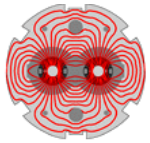


LHC Commissioning & Upgrades

as part of LARP Accelerator Systems

Vladimir Shiltsev FNAL/AD

LARP Technical Scope

Letter from Joint Oversight Group (DOE and NSF):

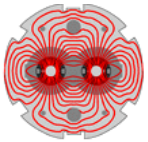
" The research program should be planned to make optimal use of the infrastructure and expertise within participating US National Laboratories and should be worked out with CERN on the basis of mutual interest.

The planned research could be expected to include:

participation in beam commissioning and ongoing optimization of beam parameters;

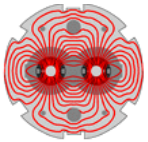
beam experiments, including construction of specialized instrumentation, aimed at both improved LHC performance and fundamental beam physics questions

design and development of equipment for improvements to the LHC, such as 2nd generation IR quads and advanced instrumentation."



LHC Technical Challenges

	Tevatron [March '06]	LHC ["nominal"]
Luminosity [cm-2 s-1]	1.7e32	100e32
Magnet style	1-in-1	2-in-1
Beam-beam tuneshift	0.025	0.010
# of bunches	36	2,808
Beam stored energy [MJ]	1	366
B-field stored energy [MJ]	300	10,600
Chromaticity snapback dQ'	~40	~100
Tolerable loss on ramp	~2-4%	~0.01-0.1%



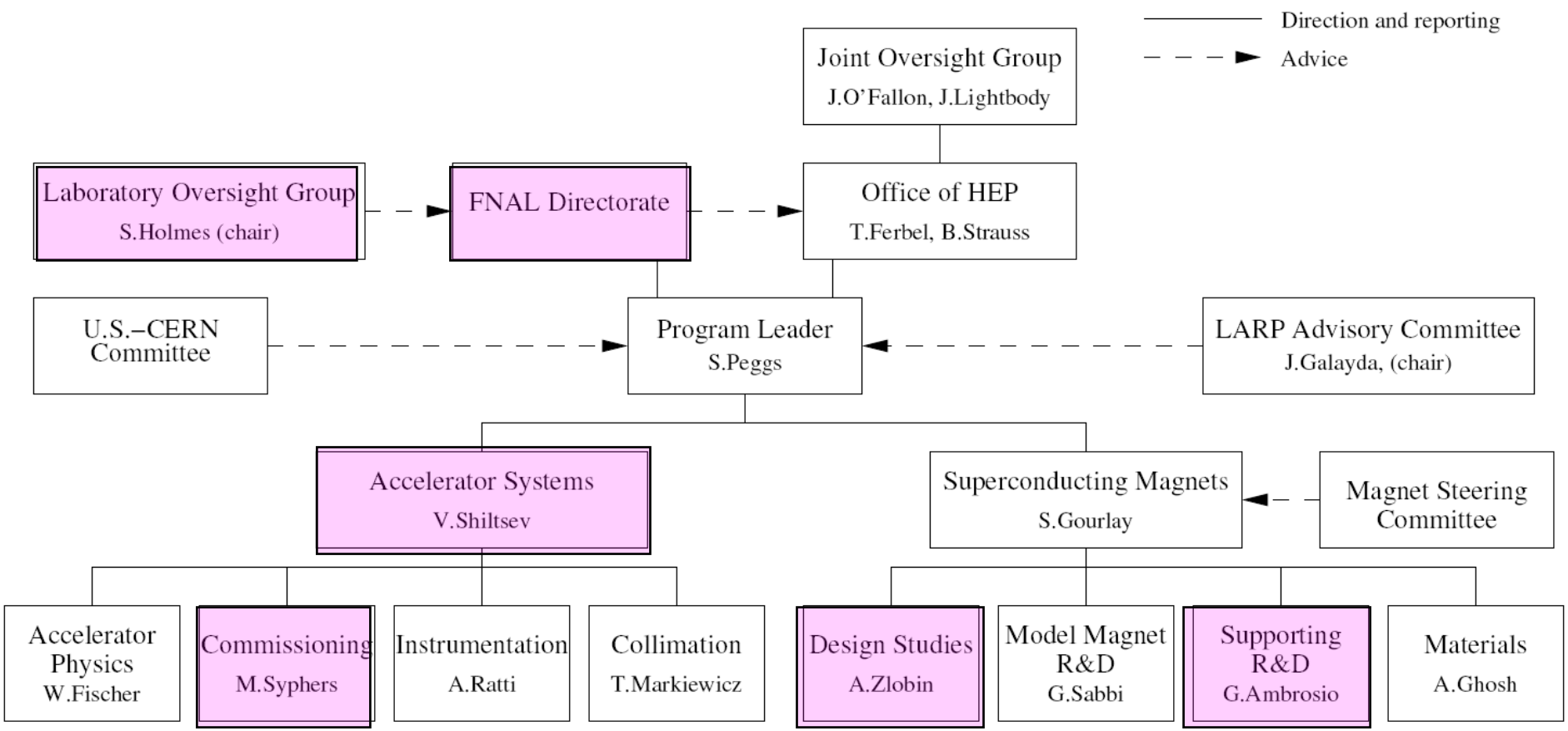
Host Lab

Letter from Joint Oversight Group (DOE and NSF) to FNAL Director:

" ... we request that Fermilab serve as Host Laboratory for US participation in these aspects of the Research Program, consistent with the International Agreement and its Accelerator Protocol."

