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Summary of Mini-Workshop on UAL and CESR, LHC, RHIC lattice description

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Summary of Mini -Workshop on UAL and CESR, LHC, RHIC lattice description

LNS, Cornell, July 10-11, 1997

F.Pilat, N.Malitsky, R.Talman, S.Tepikian, G.Trahern, J.Wei

The main ***goals*** of the mini-workshop were to review the status of the UAL (Unified Accelerator Library) software and the projects that use this software for machine lattice description, such as CESR, RHIC and the LHC and to make a plan for integrated software development for UAL and its applications. Another goal was the discussion of simulation software tools needed for the US-LHC collaboration in general and in particular Ftpot (fortran teapot).

List of participants: Cornell N.Malitsky (NM),T.Pelaia (TP), D.Sagan (DS), R.Talman (RT)
BNL F.Pilat (FP), S.Tepikian (ST), G.Trahern (GT), J.Wei (JW)

The ***agenda*** for the 2 days was the following:

Thursday, 10 July

9:00-12:00	NM	Description of PERL SMF interface and discussion of open questions.
	RT, NM	Implementation of SMF LHC lattice description (also Ftpot). Discussion.
	FP, GT	Special problems of incorporating measured field errors.
1:30-2:30	FP, JW	Accelerator physics seminar at Wilson Lab. "Plans for RHIC and Report on Commissioning So Far".
3:00-5:00	NM, FP, GT	working group on UAL (computer).
	RT, ST, JW	working group on FTPOT (computer).

Friday, 11 July

9:00-12:00	NM	Description of PERL SMF interface.
	GT	SMF implementation of RHIC.
	TP	PERL interface to CESR database.
	DS	CESR lattice description - BMAD.
	JW	Description of BNL's LHC responsibilities.
	FP	Details of LHC description (SMF).
	ST	Details of LHC description (Ftpot).
1:30-3:00	All	Planning for the future.

What follows is an attempt to summarize the various topics that arose during the presentations and the discussions.

UAL: Perl interface, new SMF, etc.

The **SMF classes** were modified over the last year and new secondary metadata collections were added for the purpose of optimization. The software is now stable and no major revisions (other than possible bug fixing) are foreseen in the near future.
The **Perl interface** to UAL was described and a copy of the slides can be found in the attachments. The interface is very flexible and supports advanced features such as superposition of elements, families of elements, etc. A few additions to the interface were suggested and agreed upon, during the working sessions, such as the methods *name(arg)*, to set the name of a Lattice Element, and *index(name)* which returns the index of a Lattice Element keyed by name.
A new Perl construct, the **Perl Sequence**, is being developed, to facilitate the task to initialize SMF from a MAD (Version 8) sequence.

CESR SMF

A preliminary description of CESR exists already and a **Perl interface** is being developed to facilitate the build-up of the SMF from the CESR "database" - a collection of several heterogeneous file describing the accelerator.

RHIC

The RHIC SMF description, developed last year, worked with the previous release of the SMF software: data from the **RHIC database** are manipulated and used to feed the (old) SMF classes in memory (see attachments). The software has to be updated to use the **Perl interface** to build the new SMF.
Once the RHIC SMF is built, the full **Teapot++** is needed for the purpose of simulation. At the moment, the analysis and correction part are not yet implemented. For that reason, and that of backward compatibility, it is necessary to 'repair' the broken link between SMF and fort.7, that is the link between SMF/Teapot++ and Fortran Teapot.

LHC

Many software requirements arise from the collaboration with the LHC and the need to build up a simulation environment that supports it. (see attachments).

In the **short term** (< 6 months) the following tools will be used:

MAD: The official CERN environment is MAD and all machine and error description of the LHC is based on MAD syntax and constructs (sequence, scripts and subroutines). One needs to be able to continue running MAD jobs and tracking for the purpose of comparing results. The capability of doing so is already in place both on the BNL and CERN systems.
SIXTRACK: Sixtrack is used purely as a tracking and postprocessing engine since it inherits machine description, errors and corrections from MAD. MAD generates output that are sixtrack input files.
FTPOT: The capability exists now to convert MAD "twiss" output files to TEAPOT (fortran) input files. A previously existing program was modified before and during the workshop to achieve this for the LHC. This also opens the possibility of LHC tracking with TEAPOT.

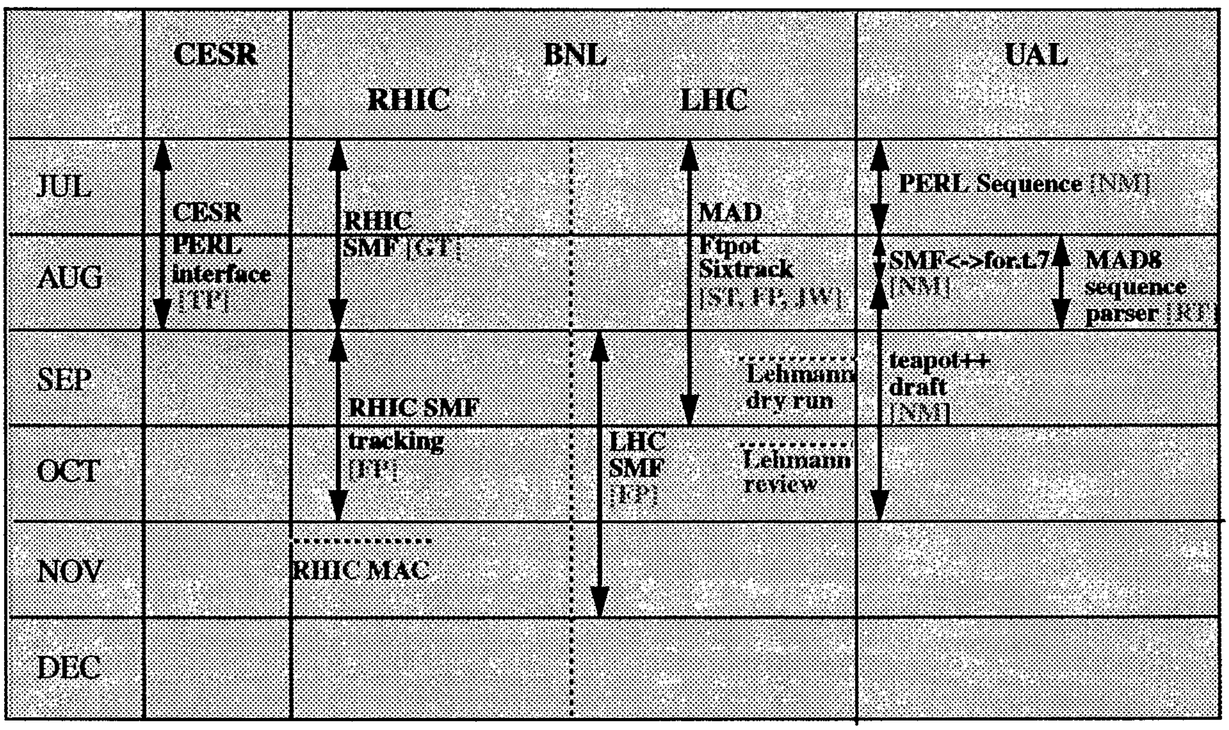
In the **medium term** (~6 months) we build and use the **LHC SMF**:

