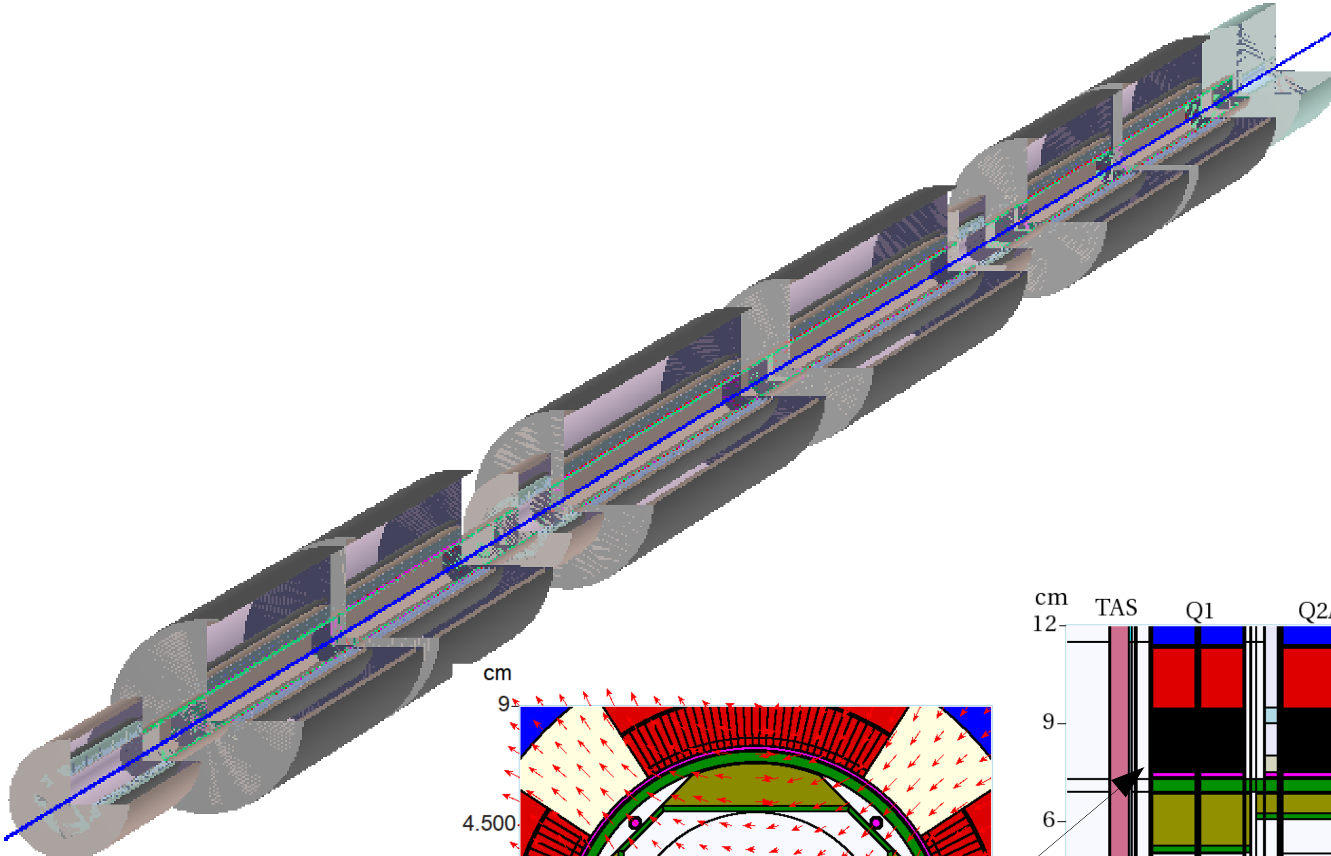
- Database handlers are implemented as static sigleton objects created before execution of first statement in MARS main program.
- Location of the databases in a file system is set by means of environment variable $MARS15DAT.
- Database handlers are immediately available after start of application, no addtional calls for initialazation are required in MARS code, it is enough to link application and library where module is implemented.
- Memory for data is allocated dynamically at the tracking time only for substances visited by particles being tracked.
- Access from Fortran code to C++ data handlers is provided by means of interface functions (wrappers).