US LHC Accelerator Research Program (LARP) Organization Chart

January 5, 2006



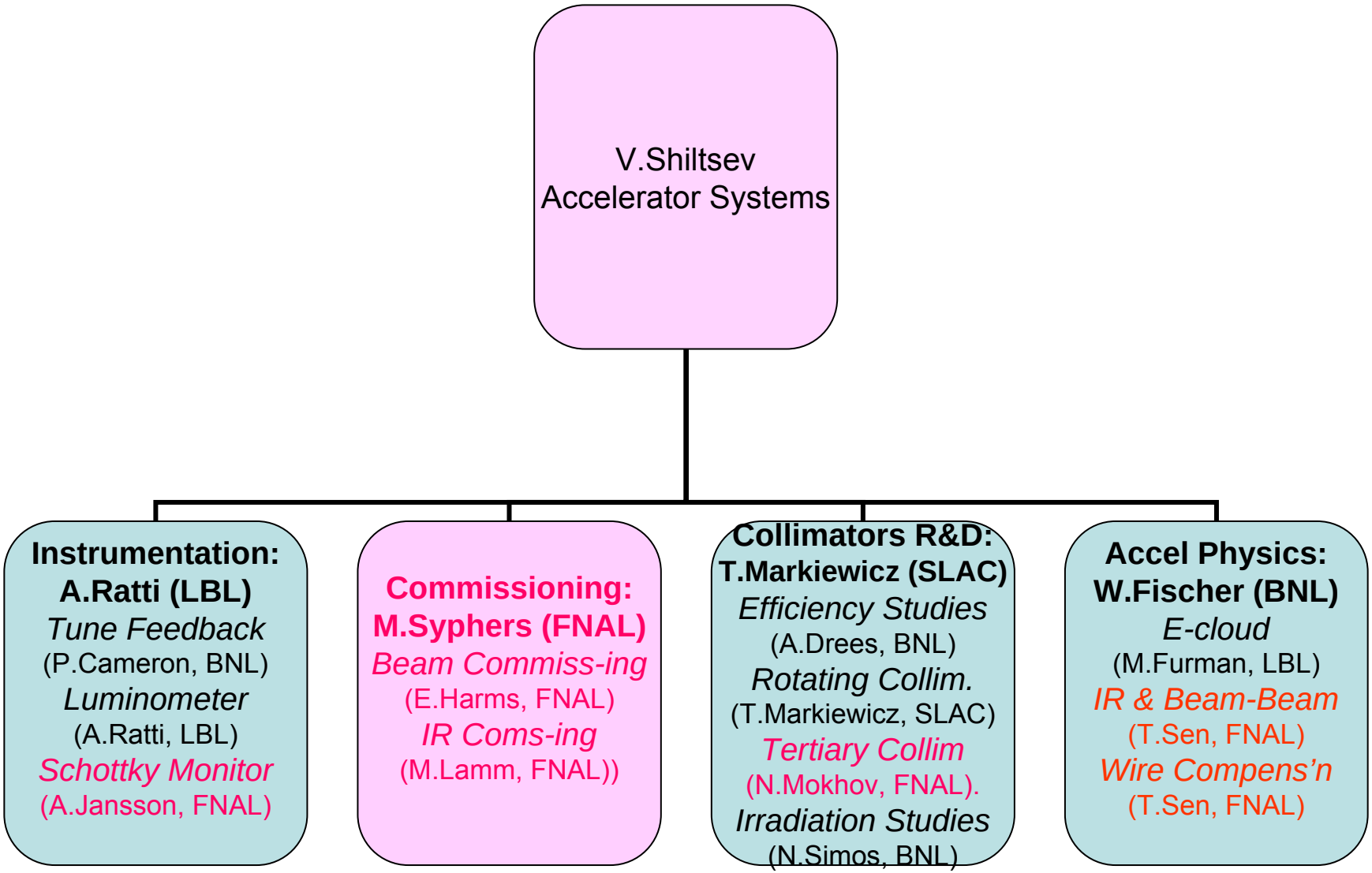
LARPAC: J.Galayda (chair), A.Chao, A.Devred, J.Minervini, C.Rode, A.Seryi, K.Wittenburg, A.Yamamoto

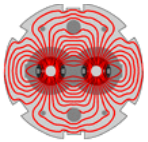
LOG: S.Holmes (chair), P.Drell, S.Ozaki, J.Siegrist

MSC: S.Gourlay, G.Ambrosio, A.Ghosh, M.Lamm, G.Sabbi, P.Wanderer, A.Zlobin

US–CERN Comm: L.Evans, R.Assmann, R.Bailey, P.Bryant, P.Lebrun, R.Ostojic, L.Rossi, F.Ruggiero, R.Saban, H.Schmickler S.Holmes, S.Gourlay, M.Harrison, J.Kerby, P.Limon, S.Peggs, T.Raubenheimer, V.Shiltsev, J.Siegrist, V.Yarba