GenElement definitions and the *sequence of LattElements* will be built from the Version 8 MAD file as translated (using an existing translator) from a Version 9 MAD file. A *Perl sequence* construct is being developed to aid the task of capturing the sequence structure in Perl. A *parser* of MAD 8 file will have to be written.

The *deviations to LattElements*, that carry the errors and corrections information, will be built from a MAD output file, the STRUCTURE file. The latter is a flat machine output which lists relevant errors information element by element.

DEVELOPMENT PLAN

This is the plan we discussed and agreed upon for integrated UAL software development in the next few months, with some superimposed deadlines arising from the RHIC and LHC projects.



For the sake of clarity I will spell out the meaning of the keywords on the arrows.

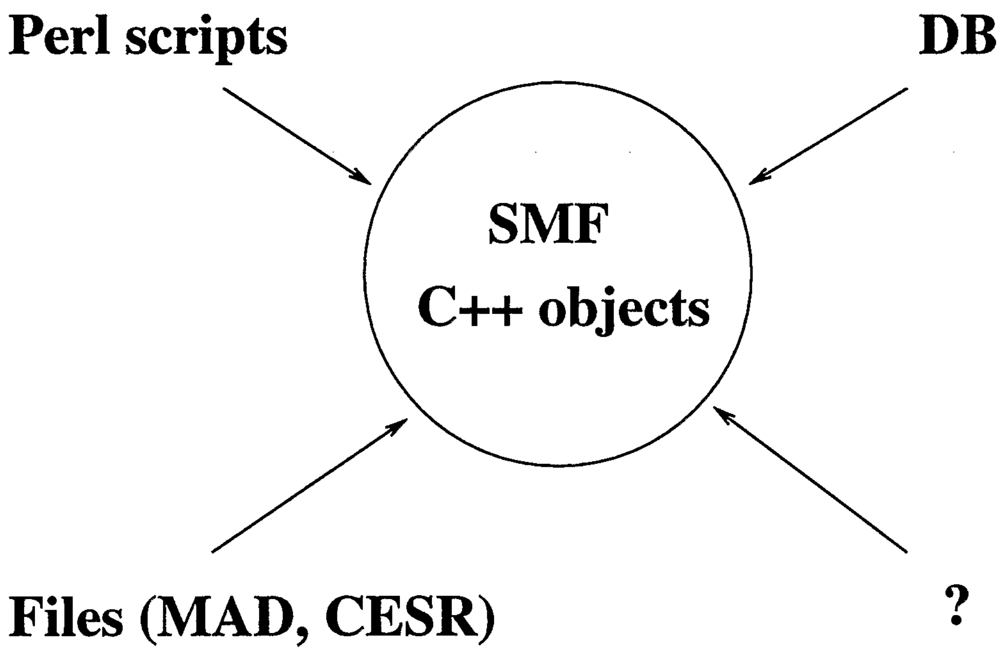
CESR PERL interface: Perl code to facilitate build up of the CESR SMF from CESR database.
RHIC SMF: Conversion of RHIC SMF code to feed Perl Interface to (new) SMF.
RHIC SMF tracking: Tracking RHIC described by (new) SMF. It will initially use FTPOT for corrections and teapot++ for tracking (hence needs the SMF<-->fort.7 connection). Will use full teapot++ when teapot++ draft is available.
MAD Ftpot Sixtrack: Short term tracking effort for LHC, on BNL and CERN systems.
LHC SMF: More specifically, "real machine" level of LHC SMF. Needs the MAD8 LHC sequence parser.
PERL Sequence: Perl construct to aid the writing of the LHC MAD8 Parser.
MAD8 Sequence parser: Captures MAD8 LHC sequence and uses PERL Sequence.
SMF<-->fort.7: Code that links (both ways) the SMF to Fortran Teapot.
teapot++ draft: C++ Teapot, including most analysis and corrections. Draft, to be tested.

PERL SMF Interface.

- FAQ
- Present interface
    - GenElement
    - Line
    - Lattice
    - LattElement
- Extension
    - Sequence

Q: Why is the SMF good ?

A: It provides hierarchical and flat accelerator representations that can be initialized from different sources.



Q: Why is PERL good ?

A: It provides

- **standard facilities (containers, statements, subroutines, etc.)**
- **object-oriented technologies (packages, objects, etc.)**
- **reusable components (library modules, packages)**
- **interface to C/C++ libraries**

to implement simple and optimal solutions.

Generic Elements.

```
$smf->elements->declare($Multipole, "marcf01, ...)          # declare elements

$marcf01->set(1.2*$L, 2.6e-06*$KL0, 2.54e-3*$KL1);          # set attributes
$marcf01->add(2.54e-3*$KL1, 2.3e-5*$KTL1);                  # add attributes
$value = $marcf01->get($KL1);                               # get attribute
$marcf01->remove($KTL1);                                    # remove attribute

$marcf01->rms->set(2.54e-4*$KL1,  2.0e-6*$KL3);             # set rms uncertainties
$marcf01->rms->add(2.4e-5*$KTL5,  3.0e-5*$KL5);             # add rms uncertainties
$rms    = $marcf01->rms->get($KL1);                         #  get rms uncertainty
$marcf01->remove($KL1);                                     # remove rms uncertainty
. . .
$marcf01->remove();                                         # remove all attributes
$marcf01->rms->remove();                                    # remove all rms uncertainties
```

Lines.

```
$smf->lines->declare("hcfd", "hcdf, "cellff", "ring"); # declare lines

$cellff->set($hcfd, $hcdf);                  # set elements and lines

$cellff->add($hcfd);                         # add elements and lines

$ring->set(-75*$cellff);                     # reflection and repetition
```

Lattices.

```
$smf->lattices->declare("accelerator");              # declare lattices

$accelerator->set($ring);
```

Lattice Elements.

