U.S.-LHC Accelerator Research Program

(LARP)

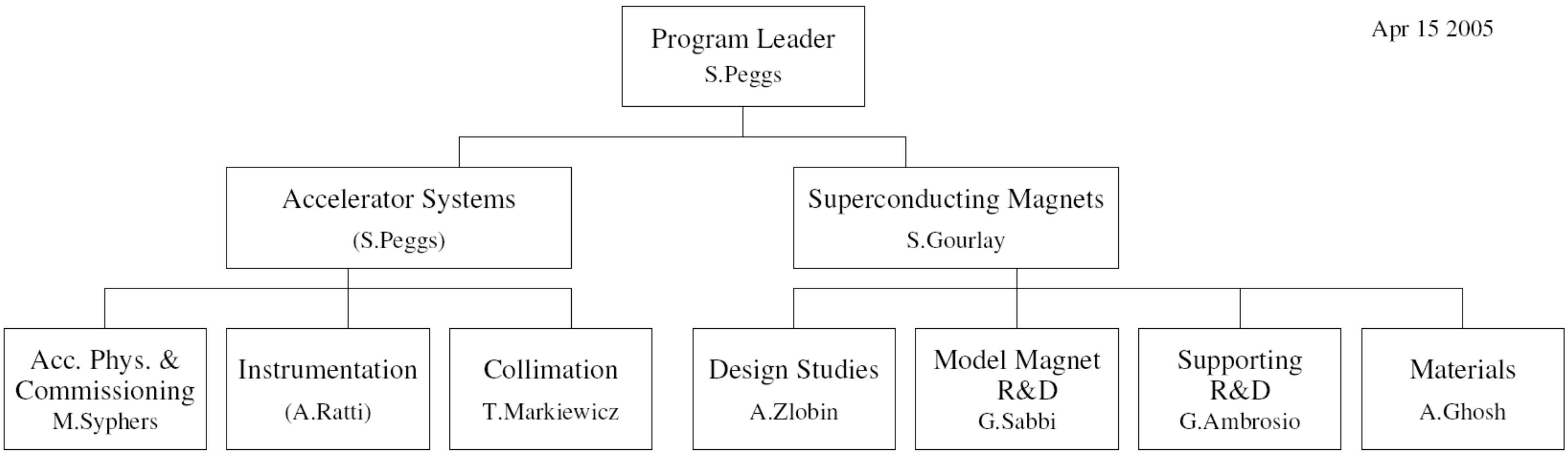
Steve Peggs, BNL

Introduction

Virtual national lab?

Membership from BNL, FNAL, LBNL, & SLAC

Plateau budget in FY06+ ~ $11 million



Accelerator Systems: Luminosity monitors, tune feedback, phase 2 collimators, commissioning, optics, ...

Superconducting Magnets (Nb_3Sn): long coils, racetrack/cosine, key & bladder/block, materials, ...

Budget guidance

US LHC Accelerator Research Program Mar 15, 2005		LARP level 2 top down planning				
WBS		FY05	FY06	FY07	FY08	FY09
	DOE guidance	3500	11000	11000	12000	12000
	Actual	3217				
1	**Accelerator Systems**	1643	3100	3100	3200	3000
1.1	**Instrumentation** (Byrd)	605	790	750	800	800
1.2	**Acc. Phys. & Comm.** (Syphers)	718	1500	1690	1800	1600
1.3	**Collimation** (Markiewicz)	320	810	660	600	600
2	**Magnet R&D**	1013	4500	4500	5400	5600
2.1	**Design Studies** (Zlobin)	153	440	440	440	440
2.2	**Model Magnet R&D** (Sabbi)	669	1880	1880	2240	2360
2.3	**Supporting R&D** (Ambrosio)	102	1230	1230	1580	1600
2.4	**Materials** (Ghosh)	89	950	950	1140	1200
3	**Program Management**	561	1400	1400	1400	1400
	Planning Contingency		2000	2000	2000	2000

Big step to plateau expected/hoped from FY05 to FY06

Full scale DOE Review of LARP on June 1 & 2 …

FY05 actuals

Alignment of individual lab budget codes with LARP WBS

Quarterly reporting has begun

More robust central project management, entering FY06 ....

Mar 15 2005			FY2005 LARP Budget				
WBS			BNL	FNAL	LBNL	SLAC	Total
US LHC Accelerator Research Program			1034	882	1111	190	3217
1	**Accelerator Systems**		511	437	505	190	1643
1.1	**Instrumentation**	**Byrd**	195	15	395	0	605
1.1.1	Phase I						
1.1.1.1	Tune feedback	Cameron	195	15			210
1.1.1.2	Luminometer	Byrd			395		395
1.1.1.3	LDM / AGM	Byrd					0
1.2	**Acc. Phys. & Comm.**	**Syphers**	241	367	110	0	718
1.2.1	Commissioning						
1.2.1.1	Beam Commissioning	Harms	40	37			77
1.2.1.2	Interaction Region Commissioning	Lamm	66	155	25		246
1.2.2	Accelerator Physics						
1.2.2.1	Electron Cloud	Furman	55		45		100
1.2.2.2	Interaction Regions & Beam-Beam	Sen	80	175	40		295
1.3	**Collimation**	**Markiewicz**	75	55	0	190	320
1.3.1	Phase I						
1.3.1.1	Cleaning efficiency studies	Drees	75	0			75
1.3.2	Phase II						
1.3.2.1	Rotating Collimator R&D	Markiewicz		30		190	220
1.3.2.2	Tertiary collimator study	Mokhov		25			
2	**Magnet R&D**		214	308	491	0	1013
2.1	**Design Studies**	**Zlobin**	122	5	26		153
2.1.1	Quadrupole						
2.1.1.1	Shell & Block design comparison	Ferracin			5		5
2.1.1.2	Shell mechanical design study	Ambrosio		5			5
2.1.2	Separation dipole						
2.1.2.1	D1 design	Gupta	16				16
2.1.2.2	D1 cooling study	Peterson	106		21		127
2.2	**Model Magnet R&D**	**Sabbi**	10	294	365		669
2.2.1	Quadrupole						
2.2.1.1	Technology Quad TQ1a	Caspi	5	180	329		514
2.2.1.2	Technology Quad TQ2a	Zlobin	5	114	36		155
2.3	**Supporting R&D**	**Ambrosio**	35	0	67		102
2.3.1	Subscale models						
2.3.1.1	Small Quad SQ01b test	Feher			46		46
2.3.1.2	Small Quad SQ02 fab & test	Ferracin	35				35
2.3.1.3	Sub-scale dipole test	Schmalzle			21		21
2.4	**Materials**	**Ghosh**	47	9	33		89
2.4.1	Conductor Support						
2.4.1.1	Strand R&D	Barzi	47	9			56
2.4.1.2	Cable R&D	Dietderich			33		33
3	**Program Management**		309	137	115	0	561
3.1	**Administration**						
3.1.1	Systems						
3.1.1.1	Accelerator Systems	Peggs	179	45	25	0	249
3.1.1.2	Magnet R&D	Gourlay	130	92	90	0	312

		Tevatron [Mar 05]	LHC [“nominal”]
Luminosity [$cm^{-2}s^{-1}$]	L	1.2×10^{32}	1×10^{34}
Magnet style		1-in-1	2-in-1
Beam-Beam parameter	ξ_1	0.010	0.004
	ξ_2	0.002	0.004
Number of bunches	M	36	2,808
BUT unfortunately ...			
Beam stored energy [MJ]		1	366
Chromaticity snap-back	$\Delta\chi$	~ 30	~ 300
Debris power [W]		~ 1	~ 900

9 kW !?

1) lose the anti-protons

2) use LOTS of bunches

3) beware stored energy, snap-back, debris power !!

4 (identified) challenges

	Challenge	Luminosity	LARP activity
1)	Snap-back	small	TF, LM, BC, ...
2)	Stored energy	medium	RC, BC, ...
3)	Beam-beam	nominal	IRBB, RC, BC, ...
4)	Debris power	upgrade	Magnet R&D, ...

Early LARP success is tightly linked to Tune Feedback, Luminosity Monitor, and Beam Commissioning activities

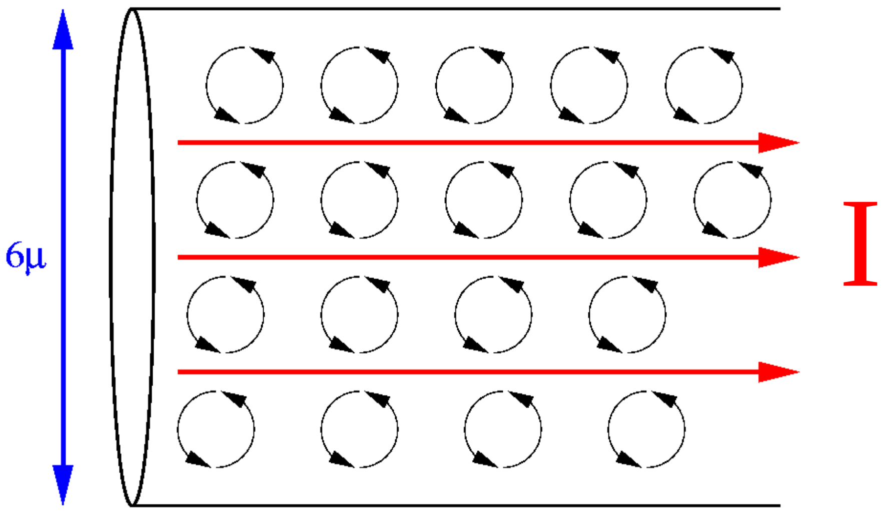
Later come Rotating Collimators, and IR & Beam-Beam, etc

Magnet R&D must proceed **now,** to be ready **then.**

Early perceptions are prejudiced by the Construction Programs success – LARP does R&D, not production!