Accelerator Systems Org Chart

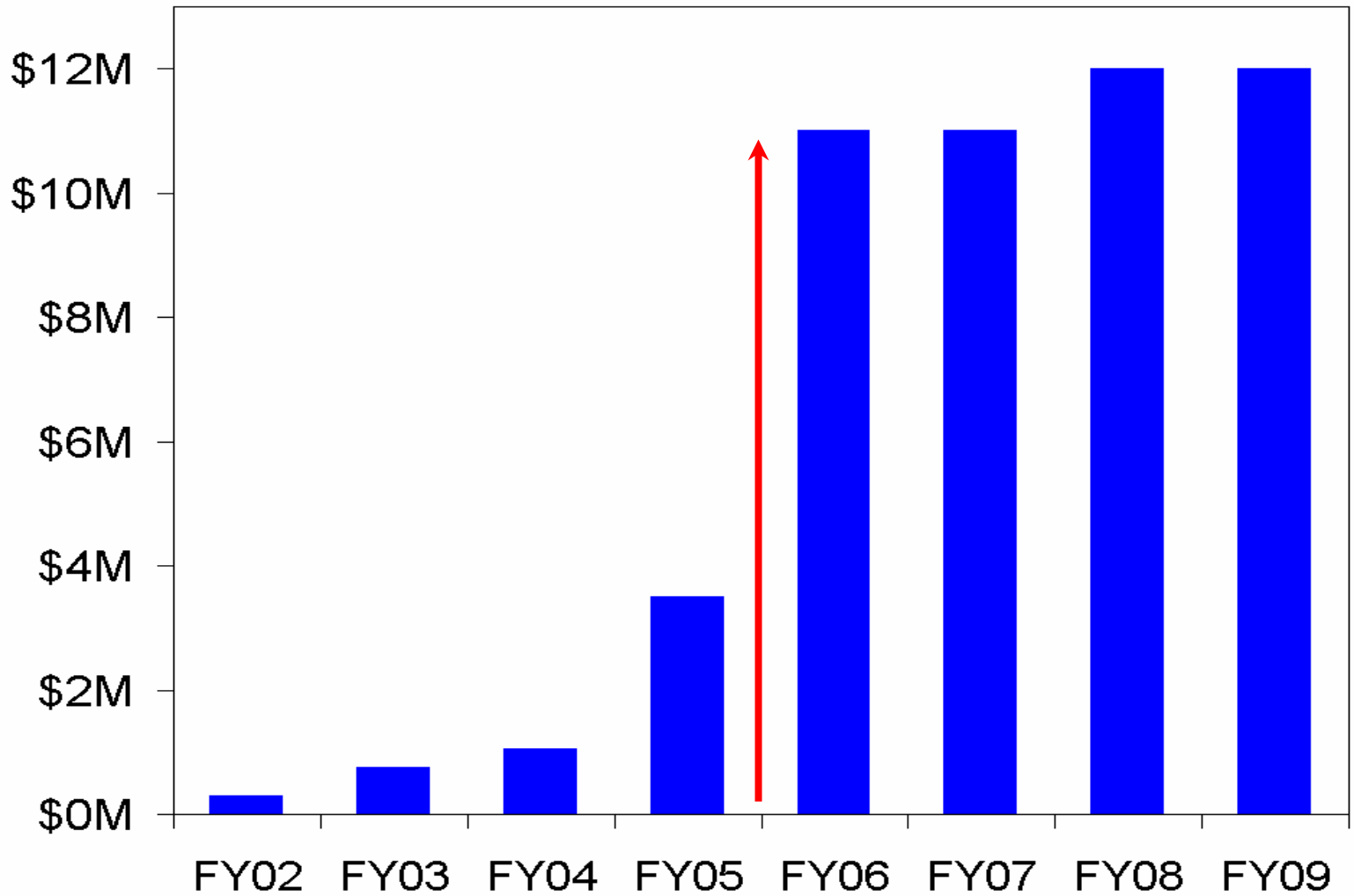


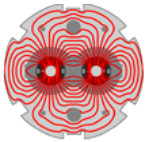


FY'06

- All tasks involve multiple labs
- Matrix organization across multiple labs is not without its challenges
- Good communications and a lot of travel are necessary
- All "direction and reporting" mechanisms are now in place
- First year of the big funding step from ~3M$ to 11M$

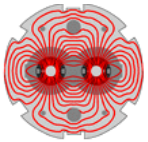
Budget Scope





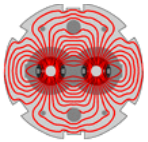
FY06 Accelerator Systems Budget

Mar 31, 2006 WBS			Total	Labor+MTSC BNL	FNAL	LBNL	SLAC
US LHC Accelerator Research Program			11000	3264	3300	4086	350
1	**Accelerator Systems**	**Shiltsev**	3684	875	1200	1309	300
1.1	**Instrumentation**	**Ratti**	1635	450	250	935	0
1.1.1	Phase I						
1.1.1.1	Tune feedback	Cameron	430	405	25		
1.1.1.2	Luminometer	Ratti	960	25		935	
1.1.1.4	Schottky monitor	Jansson	245	20	225		
1.2	**Commissioning**	**Syphers**	879	65	670	144	0
1.2.1	Phase I						
1.2.1.1	Beam Commissioning	Harms	335	35	300		
1.2.1.2	Interaction Region Commissioning	Lamm	501	30	335	136	
1.2.1.3	Hardware Commissioning	Lamm	43		35	8	
1.3	**Collimation**	**Markiewicz**	500	150	50	0	300
1.3.1	Phase I						
1.3.1.1	Cleaning efficiency studies	Drees	50	50			
1.3.2	Phase II						
1.3.2.1	Rotating Collimator R&D	Markiewicz	320		20		300
1.3.2.2	Tertiary collimator study	Mokhov	30		30		
1.3.2.3	Irradiation studies	Simos	100	100			
1.4	**Accelerator Physics**	**Fischer**	670	210	230	230	0
1.4.1	Studies						
1.4.1.1	Electron Cloud	Furman	200	50		150	
1.4.1.2	Interaction Regions & Beam-Beam	Sen	260	0	180	80	
1.4.1.3	Beam-Beam wires	Sen	210	160	50		