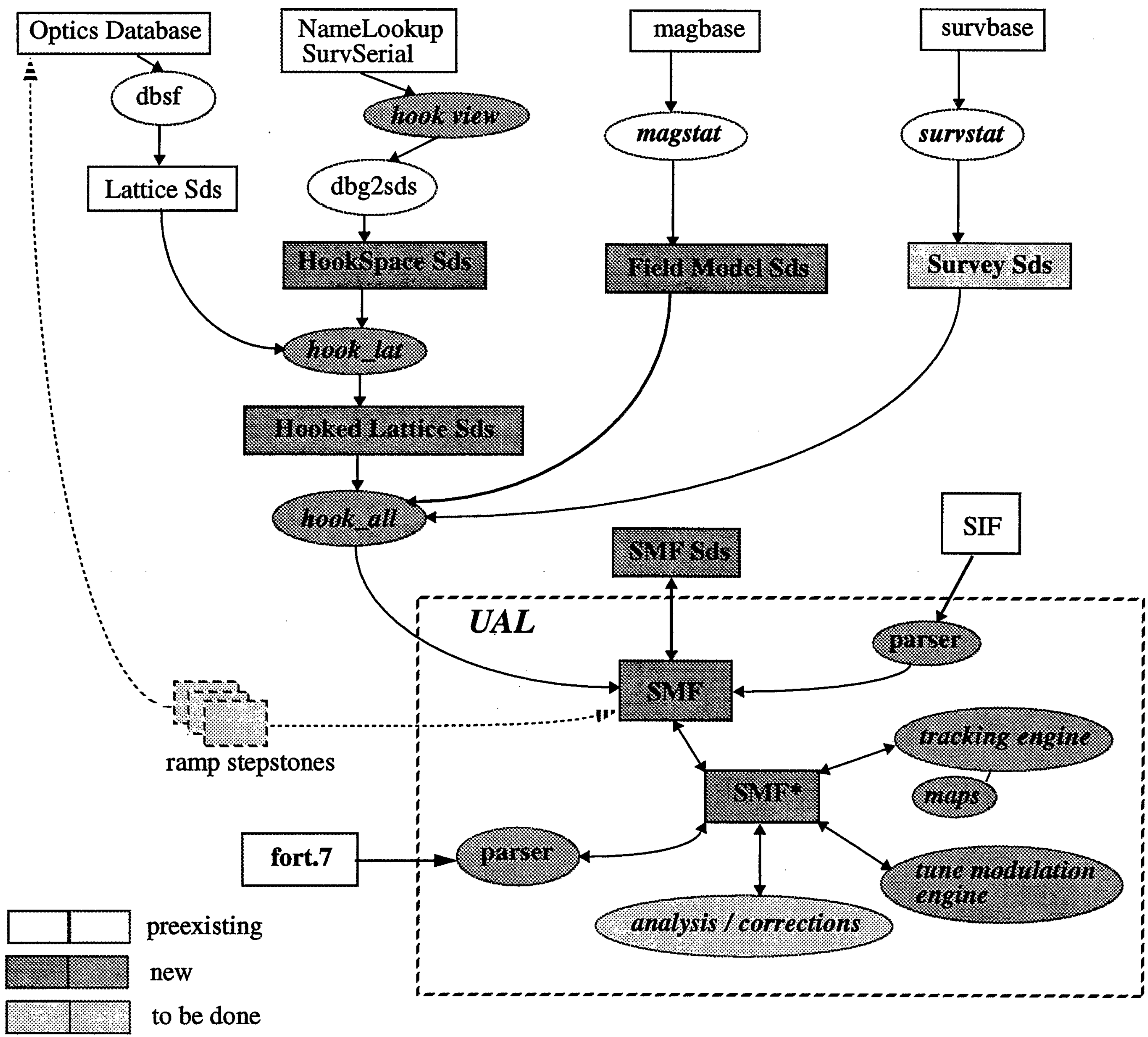
```
@array = $accelerator->indexes("name_of_gen_element");  # select latt. elements
                                                         # with the same generic
                                                         # element

for($i=0; $i < @array; $i++) {

      $index = $array[$i];
      $element = $accelerator->element( $index );        # get latt. element
      # set, add, get, or remove attributes (see GenElement interface )
}
```

Sequence of lattice elements.

```
my $sequence = new Sequence();
                                  pointer to the generic element
                                                 deviations

$sequence->set(
   [ element("name1", $gen_element, [1.2e-3*$KL1, ...]), {at => 255, from => "name2"} , ],
   . . .,
);

                          names of latt.elements

$accelerator = $sequence->lattice("name");
```

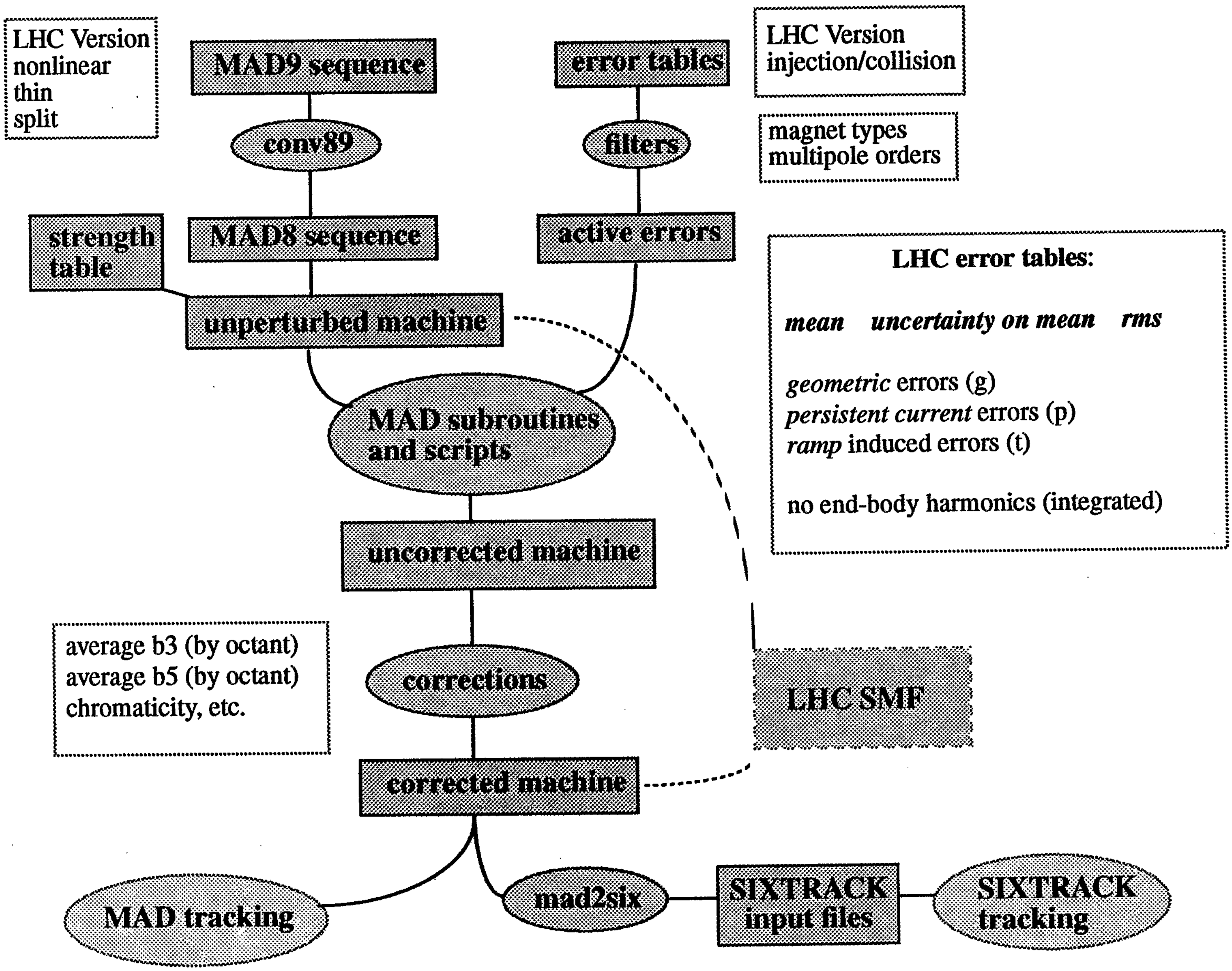
Sequence of sequences (COSY-like approach).

```
sub cell() {
   my $sequence = new Sequence();
   $sequence->set(. . .);
   return $sequence;
}

$sequence = new Sequence();
$sequence->set (
   [cell(), ],
   [element(...), {at => $position}, ],
   ...
);
```