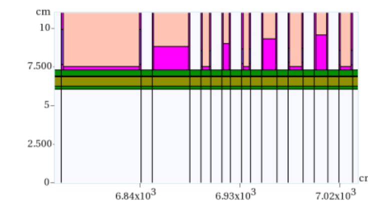
ROOT Geometry

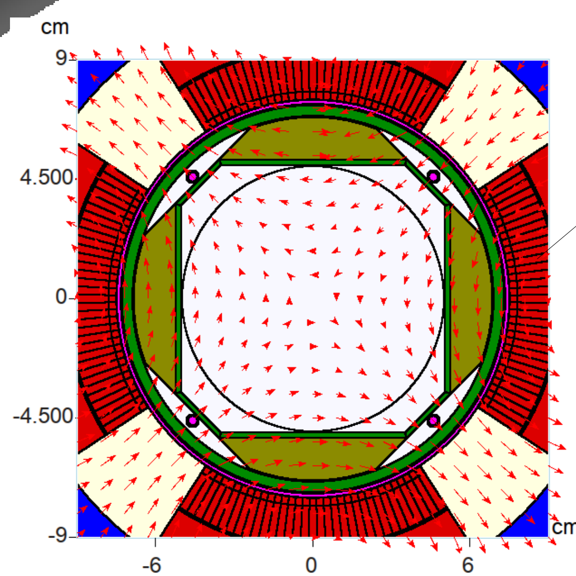
- ROOT geometry developed for MARS can be used in GEANT4/GEANT3 simulation for cross-checking of results.
- ROOT geometry, developed by third-party collaborations can be directly used in MARS.
- ROOT-based beam line builder allows to simplify geometry creation for beam lines.
- Work in progress on Extended-to-ROOT geometry converter