Accelerator Division activities

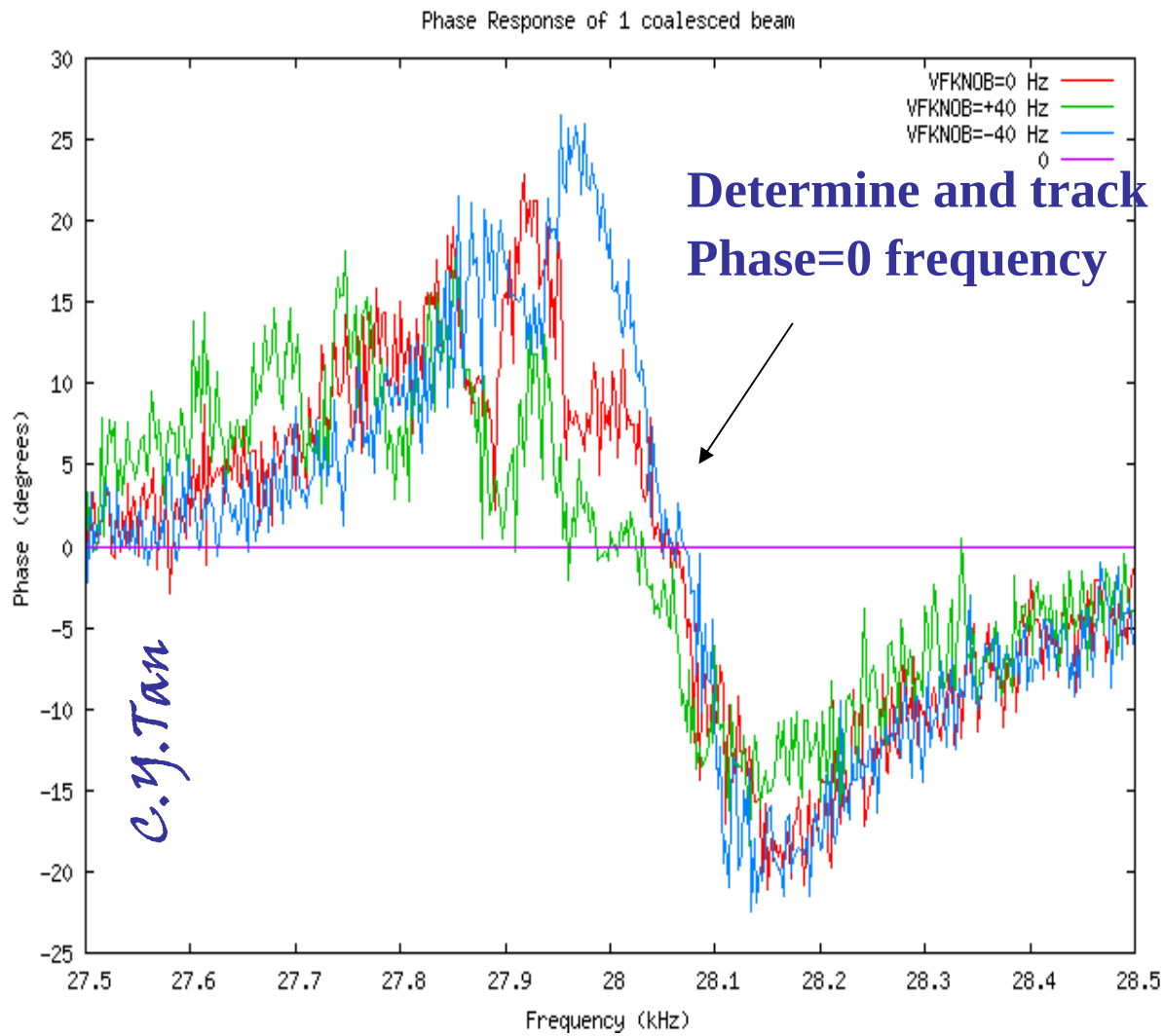
- Instrumentation
  - TuneTracker and Tune Feedback in Tevatron and RHIC
  - 4.8GHz Schottky monitor design
- Commissioning
  - Hardware commissioning
  - Beam commissioning
  - LHC@FNAL, communication and documentation
- Collimation
  - Tertiary collimators to protect detectors
- IR Design, Beam-beam and Energy Deposition
  - Beam-beam simulations and experiment at RHIC
  - Wire compensation device design and tests
  - Quad-first and Dipole-first upgrade optics