Optics Database
NameLookup
SurvSerial
magbase
survbase
dbsf
hook view
magstat
survstat
Lattice Sds
dbg2sds
HookSpace Sds
Field Model Sds
Survey Sds
hook_lat
Hooked Lattice Sds
hook_all
SMF Sds
SIF
UAL
parser
SMF
ramp stepstones
tracking engine
SMF*
maps
fort.7
parser
tune modulation engine
analysis / corrections
preexisting
new
to be done

CERN simulation software for LHC

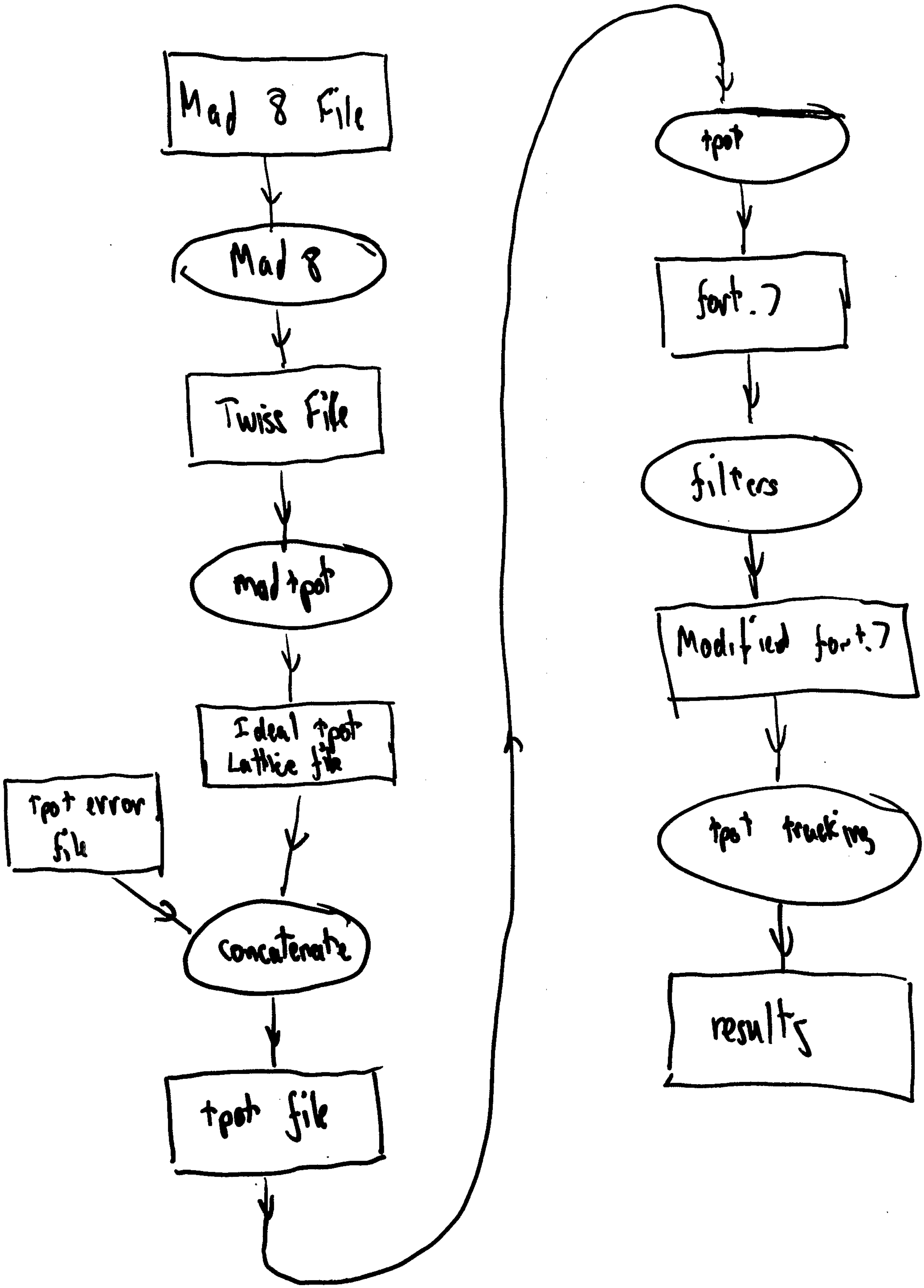
machine description:	MAD (MAD Version 9 sequence)
errors and corrections:	MAD (MAD Version 8 + MAD Subroutines)
tracking:	MAD, SIXTRACK
postprocessing:	MAD, SIXTRACK



Tracking run: 60 machines (seeds) tracked for 10^5 turns

required aperture: 6 σ ----> required aperture in simulation: 10 σ

Mad 8 to Fortran Teapot



Pre & Post Analysis Tools

[1] Teapot lattice tools.