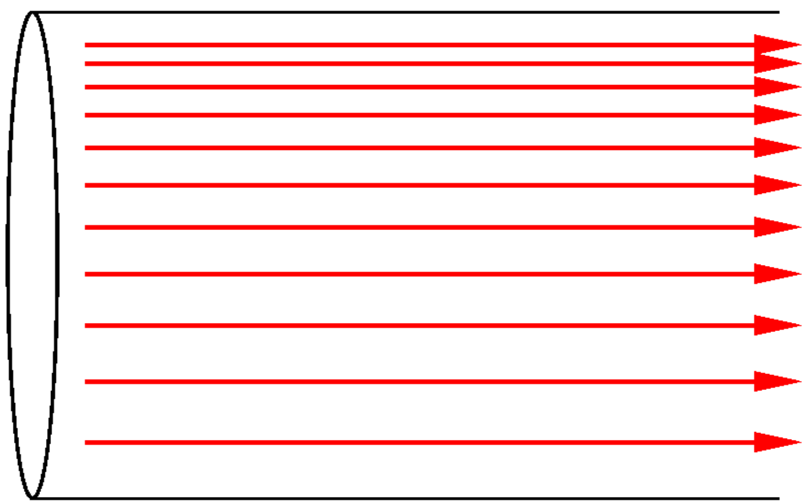
Tune Feedback

Quantum fluxoids and persistent currents



Vortex currents circulate around quantum fluxoids in a Type II superconducting filament

Need a fluxoid density gradient to get a net transport current, I

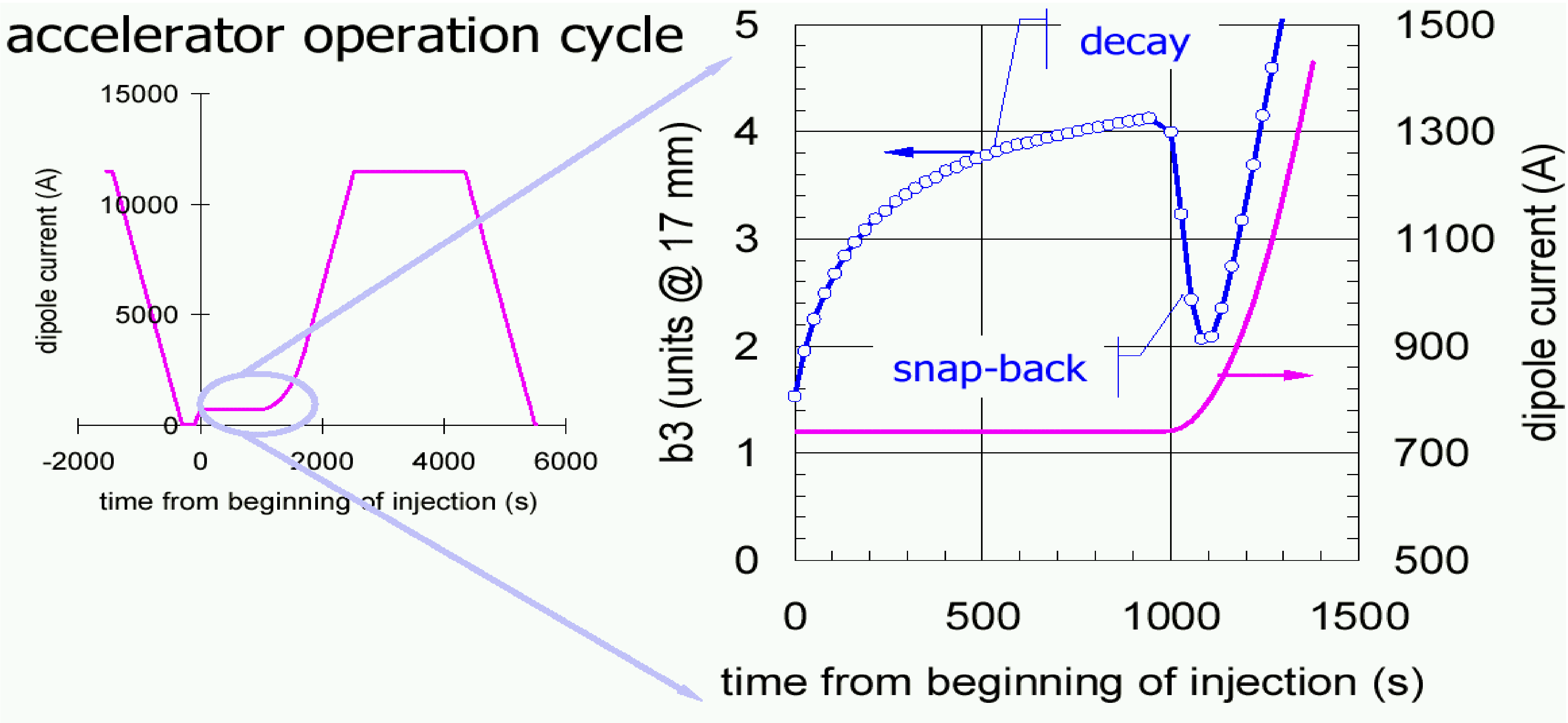


A quadratic density gradient drives a current gradient ...

Like eddy currents, these "persistent currents"

- depend on the history of the "external" field
- decay (SLOWLY) with time

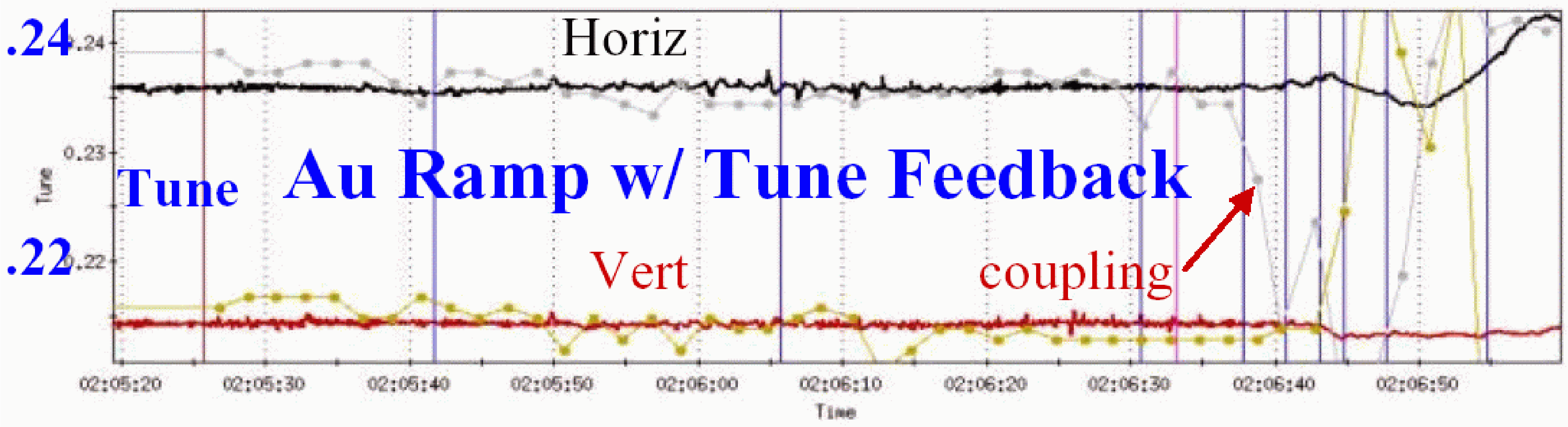
LHC predictions



"Snap-back" is not SO fast,

but the chromaticity jump is huge, ~ 300 units !

Tune feedback



Tune feedback demonstration in RHIC (original 245 MHz system)

March 05 "Tune Feedback Workshop", April 05 "LARP Review"

Implement more robust baseband system (collaboration with CERN)

Intrinsic issues with linear coupling

- chicken and egg problem …

Linear coupling tracking

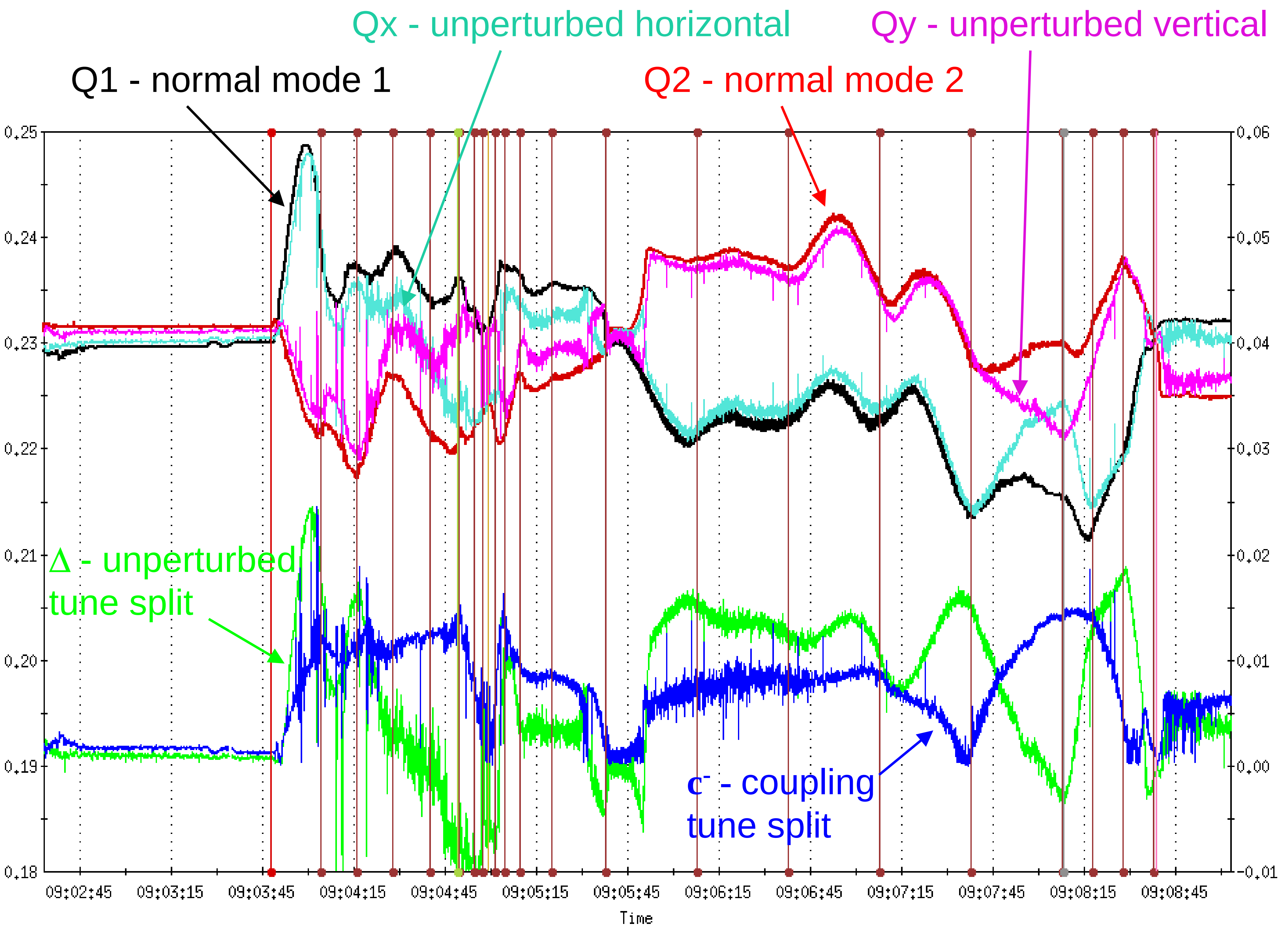
$$(Q_1 - Q_2)^2 \quad = \quad \Delta^2 \quad + \quad |C|^2$$

- Δ is the unperturbed tune split
- $|C|$ is the tune split due to coupling

"Rhodri's parameters" can be expressed in terms of observables:
"Yun's parameters"