Accelerator Division Efforts

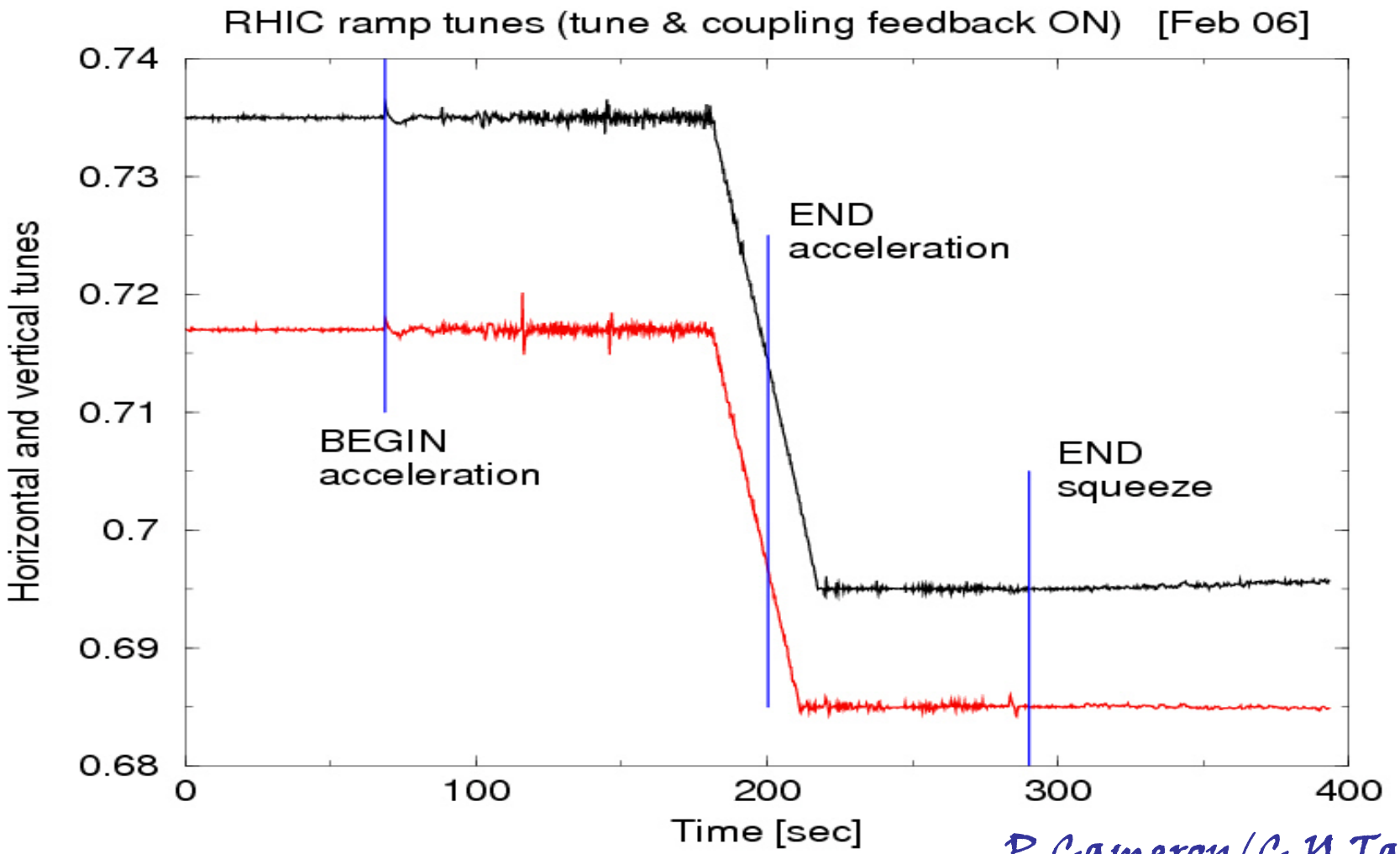
- FY'06 budget 0.9M$
- Current effort:
  - 17 people:
    - 7 Engineers and Designers
    - 3 Post-docs and guest scientists
    - 7 Physicists
  - Total ~5.5FTE
- Oct'06: 1 person scheduled to start 1 yr term to do LHC generic hardware commissioning

Fast Tevatron Tune Tracker



- Beam is lightly excited over a frequency range around f_betatron
- Zero phase response frequency declared =Q
- Accuracy in Q ~0.0001
- Very fast method (3Hz)
  - Works on every Tev ramp and in LB squeeze
- Change dP/P and determine Q'
  - Stat accuracy ~0.2
  - Syst error ~0.5 unit
- See Poster session