- [A] Orbit correction and rms orbit error
- [B] Coupling and correction
- [C] Chromatic correction

[2] Tune footprint

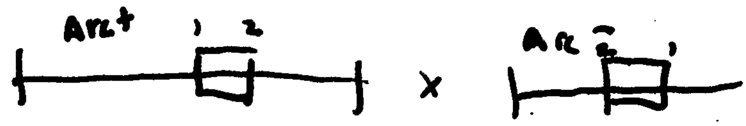
- [A] Tuneplot
- [B] tealeaf

[3] Long term tracking

- [A] Dynamic Aperture.

[4] Filters

- [A] IR correction
- [B] DX splitting
- [C] QF - QD inversion



b (even) → -b(e
a (odd) → -a(od

- [D] Real magnets in Real places

Cornell Workshop
July 11, 1997

BNL AP Support Activities for LHC

Jie Wei, Brookhaven National Laboratory

1. Overview

2. Scope and plans

   short-term and long-term tasks

   tool development

3. Status and problems

   lattice 5.0

   expected errors

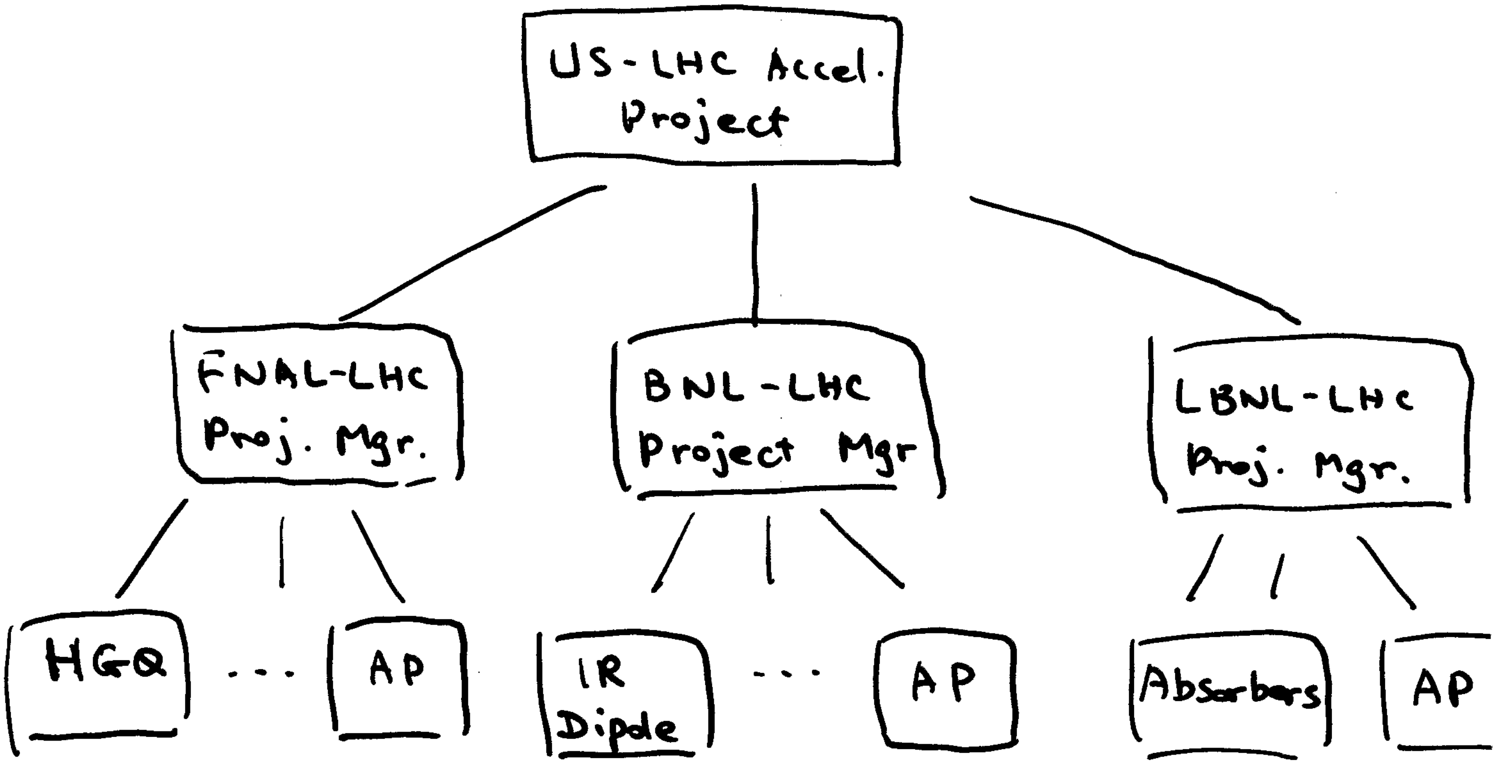
1. Overview

- Joint US-LHC Accelerator Project; IR magnets manufacture for LHC
  - BNL: IR dipoles, RF Section magnets, ... AP
  - FNAL: IR quads, IR layout & integration, ... AP
  - LBNL: IR absorbers, cryoboxes, ... AP