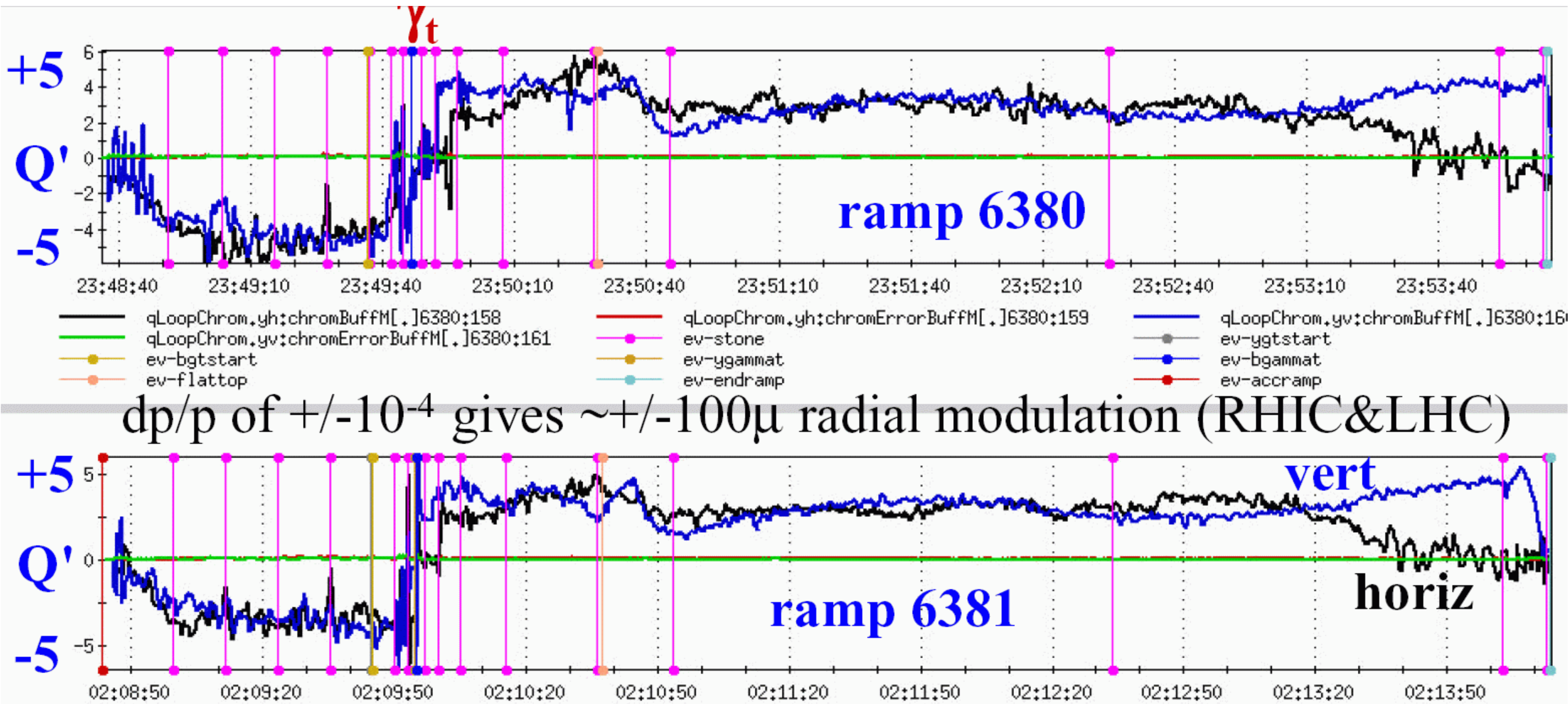
- $\Delta \quad = \quad |Q_1 - Q_2|(1 - r_1 r_2)/(1 + r_1 r_2)$
- $|C| \quad = \quad 2\ \mathrm{sqrt}(r_1 r_2)\ |Q_1 - Q_2|/(1 + r_1 r_2)$

Where r_1 & r_2 are ratios of H & V amplitudes in eigenmodes 1 & 2



Qx - unperturbed horizontal
Qy - unperturbed vertical
Q1 - normal mode 1
Q2 - normal mode 2
Δ - unperturbed tune split
c⁻ - coupling tune split
0.25
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
09:02:45
09:03:15
09:03:45
09:04:15
09:04:45
09:05:15
09:05:45
09:06:15
09:06:45
09:07:15
09:07:45
09:08:15
09:08:45
Time

Chromaticity tracking



Chromaticities tracked through two “identical” RHIC ramps
(feedback not yet attempted)

Cleaning efficiency studies

How much is 350 MJoules?

Kinetic energy

- 1 small aircaft carrier of 10^4 tonnes going 30 kph
- 450 automobiles of 2 tonnes going 100 kph

Chemical energy

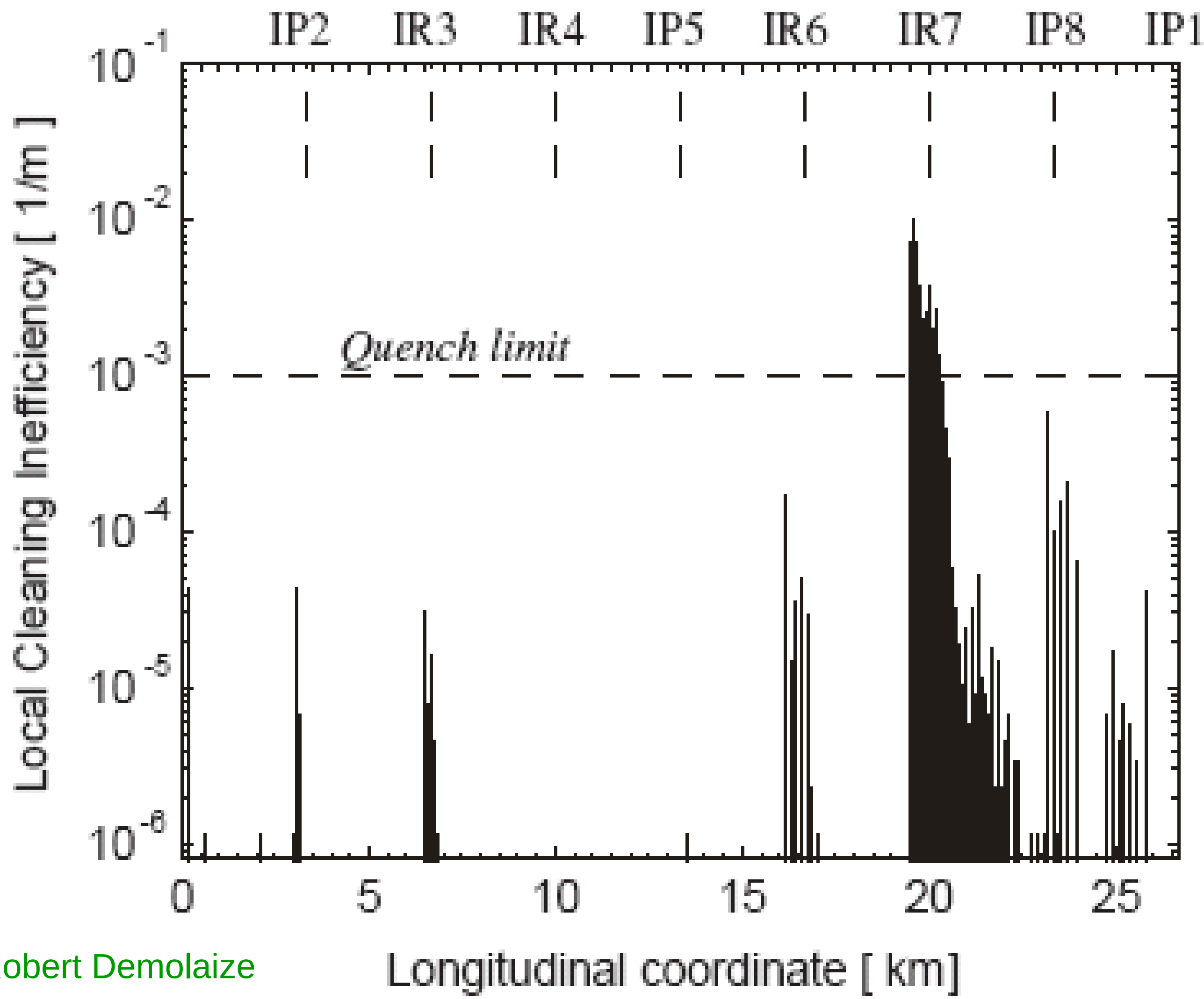
- 80 kg of TNT
- 70 kg of (swiss?) chocolate

Thermal energy

- melt 500 kg of copper
- raise 1 cubic meter of water 85 C: “a tonne of tea”

(Suggesting that “physical intuition” is tuned to instantaneous power?)

Simulated loss map at LHC injection (450 GeV)



