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](http://root.cern.ch))
- Language - C/C++, C++ linker to build MARS applications
Replacement for FFREAD

- Does not depend on computer architecture
- Allows arbitrary precision for numbers on input
- Does not require changes in input files for existing MARS applications
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' '8UUUUUUUUUUUUUUU8' ! 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 Histograms

- Handler to use ROOT histograms
- Interface functions to book and fill 1,2-D histograms from Fortran programs
- No preliminary initialization 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:

```plaintext
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:**

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

**Filling 2D histogram:**

```plaintext
IDH=601
call fill_h2d(IDH,x,y,w)
```
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 singleton 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 additional calls for initialization 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

Longitudinal peak dose profile on D1 inner coil

Peak: 15.5 MGy/3000 fb\(^{-1}\) < 20 MGy target
Higgs Factory (HF) ROOT-based Model in MARS

3D visualization by means of ROOT OpenGL viewer

Horizontal slice in MARS GUI
### Comparison of element positions calculated by beamline builder with MAD

<table>
<thead>
<tr>
<th>Element position</th>
<th>Rotation angles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X, m</td>
</tr>
<tr>
<td>Begin BUMPY10</td>
<td></td>
</tr>
<tr>
<td>begin</td>
<td>0.0</td>
</tr>
<tr>
<td>RBEND, V6UP1</td>
<td></td>
</tr>
<tr>
<td>MAD</td>
<td>-0.02595</td>
</tr>
<tr>
<td>BLB</td>
<td>-0.02595</td>
</tr>
<tr>
<td>RBEND, V4UP5</td>
<td></td>
</tr>
<tr>
<td>MAD</td>
<td>-4.41512</td>
</tr>
<tr>
<td>BLB</td>
<td>-4.41512</td>
</tr>
<tr>
<td>Last drift, FFTRGTX</td>
<td></td>
</tr>
<tr>
<td>MAD</td>
<td>-33.3500</td>
</tr>
<tr>
<td>BLB</td>
<td>-33.3499</td>
</tr>
</tbody>
</table>

### MARS geometry for LBNE beam line

#### Diagram

- FFTRGTX
- V6UP1
- V4UP5

3-D LBNE primary beam line
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 horizontal 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.