TCFB on RHIC ramp

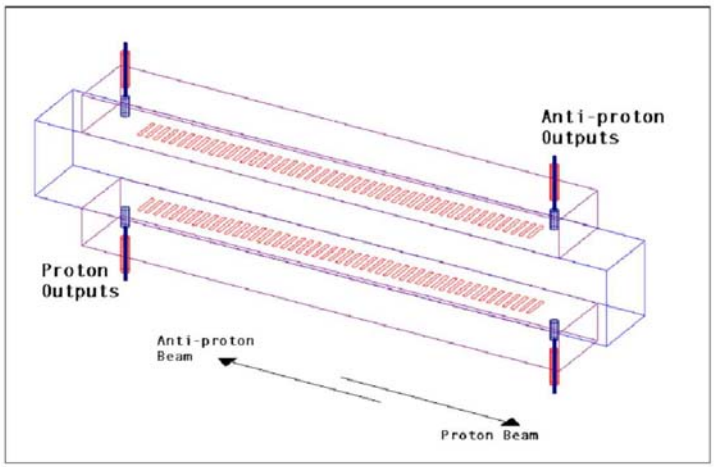


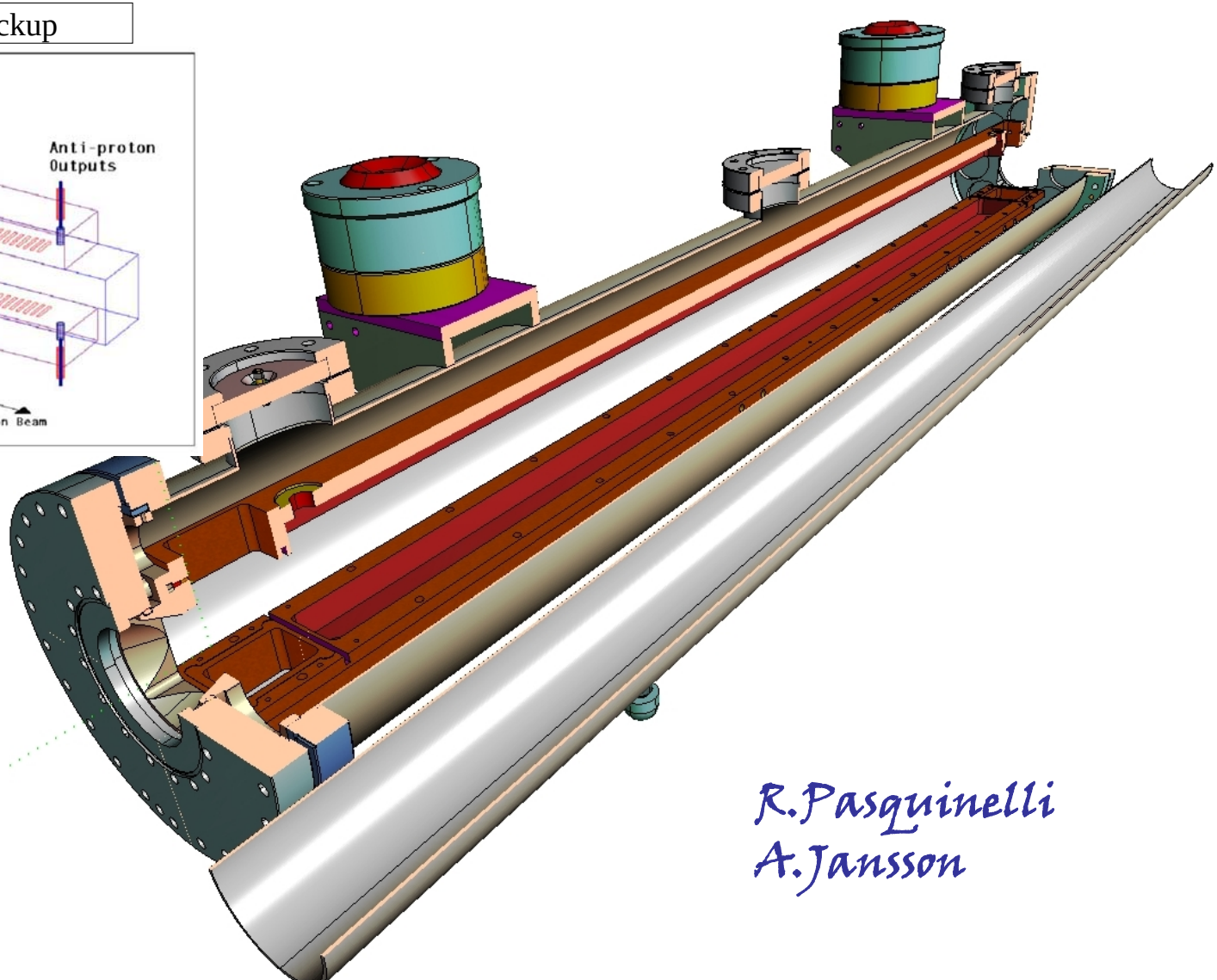
P.Cameron/C.Y.Tan

LHC 4.8 GHz Schottky Design

LARP

Slotted Waveguide Pickup





- Remarkable Progress:
  - Final drawings ready for CERN inspection
  - Final Design Review 06/19/06 at CERN