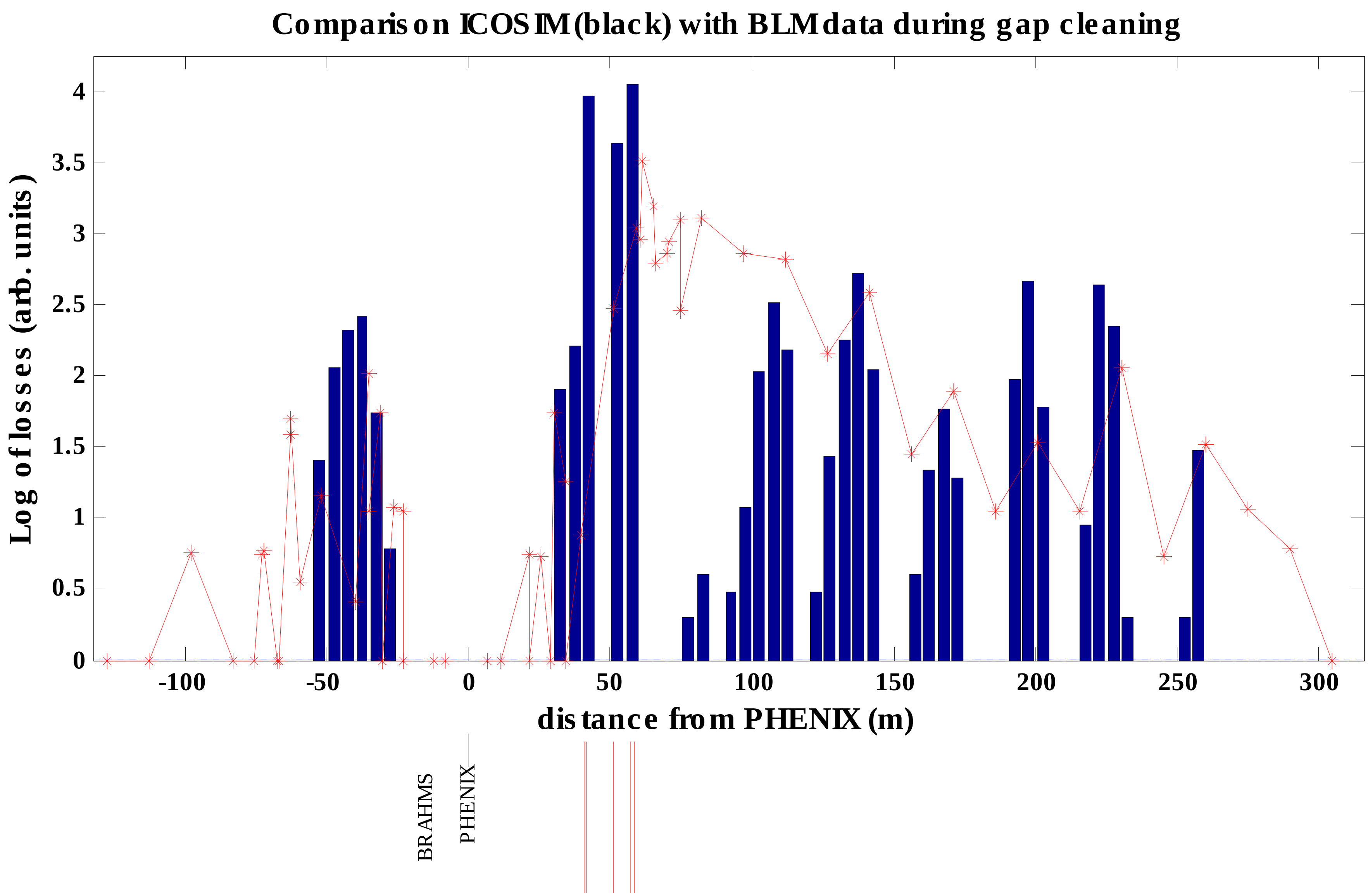
Courtesy of G. Robert Demolaize

Are proton simulations reliable at the 10^{-3} inefficiency level?

Heavy ions at RHIC

- Beam Loss Monitor data from abort gap cleaning during production
  - More data with better controlled conditions (loss maps with only one collimator in and all others out) now available for Cu
- ICOSIM a simpler code than SIXTRACK
  - Data analysis by H. Braun (CERN)
  - Import code to BNL for the short term
  - Merge ion specific parts of code with SIXTRACK
- Reasonable agreement observed
  - Ions typically do NOT make multiple turns around ring

Reasonable agreement for ions …

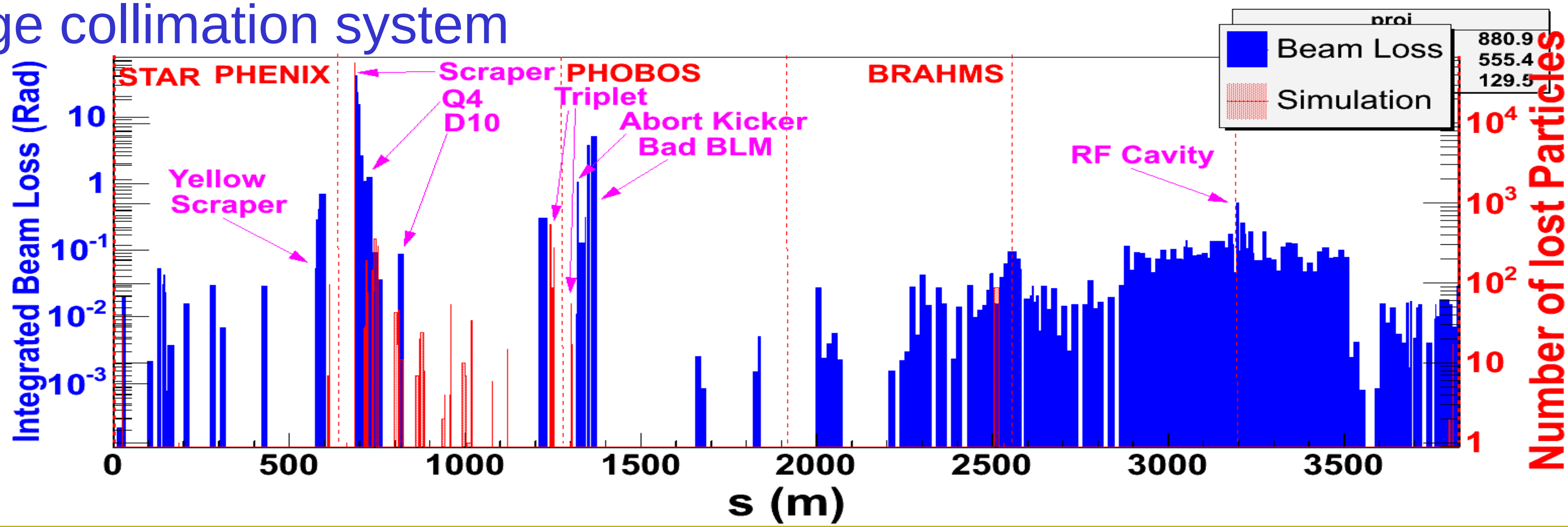


Protons at RHIC

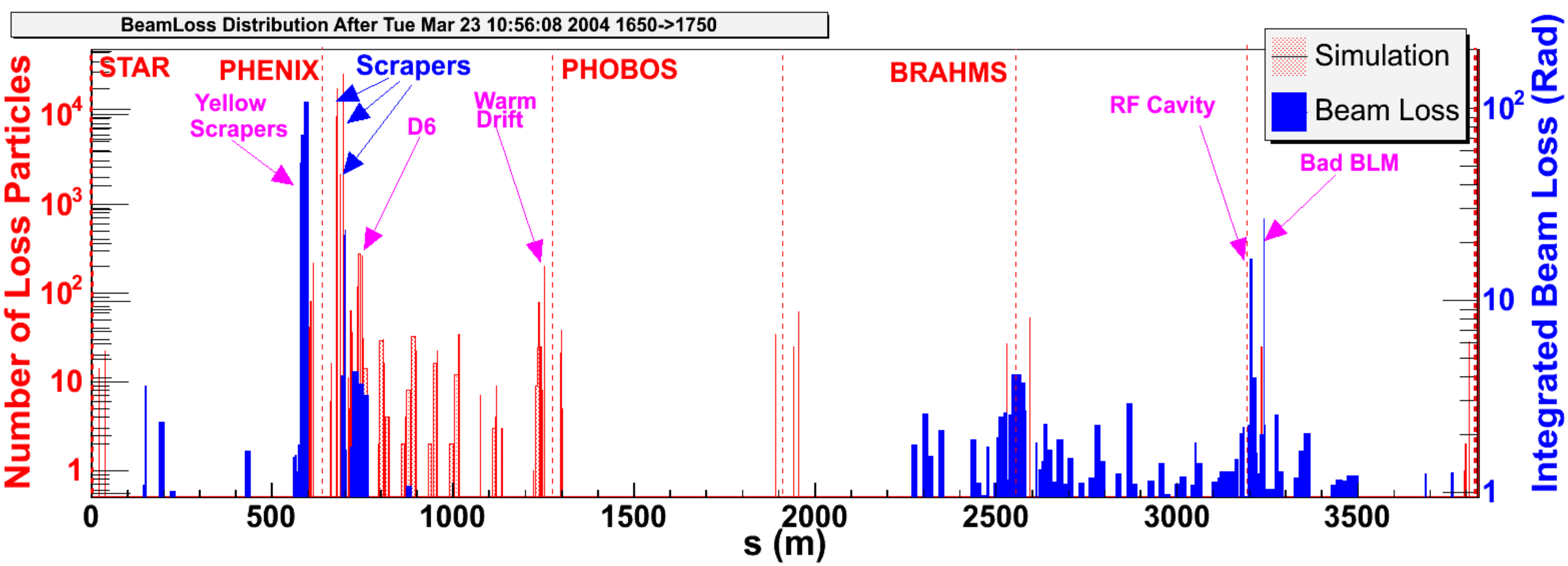
- Beam Loss Monitor data from log files during a physics run
  - Dedicated data taking with better controlled conditions will be performed during the current run
- Existing simulations from “Teapot” & “K2” codes, with known problems
  - Agreement poor
    - Multi-turn tracking more challenging
  - SIXTRACK code installed for some time
    - Needs updating & RHIC lattice installed
      - CERN collaborator coming soon
- Postdoc search still ongoing

… poor agreement with protons

1-stage collimation system



2-stage collimation system

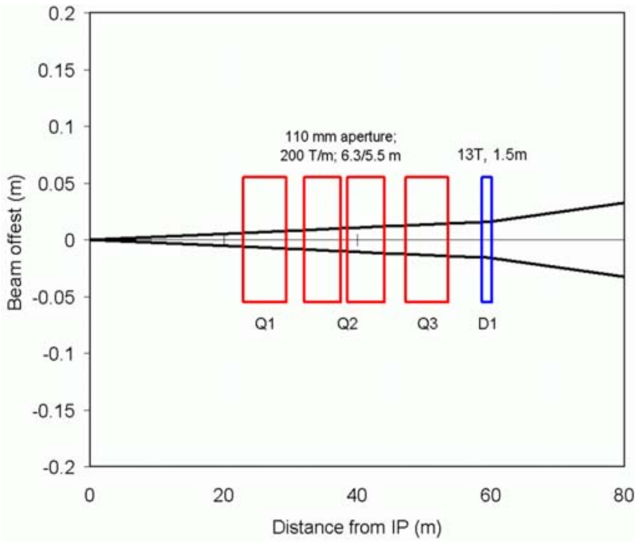


Interaction region upgrade

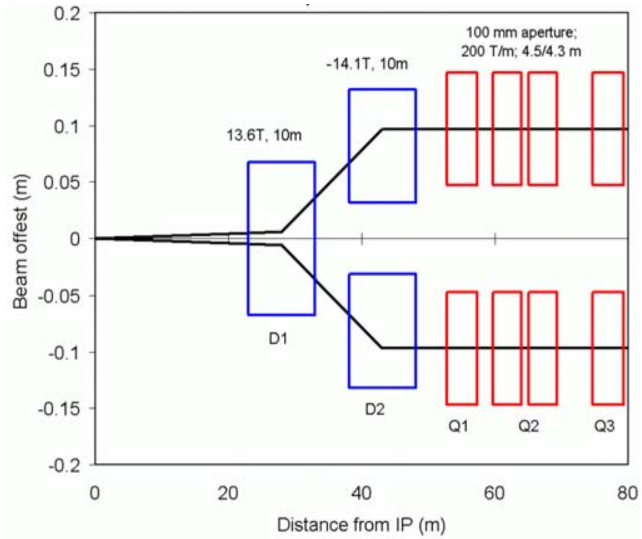
(Magnet R&D)