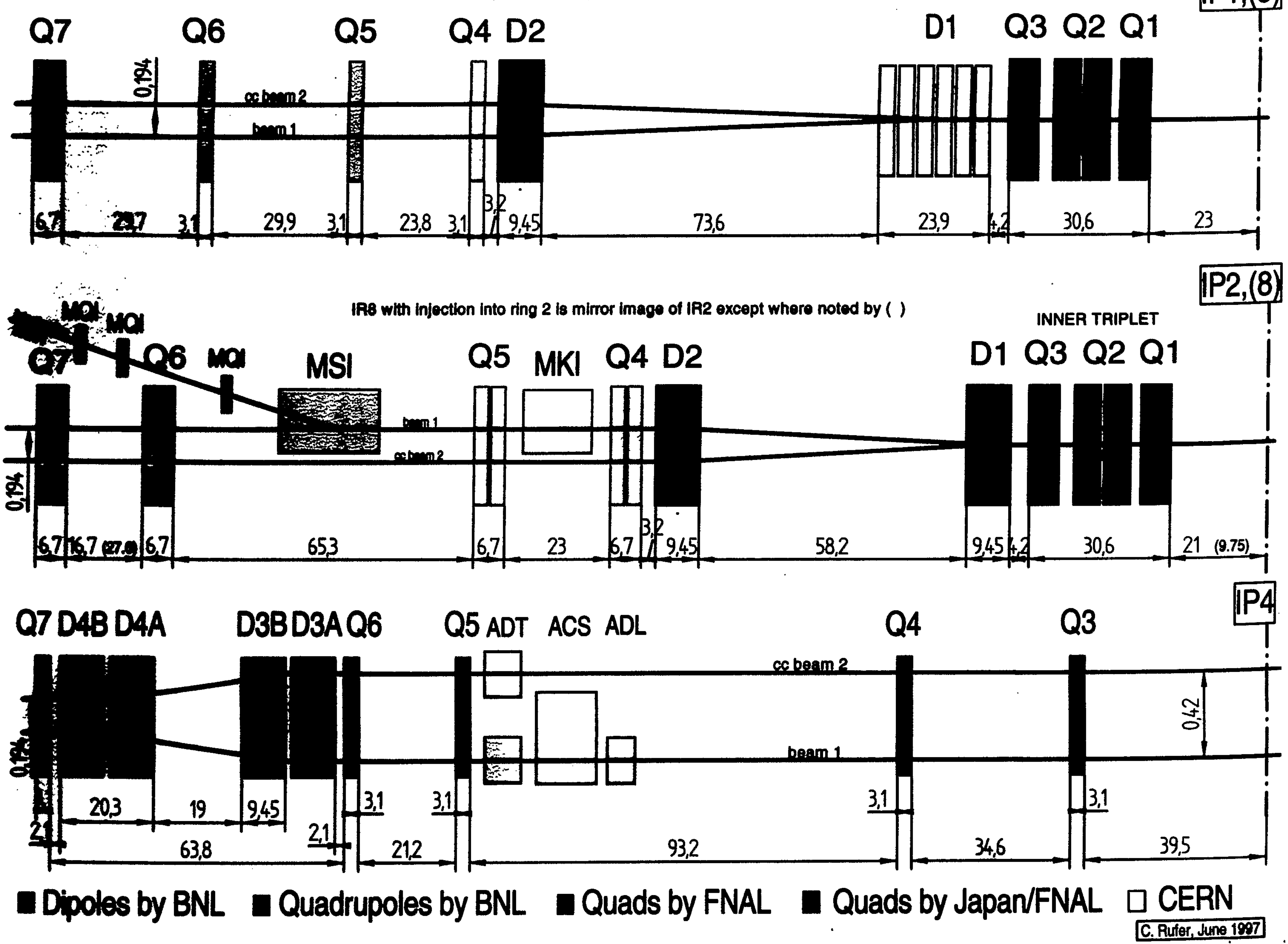
- BNL AP plans to assist in assuring the quality of both LHC beam splitting magnets built at BNL, and LHC triplet quads built at FNAL.

- We gained considerable experience in working with the RHIC Magnet Division, in ensuring the performance of (particularly) RHIC interaction region magnets. Some of this work is on-going.

- BNL AP: 2 FTEs of effort, until year 2004.


US-LHC Accel. Project
FNAL-LHC Proj. Mgr.
BNL-LHC Project Mgr
LBNL-LHC Proj. Mgr.
HGQ
...
AP
IR Dipole
...
AP
Absorbers
AP

LHC INSERTIONS 1& 5, 2 & 8, and 4 Lattice Version 5.0



Issues relevant :

FNAL AP Activities (W. Chou)

* 6+1 PAC97 papers on LHC AP issue

  W. Chou, D. Ritson

  Dynamic aperture studies during collisions..

  C. Johnstone

  Local chromaticity correction of the LHC

  ...

* Suggest inadequate crossing angle & aperture

  HGQ Coil ID [70 mm $\overset{?}{\Rightarrow}$ 80 mm]

* CERN Response :

  may likely increase crossing angles

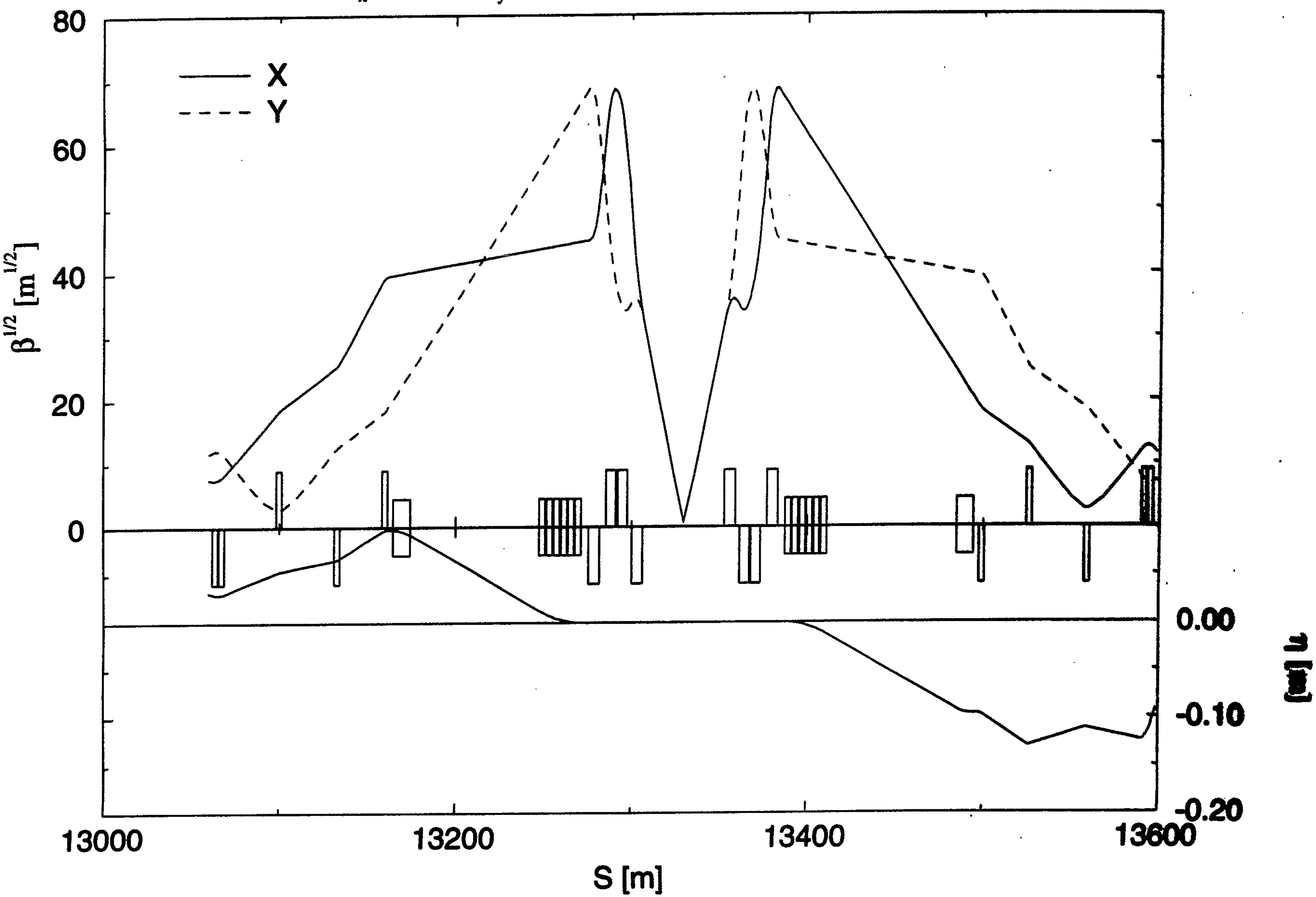
  Φ [200 μr $\overset{?}{\Rightarrow}$ 350 μr]