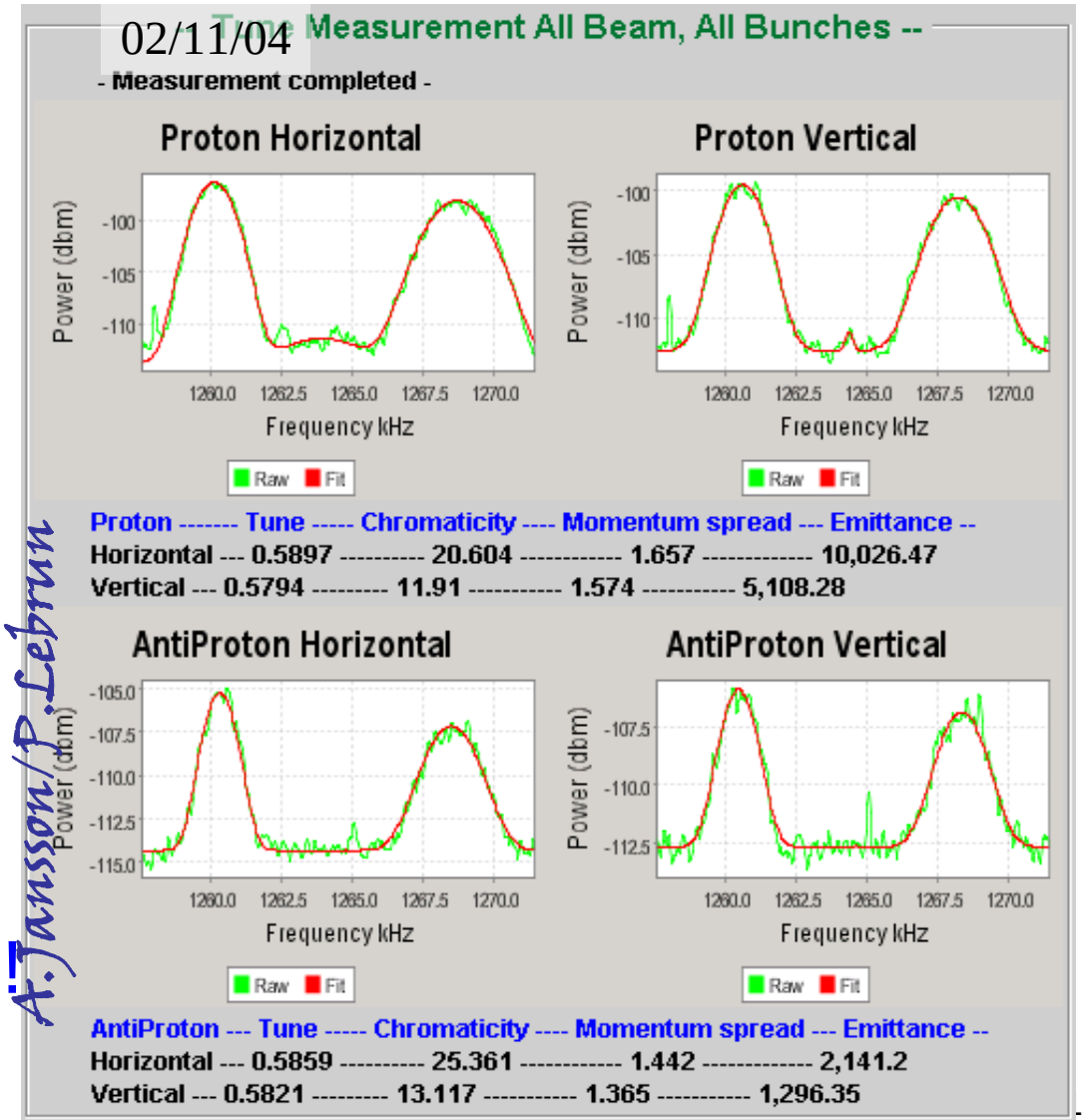
R.Pasquinelli
A.Jansson

1.7GHz Schottky Spectra

#3226
02/11/04

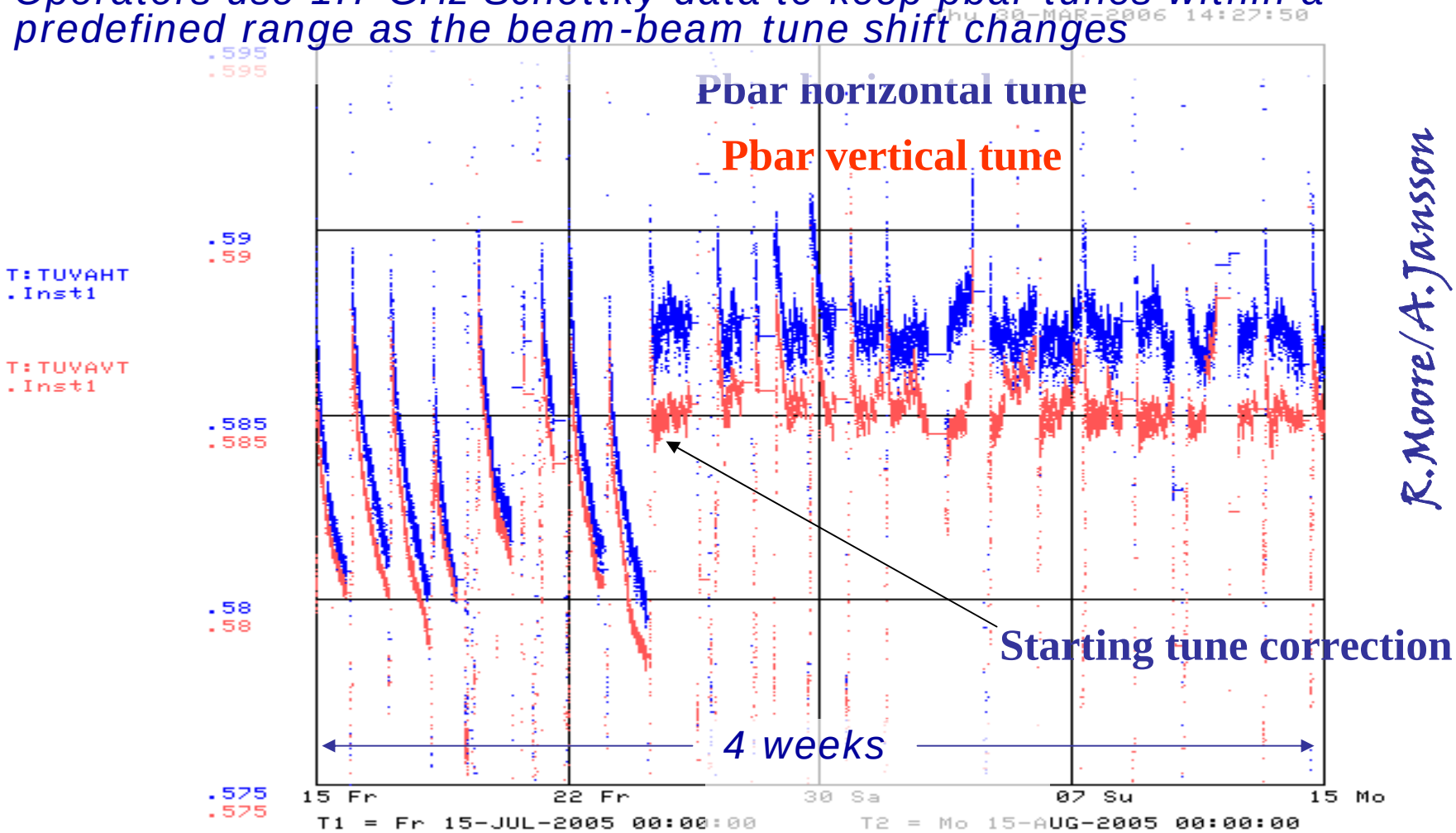
- Q and 1-Q lines are seen
- Fit gives:
  - Betatron frequency (accuracy ~0.001)
  - dP/P ∝ sum of two widths
  - C_vh ∝ difference of two widths
  - Emittance ∝ area under the peaks
- For each bunch!