Representative layouts

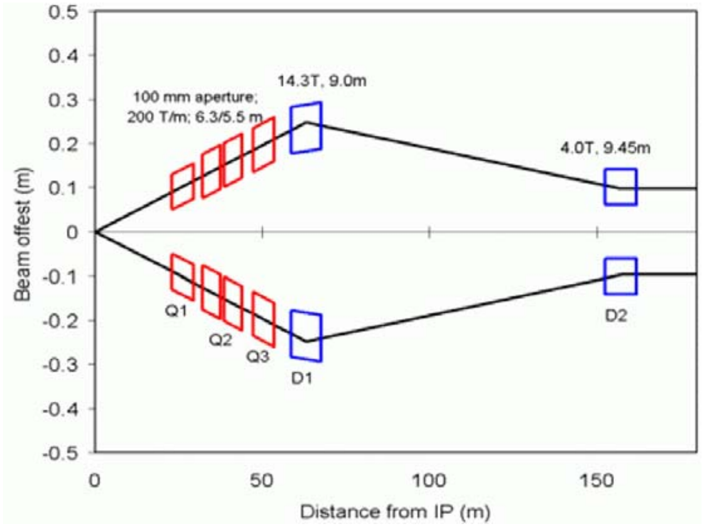
“Quad first”



“Dipole first”



“Large crossing angle”



All scenarios incorporate state-of-the-art IR quads

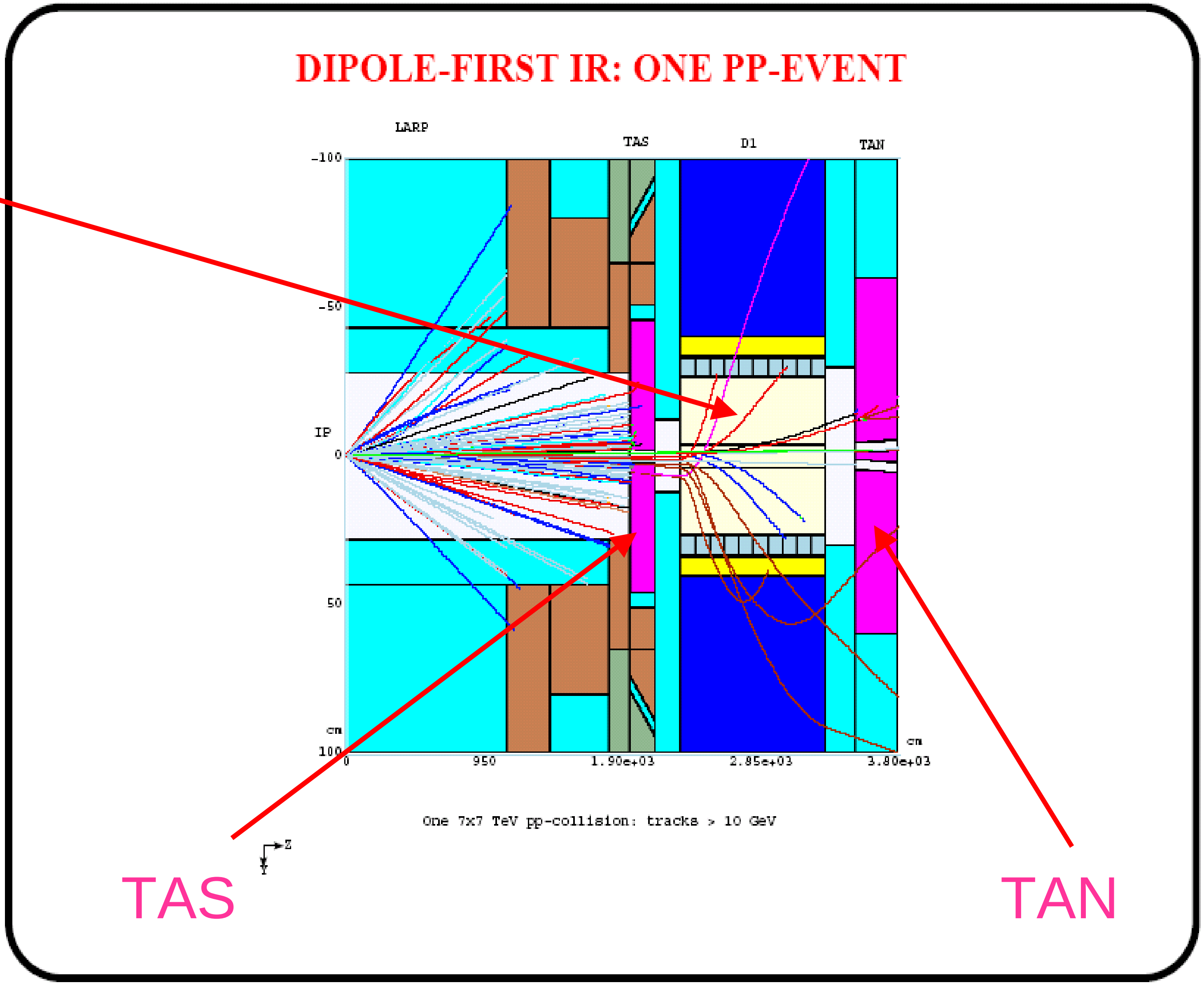
Some also use new-concept beam separation dipoles

Other potential sub-system upgrades: beam-beam compensators, crab cavities, accelerating cavities, cryogenics, beam dumps, ...

Need real operating experience to make optimal decisions!

Dipole first debris

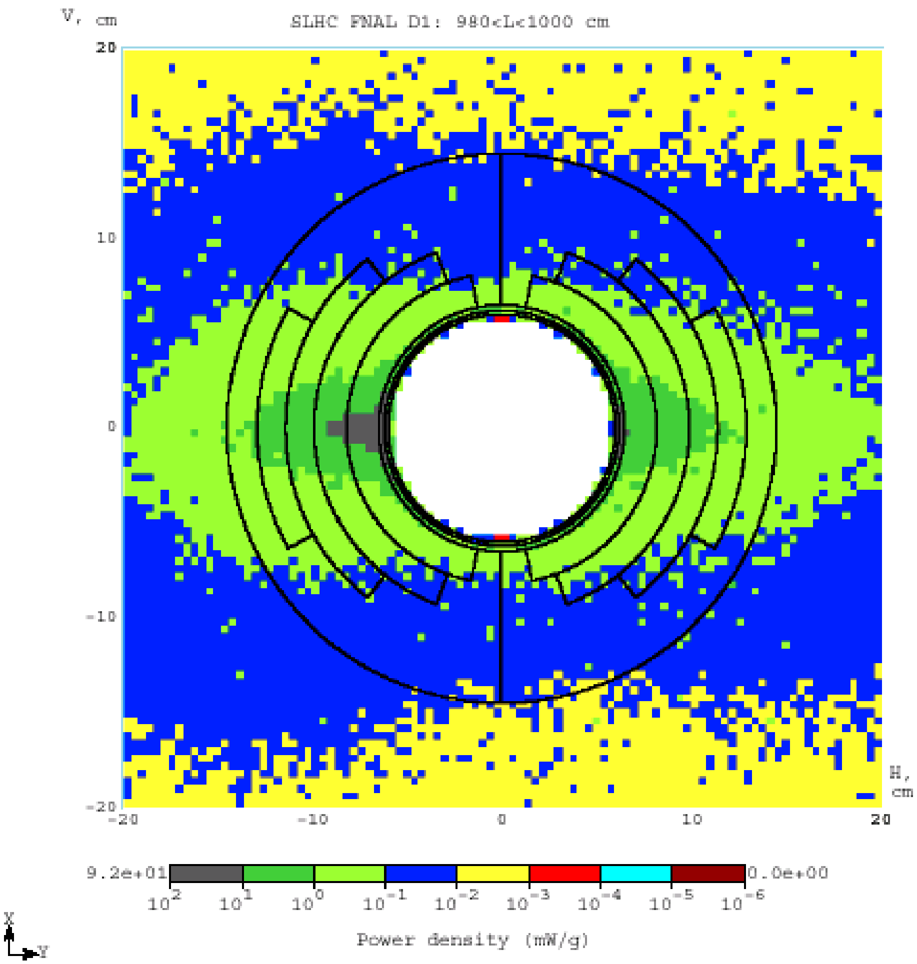
Most debris particles (many kW?) are swept into the first dipole in a "dipole first" scheme

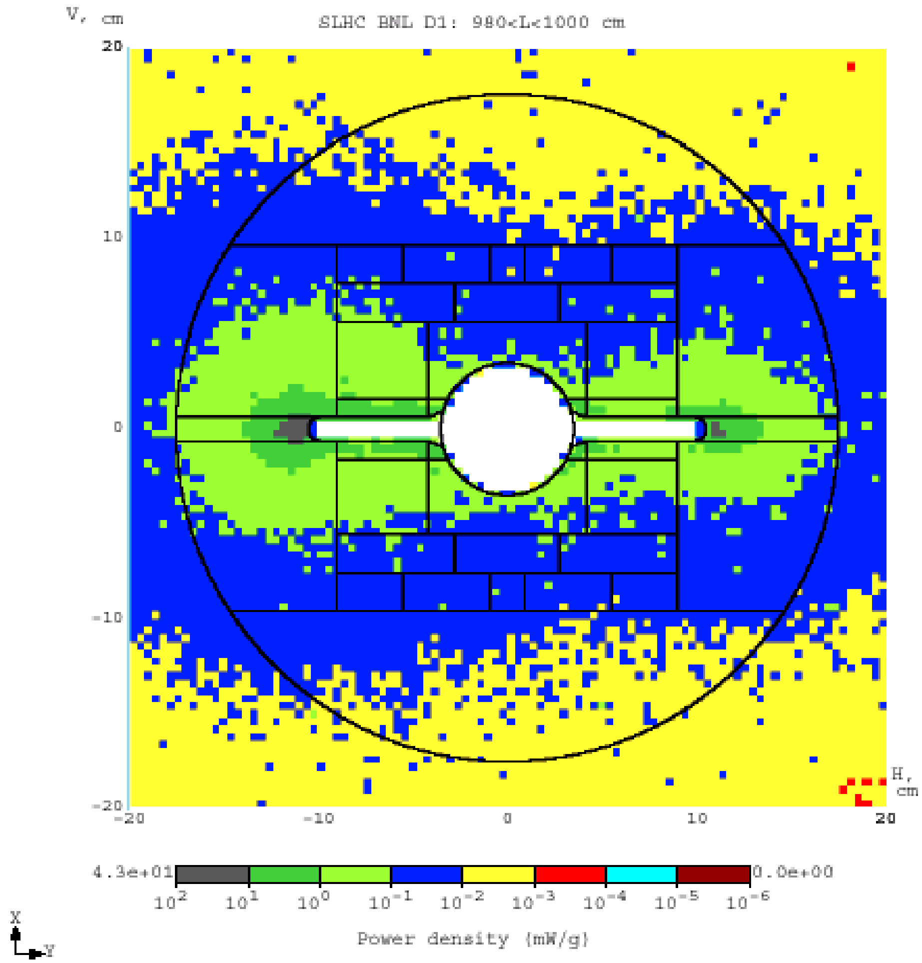


Question:

"Could a magnetic TAS help limit the flux hitting the first dipole?"