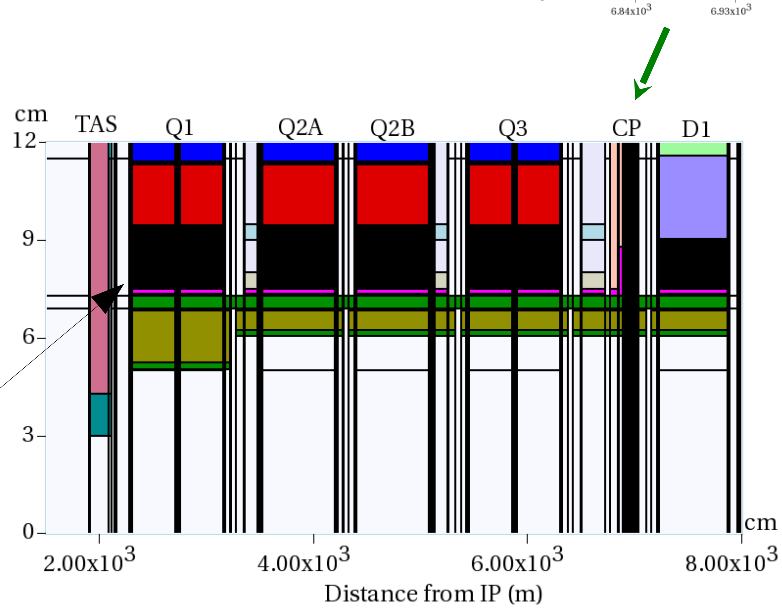
150-mm HL-LHC IT and D1: MARS15 model



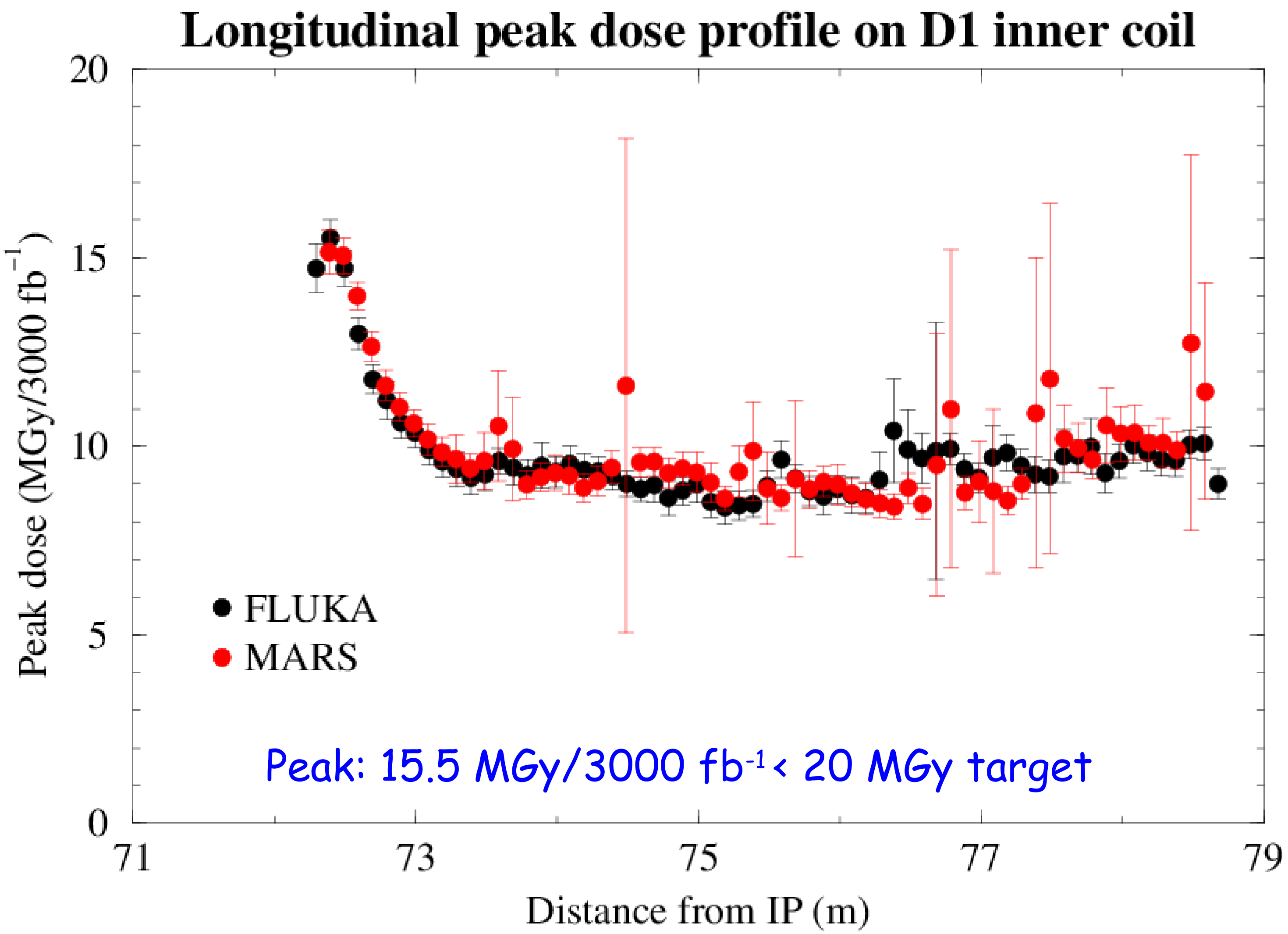