* W. Chou asking $9.9 M, including $0.64 M for consulting (D. Ritson, +1)

* CERN : MAD as "official" codes, anything else to be compared with.

LHC version 5.0, collision optics

$\nu_x = 63.31$ $\nu_y = 59.32$ FILE = lhcIP5.optics



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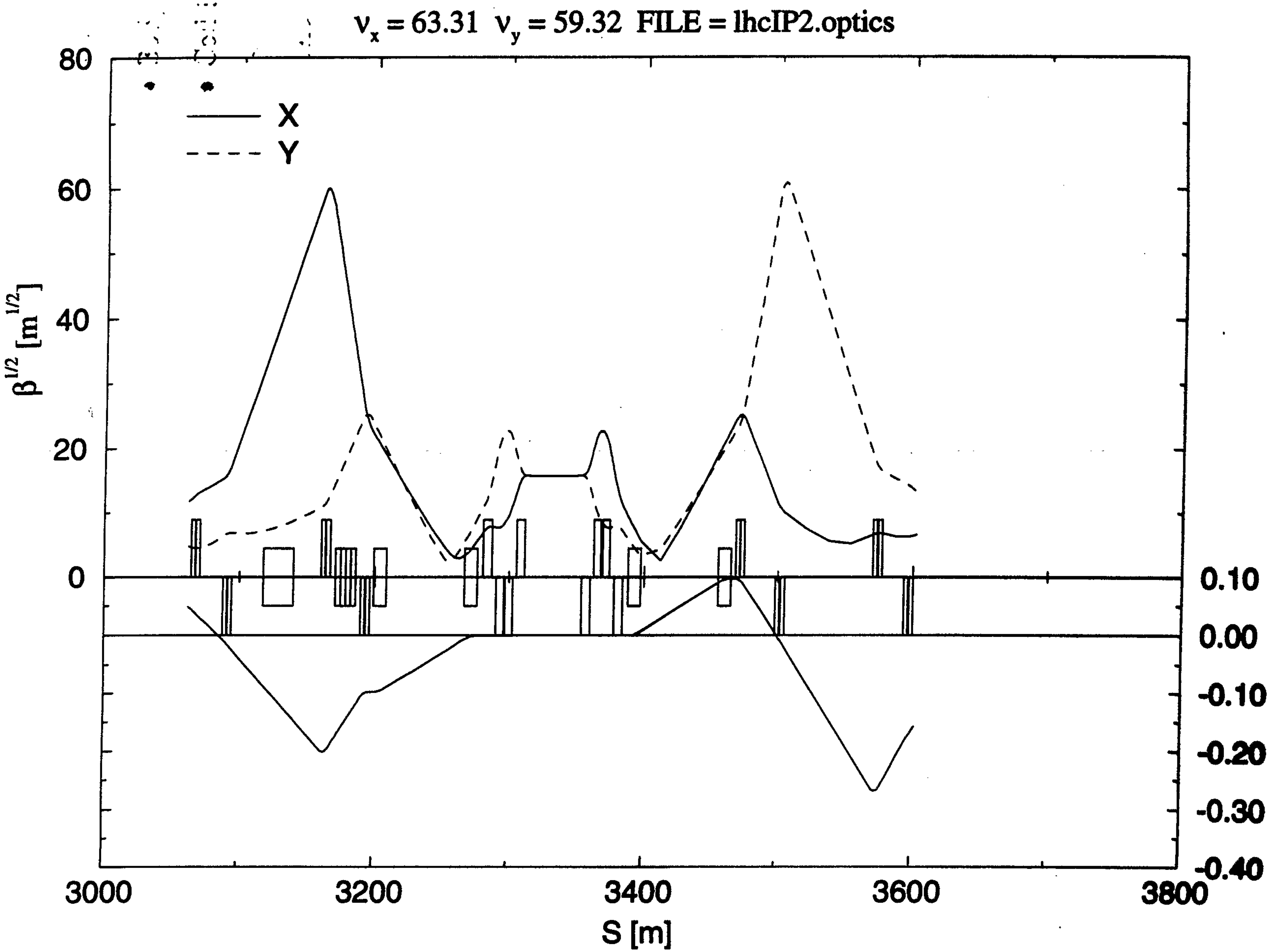
LHC version 5.0, collision optics



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Goal:

<u>short term</u> ($\lesssim$ 6 month)

* evaluate the impact of expected errors
* illustrate the effectiveness of compensation schemes
* proof-of-principle example of SMF + TPOT++

<u>long term</u> (until 2004)

* routine evaluation of measured and expected errors
* routine evaluation of compensation schemes

2. Scope and plans

Short-term tasks:

- maintain current version of MAD, SIXTRACK, & FTPOT
- up-to-date on nominal LHC lattice (5.0) and operational conditions (Φ)
- create corresponding lattice files for FTPOT
- up-to-date on expected multipole errors for both body and fringe fields in dipoles and quads
- action-kick analysis to evaluate the impact of expected IR magnet errors on LHC performance under various collision schemes of crossing angle and β^*
- tracking with FTPOT and/or SIXTRACK with magnet errors on IR magnets only for tune footprint evaluation and dynamic aperture evaluation (Φ effectively taken into account
- MAD tracking to "validate" and spot-check FTPOT and/or SIXTRACK results
- propose possible compensation schemes
  - magnet orientation to minimize lead-end error
  - evaluate the optimum body allowed harmonics for amplitude-weighted body-ends compensation
  - tuning shim performance and multipole candidates
  - corrector layers, locations, and arrangement
  - sorting schemes