Open midplane dipole





- Energy deposition is a severe problem for dipole-first IR.
- P_{dipole} ~3.5 kW for L = 10^{35} cm^{-2} s^{-1}.
- - "Exotic" magnet designs require feasibility study

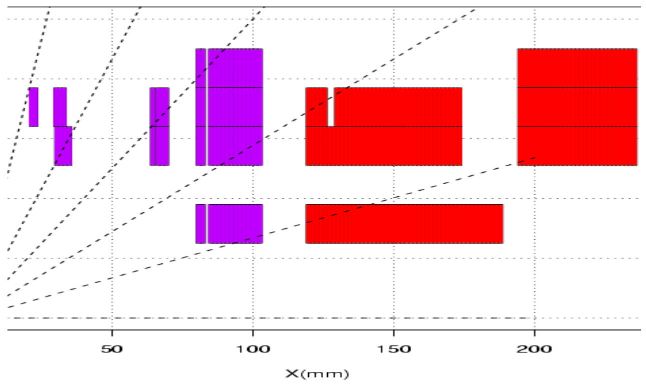
Design iterations in 2004

Design A (06/04):

V/H gap = 50/160 mm

Design/Quench Field = 13.5/15 T

Proof of principle open midplane design became big and expensive.

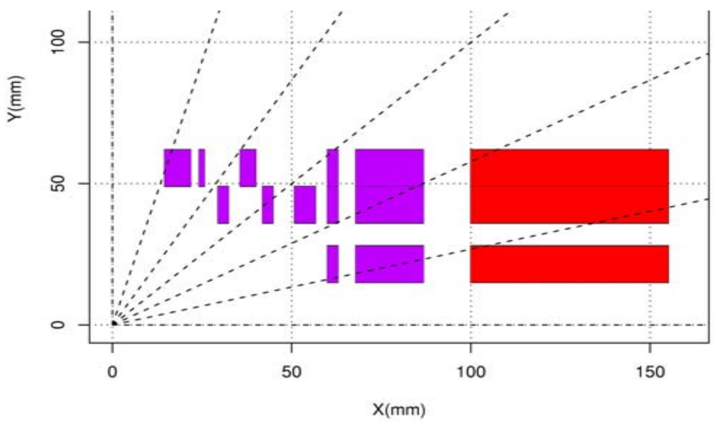


Design B (10/04):

V/H gap = 30/120 mm

Design/Quench Field = 13.5/14.5 T

Smaller magnet with suspected inadequate debris performance

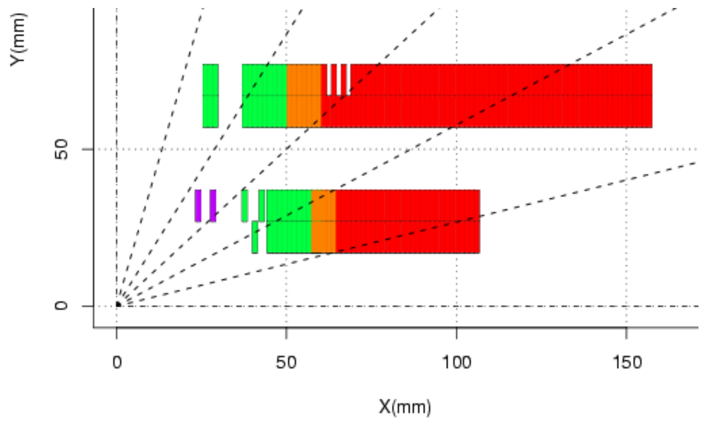


Design C (12/04):

V/H gap = 34/80 mm

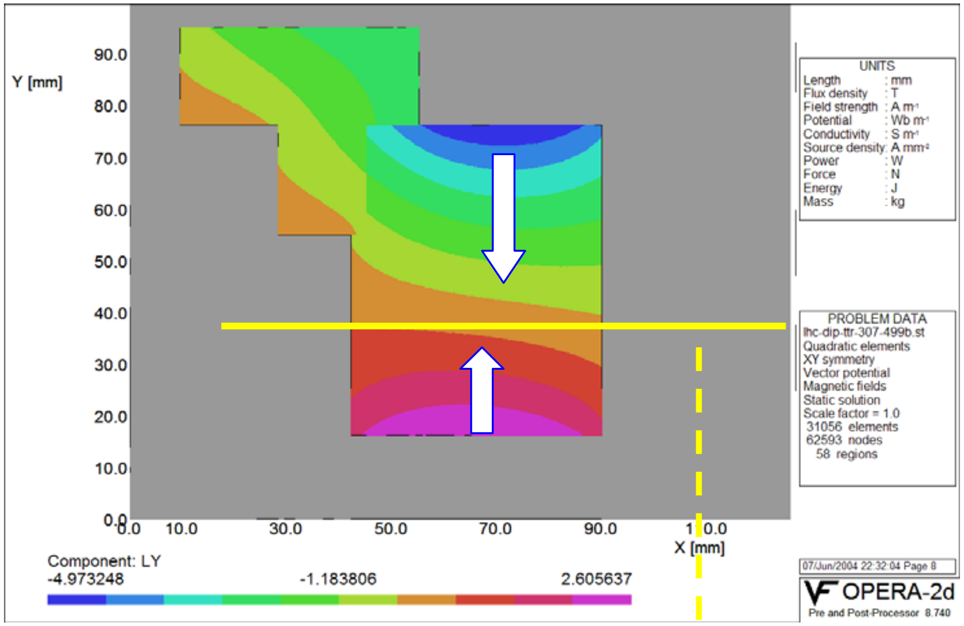
Design/Quench Field = 15/16 T

An aggressive target



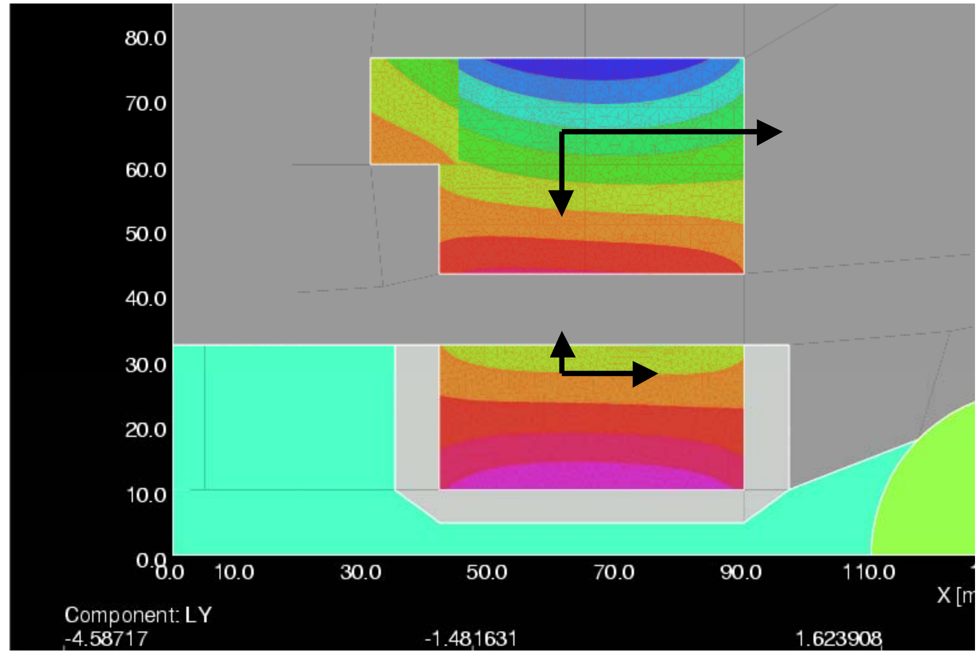
“Levitating” coils

Original design



Zero vertical force line

New design concept



Since there is slight upward force on the lower block, little support is required if the structure is segmented.

This opens up the (vertical) midplane gap

Open Mid-plane Dipole review - Dec 04

“While the 'dipole first' scenario may not be implemented in the first IR upgrade, it remains a viable option for later upgrades.”

"The 'open mid-plane dipole' developed at BNL is a novel concept with several features well suited to face the challenges of the separation dipole (D1) in the 'dipole first' scenario.”

“We suggest continuing and expanding this development to include the aspects not yet covered .... in order to achieve a complete conceptual design ...”

But now it is time for BNL to move on to collaborate with the rest of the LARP program on Nb_3Sb quadrupoles

Quadrupoles

Ruggiero, Taylor, et al (EPAC 04)

"The choice of the coil aperture is driven more by the power density limit than by the beam acceptance"

LARP External Review (June 2004)

"... demonstration of a working long (Nb_3Sn) quadrupole, the first of its kind in the world, will be a key element in the decision to start … the LHC luminosity upgrade."

	Gradient [T/m]	Length [m]	Aperture [mm]	FY05	FY06	FY07	FY08	FY09
Model Magnets								
High gradient (costheta)	> 200	1	90		X X	X X		
Ultimate gradient	> 250	1	90				X	X
Long length, high gradient	> 200	4	90				X	X
Supporting R&D								
Sub-scale tests		0.3		X X	X X	X X	X X	X
Practice Coil		4			X	X		
Long coil tests		4				X	X	

LARP

LHC / RHIC / LARP

RHIC as test bed

Already in place:

- Phase Lock Loop (tune feedback)
- collimators
- ZDC luminosity monitors

Soon to be in place:

- Schottky monitor
- electron cloud detector
- “DAB” standard digitization boards

Potential:

- Beam-Beam long range compensation wires
- ionization gas luminosity monitors

To a greater or lesser extent these developments are:

- “bi-lateral” between RHIC & CERN
- “multi-lateral” between many labs

Commissioning Task Force

LARP has created a Commissioning Task Force, chaired by Vladimir Shiltsev (FNAL), to look at ALL potential LARP commissioning roles

Deliverable is a white paper, ready before this summers CERN-U.S. Executive Committee meeting

This includes a head count based on a preliminary survey of potential names

Information exchange and development at the LARP collaboration meeting (April)

Vladimir's white paper presentation to CERN-U.S. committee may be the most significant next step in the Hardware Commissioning story

Until then (basically) “wait and see” ...