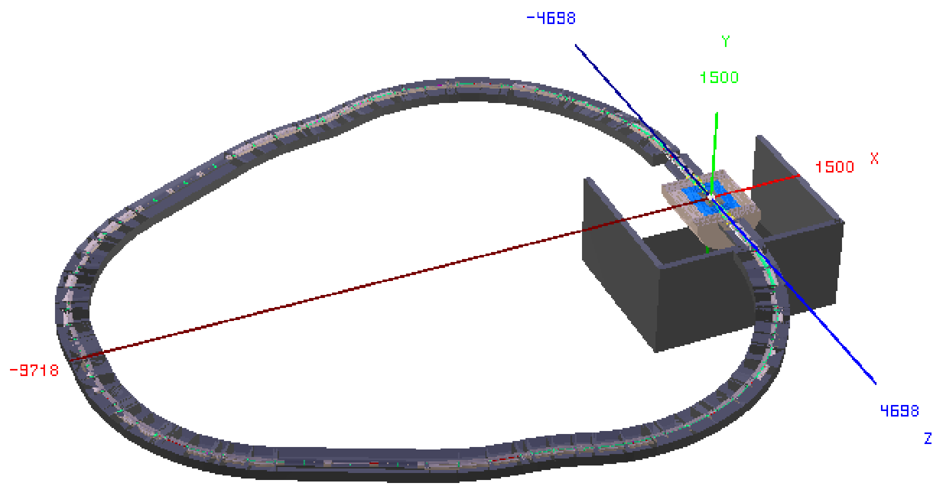




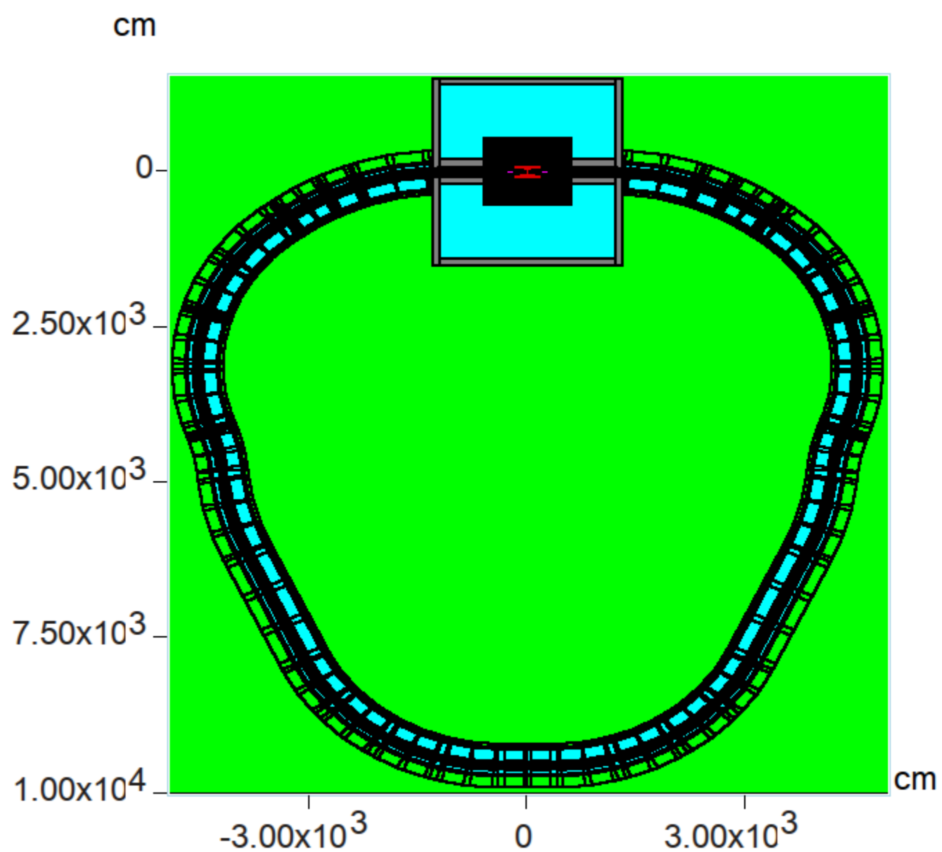
150mm D1: Peak Dose Longitudinal Profile