Mid /Long-term tasks:

- evaluate the impact of the measured errors of manufactured IR magnets on LHC performance, and provide quick feedback to magnet builders
- propose compensation schemes for measured magnet errors

⇓ Mid

- develop Standard Machine Format (SMF) translator for MAD and/or SIXTRACK
- develop triplet filter, crossing-angle filter, and slice filter for LHC
- develop SMF interface for the filters
- create a SMF LHC lattice with errors
- track the SMF LHC lattice with compatible codes

⇒ desirably with TPOT++

- analysis
- global correction
  tunethin, chromfit, decouple
- (Local correction)
- tracking

Tool development:

- MAD to FTPOT lattice convertor
- tune footprint generator from FTPOT output
- Standard Machine Format (SMF) translator for MAD and/or SIX-TRACK
- triplet filter, crossing-angle filter, and slice filter for LHC
- SMF interface for the filters
- statistic analysis codes to monitor measured magnet errors

- TPOT ++

3. Status and Problems

Lattice 5.0:

Table 1: Crossing angle and β^* for LHC collision

	IP	nominal	option
β^* (m)	1	0.5	0.5?
	5	0.5	0.5?
	2	250	0.25 - 0.5?
	8	33	?
crossing angle	1	± 100	± 175?
(μr)	5	± 100	± 175?
	2	± 100	?
	8	± 100	?

Main condition / assumption :

* β^* $\Rightarrow$ β_{max} @ HGQ & D1

* crossing angle $\Rightarrow$ $\pm 100\ \mu r \Leftrightarrow \pm 5$ mm

Expected harmonics:

Table 2: Expected harmonics for LHC high gradient quadrupoles (HGQ).

Order, n	Normal			Skew		
BODY [unit]	$\langle b_n \rangle$	$d(b_n)$	$\sigma(b_n)$	$\langle a_n \rangle$	$d(a_n)$	$\sigma(a_n)$
2	—	—	—	—	—	—
3	0.0	0.5	2.9	0.0	0.5	2.9
4	0.0	0.5	2.0	0.0	0.5	2.0
5	0.0	0.5	1.0	0.0	0.5	1.0
6	0.0	0.5	1.4	0.0	0.5	0.7
7	0.0	0.5	0.4	0.0	0.5	0.4
8	0.0	0.5	0.3	0.0	0.5	0.3
9	0.0	0.5	0.4	0.0	0.5	0.4
10	0.0	0.5	0.3	0.0	0.5	0.3
LEAD END [unit-m]	$\langle B_n \rangle$	$d(B_n)$	$\sigma(B_n)$	$\langle A_n \rangle$	$d(A_n)$	$\sigma(A_n)$
2	—	—	—	18.1	—	—
6	4.6	—	—	−0.4	—	—
10	−0.8	—	—	−0.2	—	—
RETURN END [unit-m]	$\langle B_n \rangle$	$d(B_n)$	$\sigma(B_n)$	$\langle A_n \rangle$	$d(A_n)$	$\sigma(A_n)$
6	0.6	—	—	0.0	—	—
10	−0.7	—	—	0.0	—	—

Note:

- **Body harmonics converted from the after-correction HGQ harmonics of Tables 5 and 6 (storage only) of the paper by Sabbi et. al.**
- **End harmonics converted from Tables 5 of the paper by Caspi and Chow.**
- **Coil id is 7.0 cm.**
- **Quoted harmonic values are given in "units" of 10^{-4} of the main quad field at 2.2 cm reference radius. European convention: b1 is dipole!**

Table 3: Expected harmonics for LHC IR dipoles (D1, D2, D3, D4).

Order, n	Normal			Skew		
BODY [unit]	$\langle b_n \rangle$	$d(b_n)$	$\sigma(b_n)$	$\langle a_n \rangle$	$d(a_n)$	$\sigma(a_n)$
2	0.0	1.0	0.4	−2.0	1.0	1.5
3	0.0	4.0	2.0	−1.1	0.1	0.2
4	0.0	0.3	0.1	−0.5	0.3	0.4
5	0.4	1.0	0.6	0.2	0.05	0.1
6	0.0	0.1	0.03	−0.1	0.2	0.05
7	1.3	0.5	0.2	−0.1	0.03	0.03
8	0.0	0.01	0.01	0.0	0.03	0.05
9	0.05	0.1	0.03	0.02	0.02	0.01
10	0.0	0.03	0.01	0.0	0.01	0.01
11	−0.5	0.1	0.03	−0.01	0.01	0.01
LEAD END [unit-m]	$\langle B_n \rangle$	$d(B_n)$	$\sigma(B_n)$	$\langle A_n \rangle$	$d(A_n)$	$\sigma(A_n)$
2	−2.0	2.0	1.0	2.0	4.0	1.0
3	21.0	2.0	2.0	−10.0	1.0	1.0
4	0.3	0.2	0.2	0.0	1.0	1.0
5	1.0	0.5	0.2	2.0	0.5	0.3
6	0.0	0.2	0.2	0.0	1.0	0.2
7	1.0	0.5	0.1	−0.9	0.2	0.2
8	0.0	0.1	0.1	0.0	0.1	0.1
9	−0.2	0.2	0.1	0.3	0.1	0.1
10	−0.2	0.2	0.2	0.0	0.1	0.1
11	0.1	0.1	0.1	−0.1	0.1	0.1
RETURN END [unit-m]	$\langle B_n \rangle$	$d(B_n)$	$\sigma(B_n)$	$\langle A_n \rangle$	$d(A_n)$	$\sigma(A_n)$
2	1.4	1.0	1.0	3.0	0.5	1.0
3	−1.0	4.0	1.0	−0.8	0.5	1.0
4	0.3	0.1	0.1	0.2	0.3	0.5
5	08	0.5	0.2	0.2	0.1	0.1
6	0.0	0.1	0.1	0.2	0.1	0.2
7	0.0	0.1	0.1	0.1	0.05	0.1
8	0.0	0.1	0.1	0.0	0.05	0.1
9	−0.2	0.1	0.1	0.1	0.05	0.1
10	−0.2	0.1	0.1	0.0	0.05	0.1
11	−0.1	0.1	0.1	0.0	0.05	0.1

Note:

- Body and end harmonics provided by R. Gupta.
- Coil id is 8.0 cm.
- Quoted harmonic values are given in "units" of 10^{-4} of the main dipole field at 2.5 cm reference radius. European convention: b1 is dipole!