Commissioning

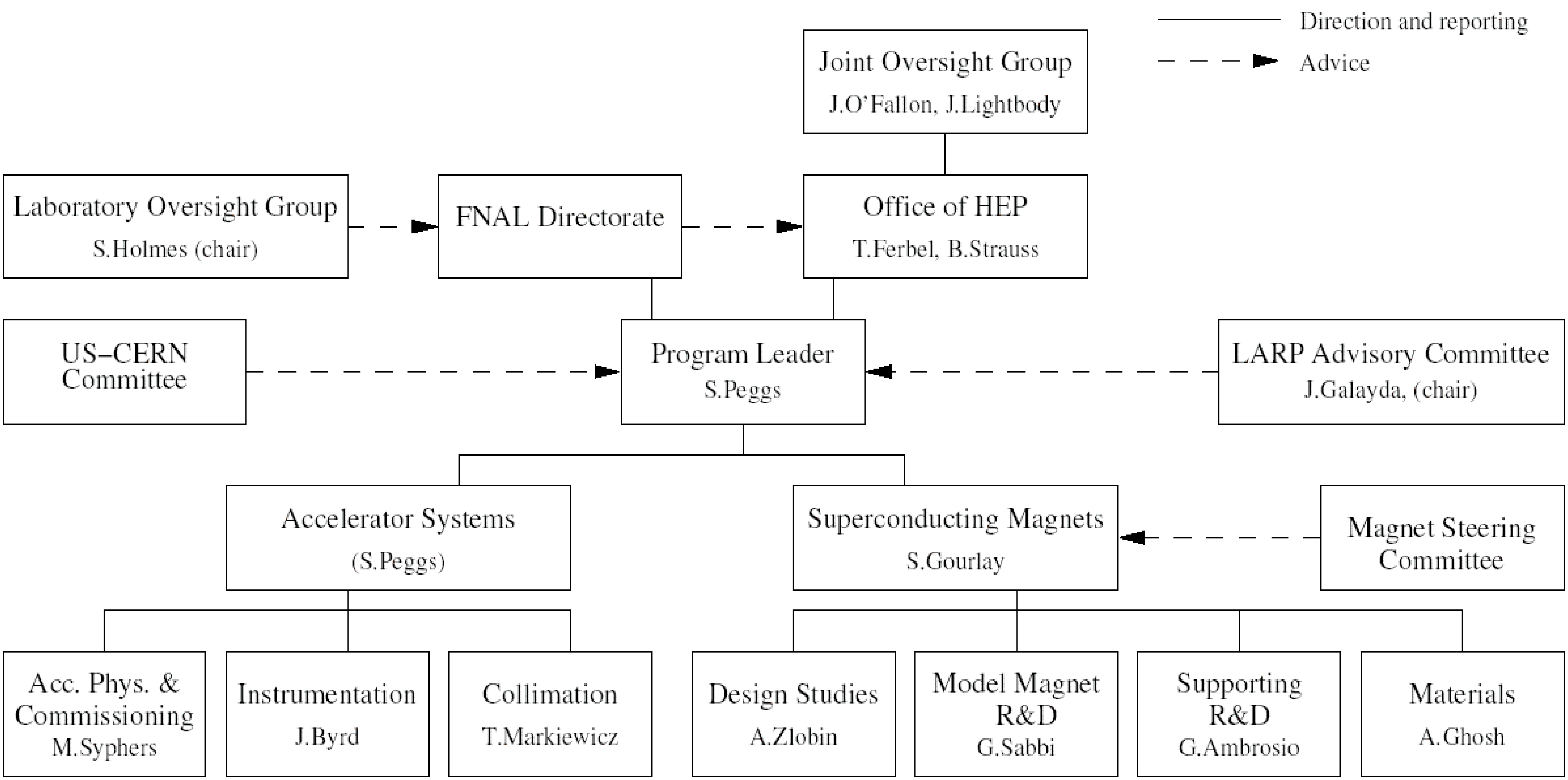
IR commissioning	of U.S. built deliverables
Beam commissioning	RHIC personnel involvement?
Instrumentation commissioning	and exploitation
Hardware commissioning	maintain summer 07 schedule
currently outside LARP scope	

Most important is the (partially unresolved) availability of RHIC Accelerator Physicists for beam commissioning …

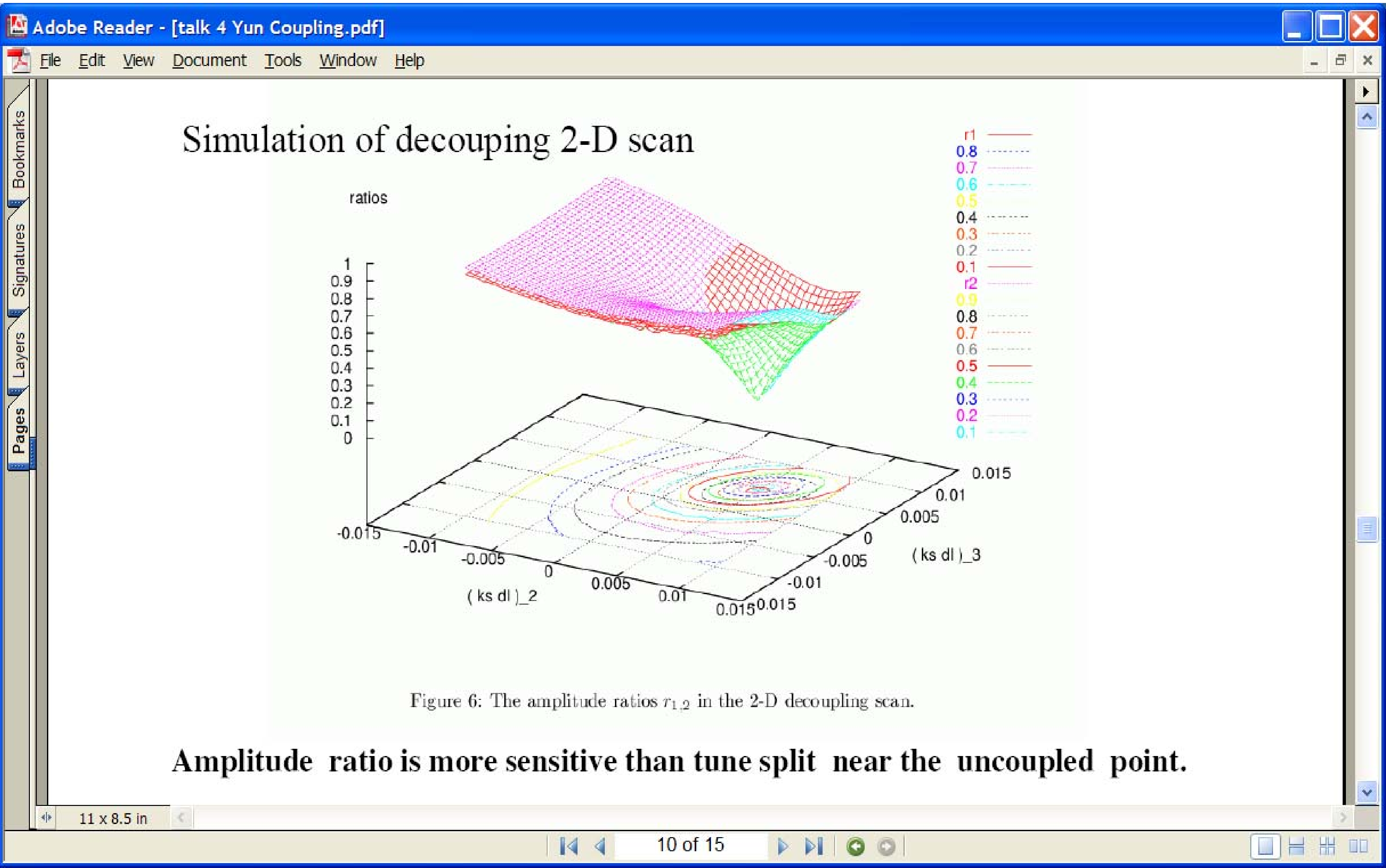
Back up slides

Research Program Management Plan

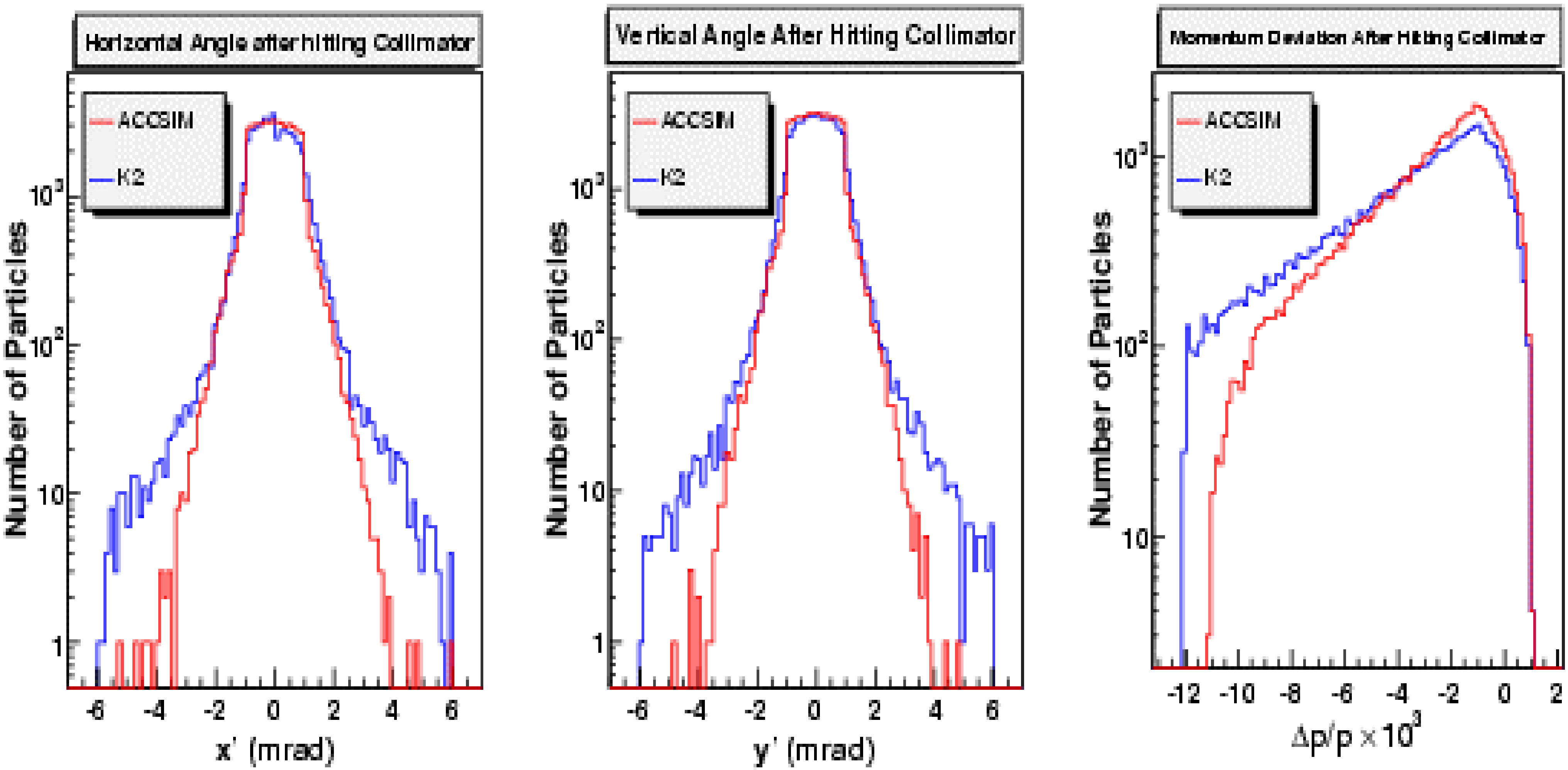
Construction (by Peggs & Holmes) restarted
after recent resolution of org chart, etc ...