Higgs Factory (HF) ROOT-based Model in MARS

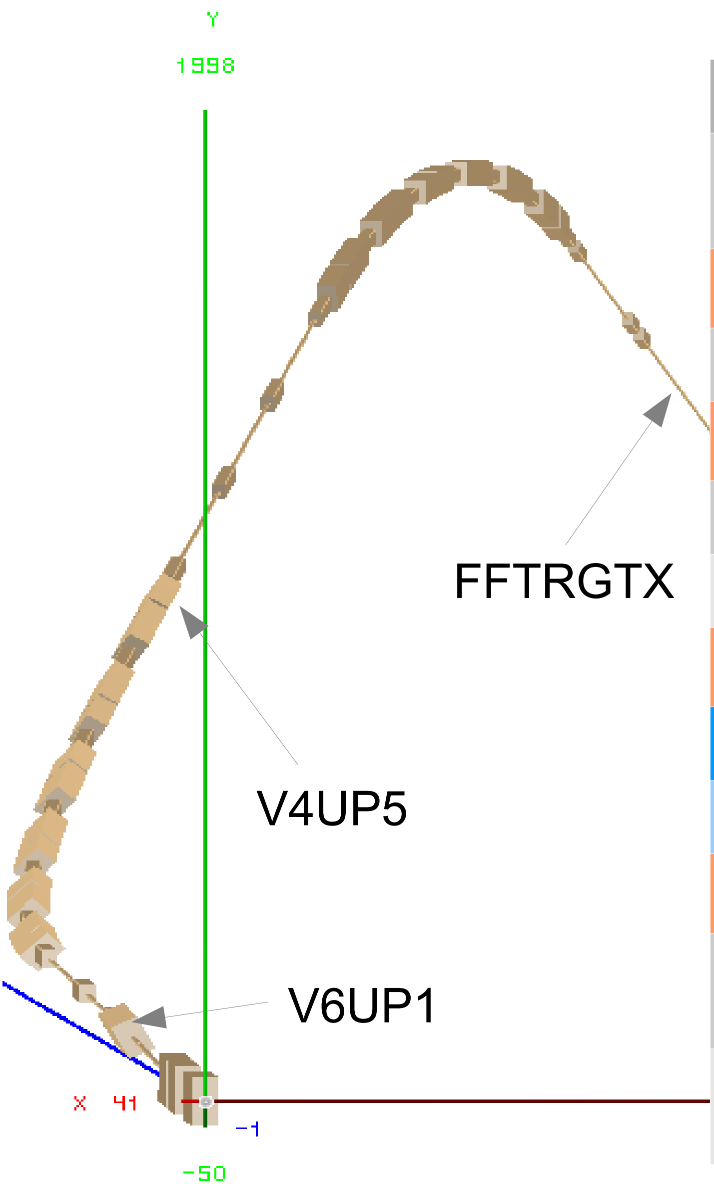


3D visulization by means of ROOT OpenGL viewer



Horizontal slice in MARS GUI

3-D LBNE primary beam line



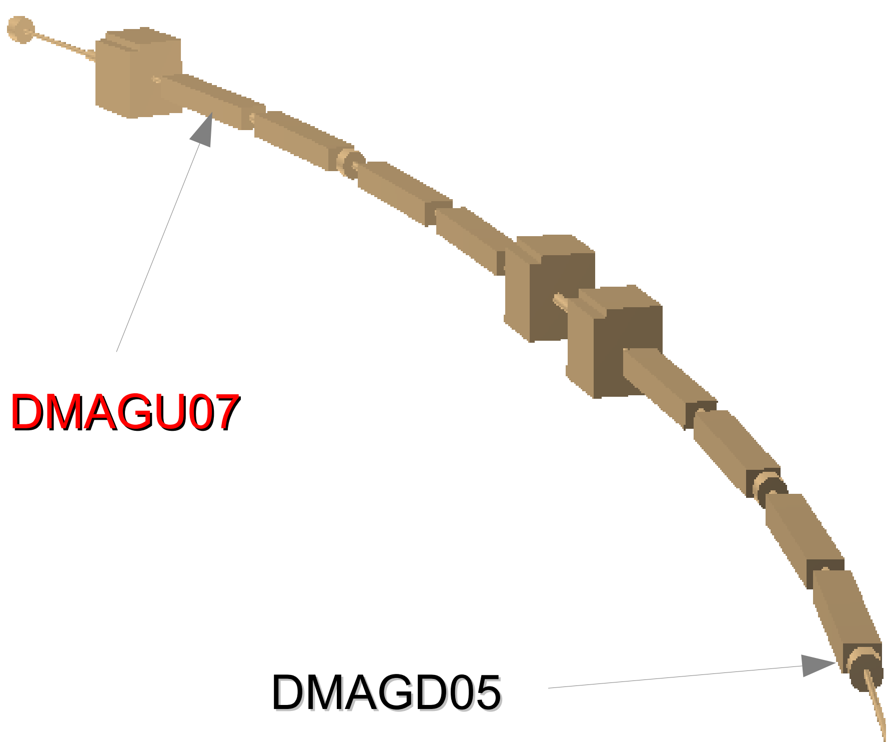
MARS geometry for LBNE beam line

Comparison of element positions calculated by beamline builder with MAD

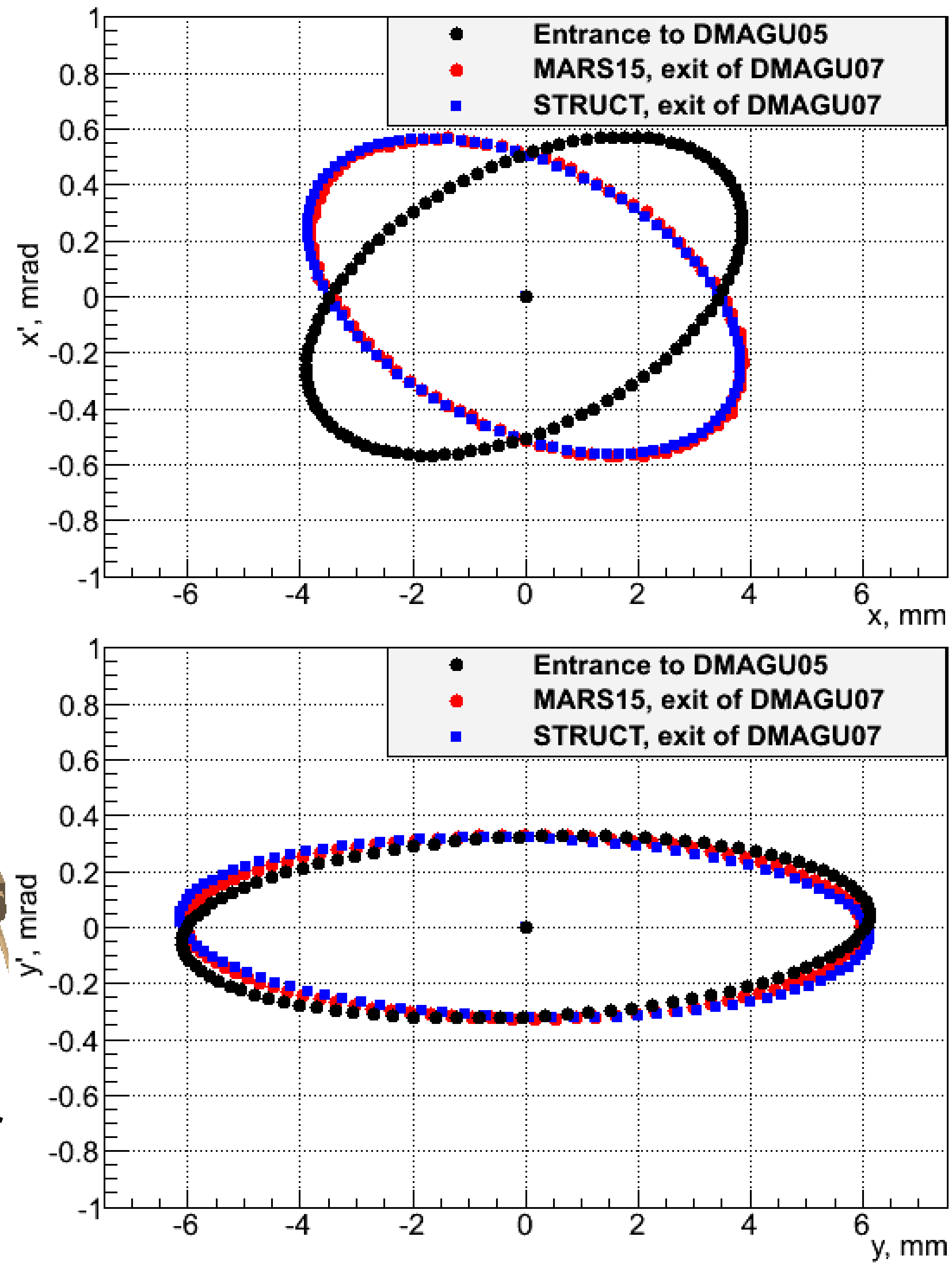
	Element position			Rotation angles		
	X, m	Y, m	Z, m	Theta, mrad	Phi, mrad	Psi, mrad
Begin BUMPY10						
begin	0.0	0.0	0.0	0.0	0.0	0.0
RBEND, V6UP1						
MAD	-0.02595	0.56972	32.87976	-8.509	10.315	0.158
BLB	-0.02595	0.56972	32.87976	-8.509	10.315	0.158
RBEND, V4UP5						
MAD	-4.41512	5.33972	138.67405	-102.388	114.125	0.625
BLB	-4.41512	5.33973	138.67405	-102.388	114.125	0.626
Last drift, FFTRGTX						
MAD	-33.3500	10.4473	370.47822	-125.317	-101.033	0.
BLB	-33.3499	10.4473	370.47828	-125.317	-101.033	0.