2D plot of r1 r2



Comparison of ACCSIM and K2: Output



K2 angle distributions have larger tails. Approximately 50 particles in the K2 tail are not shown The energy distributions are different. K2 has a much larger tail, 3% of the particles in the K2 tail have $\Delta p/p<-12x10^3$.

LARP

Basic Layout of The Current D1 Design

Magnet is consisted of simple racetrack coils (two double pancake)

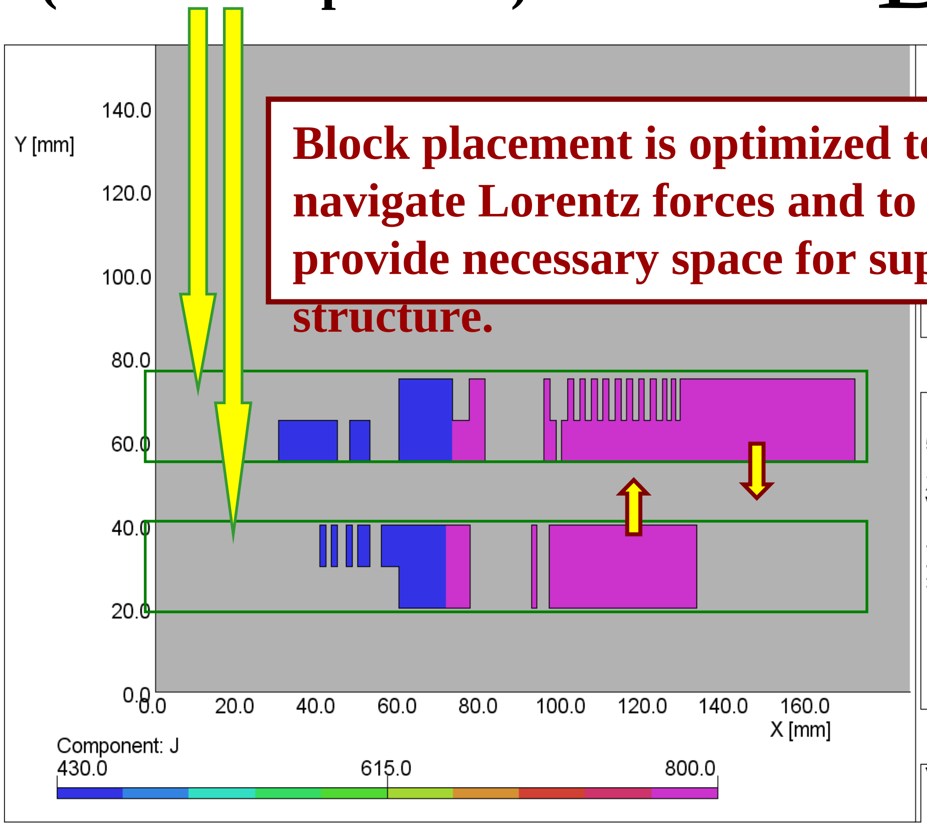
Design/Quench/Peak Field: 13.5 T/15 T/16 T

Nominal horizontal coil spacing : 120 mm

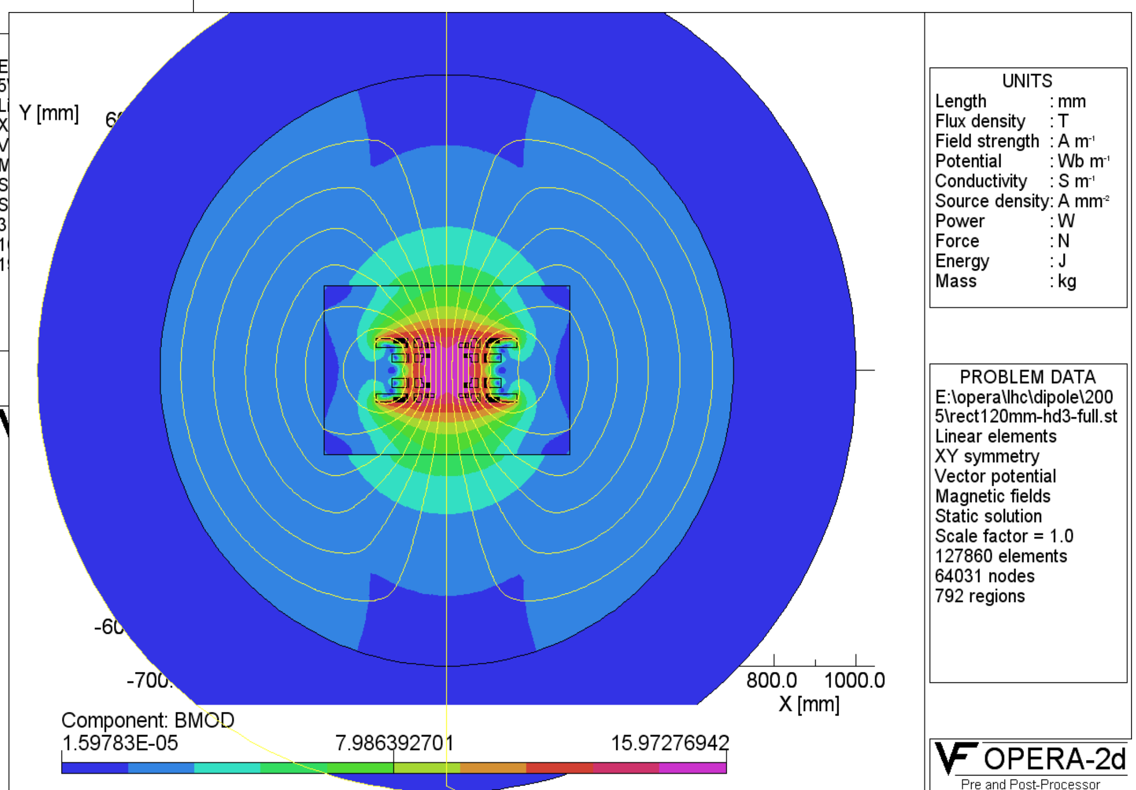
Nominal vertical coil spacing : 40 mm

Number of layers : 4

Number of turns: 230

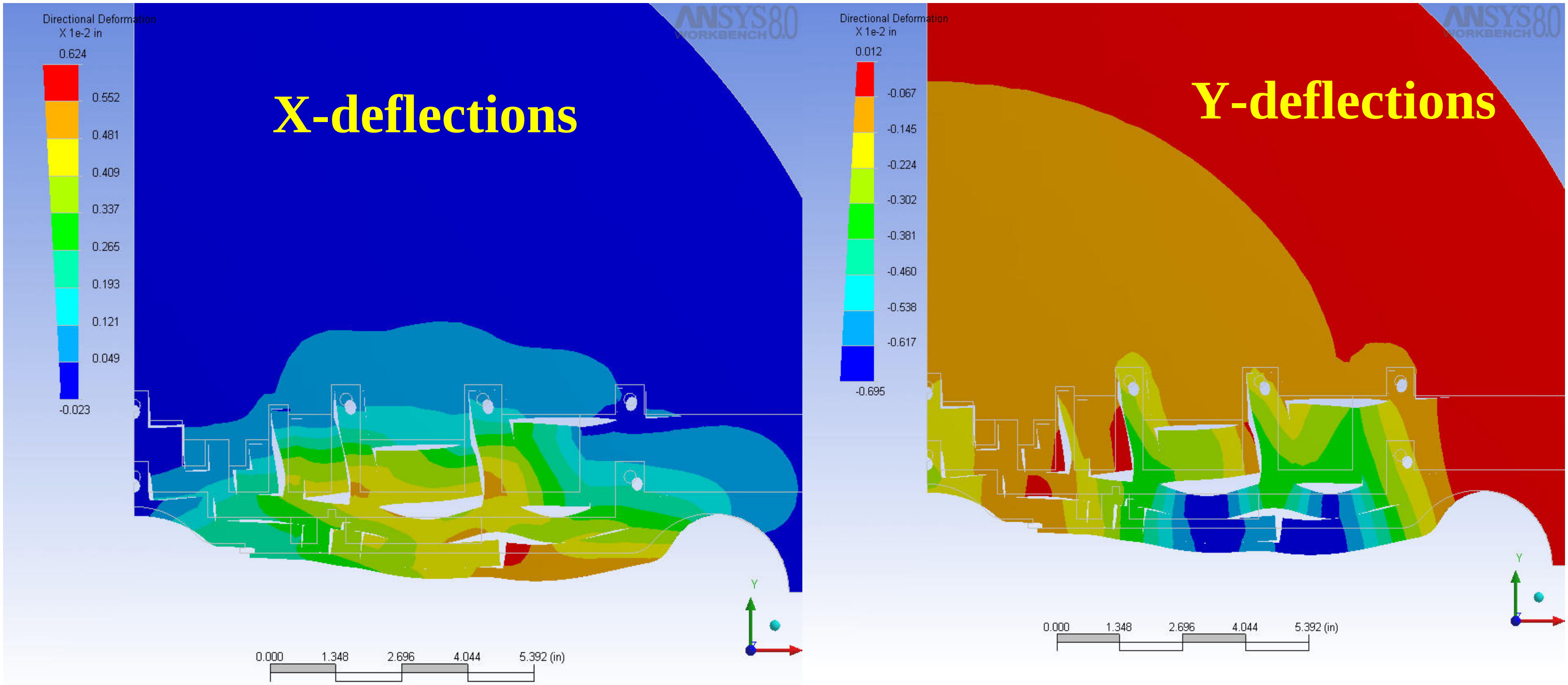


Block placement is optimized to navigate Lorentz forces and to provide necessary space for support structure.



Lorentz force is upward in lower blocks. This eliminates the need of midplane support structure to contain vertical Lorentz forces.

Mechanical Analysis



In the present design the relative values of the x and y deflections are 3-4 mil (100 micron) and the maximum value is 6-7 mil (170 micron).

Above deflections are at design field (13.6 T). They are ~1-2 mil higher at quench field.

Commissioning Task Force
(Shiltsev et al)

CTF makes great progress, including here at PJ

Concept of a Machine Commissioning Project (MCP)

Global Hardware Commissioners eligible for Project Associate status

Grey area between Deliverable HC and GHC: “mission creep”?

Pairing of junior & senior commissioners

RORO – Read Only Remote Operations ??

Surprising/interesting manpower numbers

- financial assumptions must be stated to US labs

RHIC: <6 month runs compatible with >6 month visits?

Integration into Roger Bailey's table ...