ROOT based beam line builder test:

comparison with STRUCT tracking code

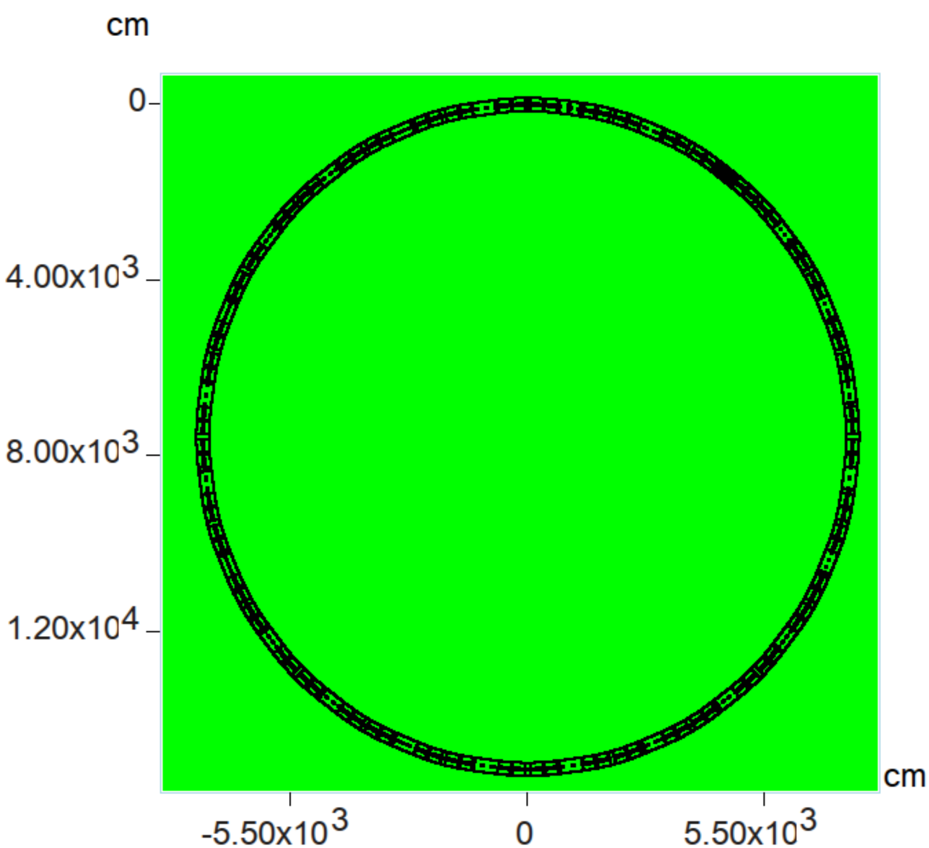


MARS geometry for the FNAL booster sections 5 and 6

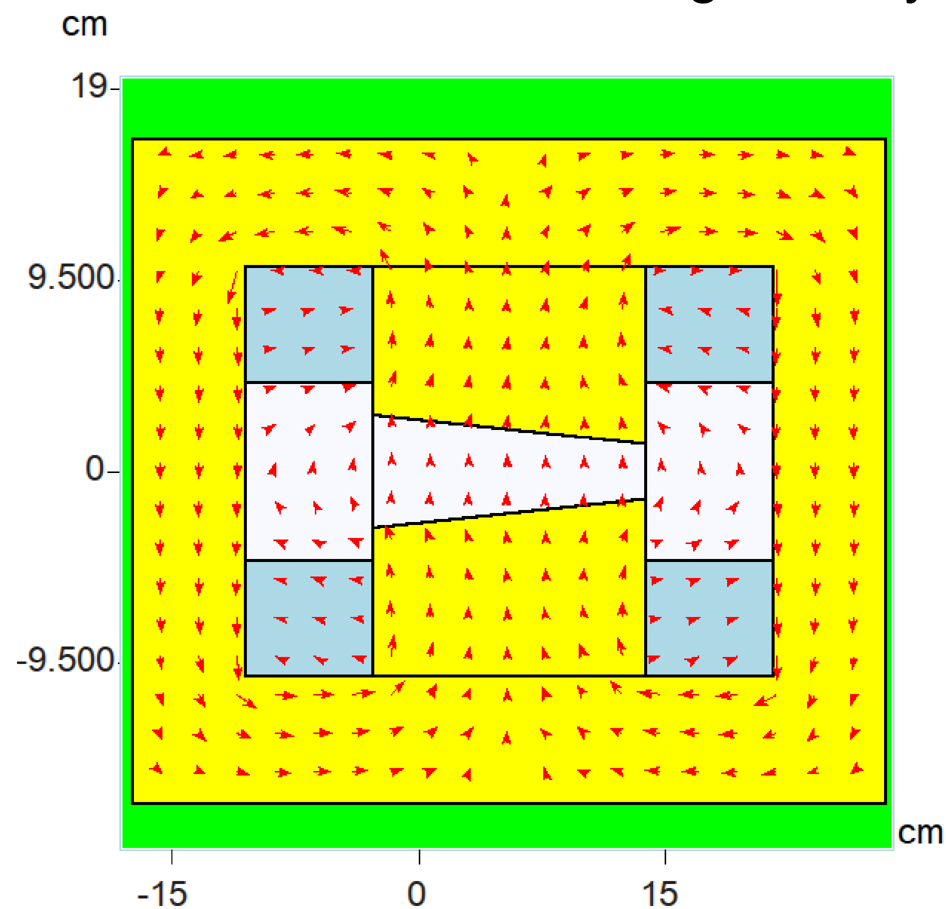


MARS/MAD-X Geometry Builder

Current sequence and survey tables in MAD-X are used to build geometry



Common view of Booster in MARS15 GUI



Cross section of FMAG in the Booster ring

MARS and MAD-X PTC module

Trajectories in horizonal plane

MAD-X/ROOT/MARS Integration

- MAD-X is compiled as library.
- Interactive mode is disabled as well as signal handler, set of new functions is implemented.
- Geometry builder is implemented, MAD-X input file is used now to build ROOT geometry.
- Aperture boundary check based on ROOT geometry is implemented for MAD-X PTC tracker, now in testing/ debugging stage.
- Functions to exchange particles between MARS and MAD-X tracker engines implemented.

Conclusion

- Presented software, created for solving applied tasks in projects LBNE, PIP, HiLumi LHC, & MAP, is used in MARS upgrade.
- Newly developed tools allow increase of productivity of MARS simulations.

General Workflow for Beam Loss and MDI Tasks