... non-invasive!



Tevatron Tune Stabilization

- *Operators use 1.7 GHz Schottky data to keep pbar tunes within a predefined range as the beam-beam tune shift changes*



LARP Hardware Commissioning Tasks

Installation Oversight

M.Lamm

Since DOE Review Last Fall:

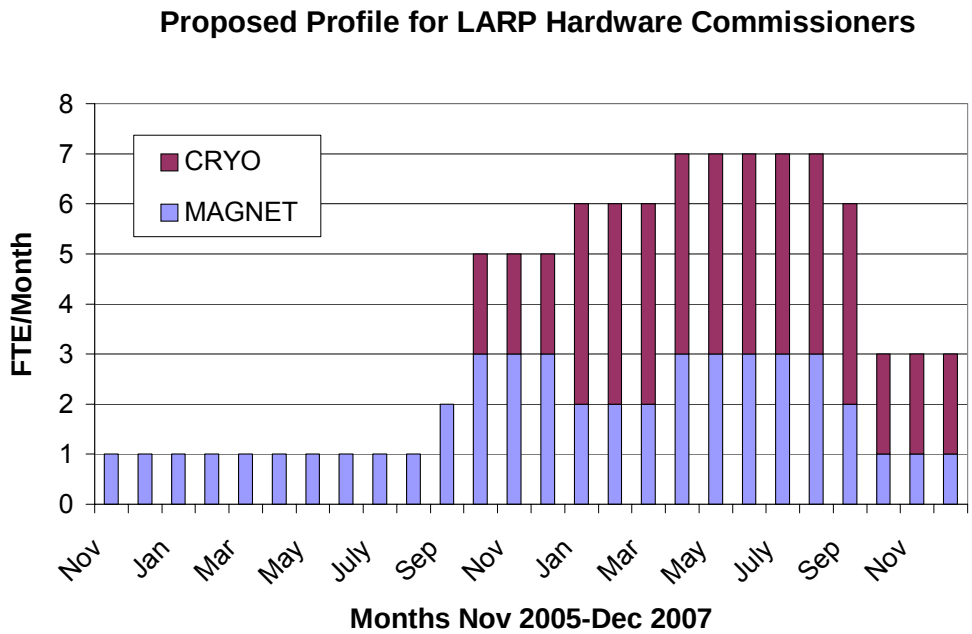
- First USLHC String (Q1-Q3/Feedbox/D1) transported to tunnel
- LARP Oversight and technology transfer for USLHC interconnects
- Transportation and Installation of Second IR quad/DFBX/D1 on going.
- Limited LARP oversight planned for all US deliverable installations

Photos from Jan 2006 IR 8L installation

LARP Hardware Commissioning Tasks

Commissioning of US Deliverables and General HC

- LARP commissioners receive “Project Associate” status, join a CERN group (AT/ACR or AT/MEL) for nominally one year and contribute to the groups general HC responsibilities as well as US deliverables.
- Short term HC support from US experts as needed



- One commissioner stationed at CERN now. 3-4 additional to follow in the fall of 2006.
- Peak participation coincides with anticipated peak commissioning period FY07.

M.Syphers/M.Lamm

Beam Commissioning Status

- Several US visitors to CERN in January/February 06
  - Nearly continuous presence for ~6 weeks
  - Chamonix workshop
  - Beam Commissioning logistics
  - Software
  - CCC opening
  - get to know LHC beam principals

- Informal review of LHC Beam Commissioning structure completed
  (~13 people are currently being considered)

- Beam Commissioning 'Expression of Interest'
  (circulated in all 4 Labs)

- Refining areas of involvement, beginning to assign names/share with CERN counterparts

- Gearing up for LARP presence during SPS running, more so for Sector test

- Details presented in Poster Session

E.Harms/M.Syphers

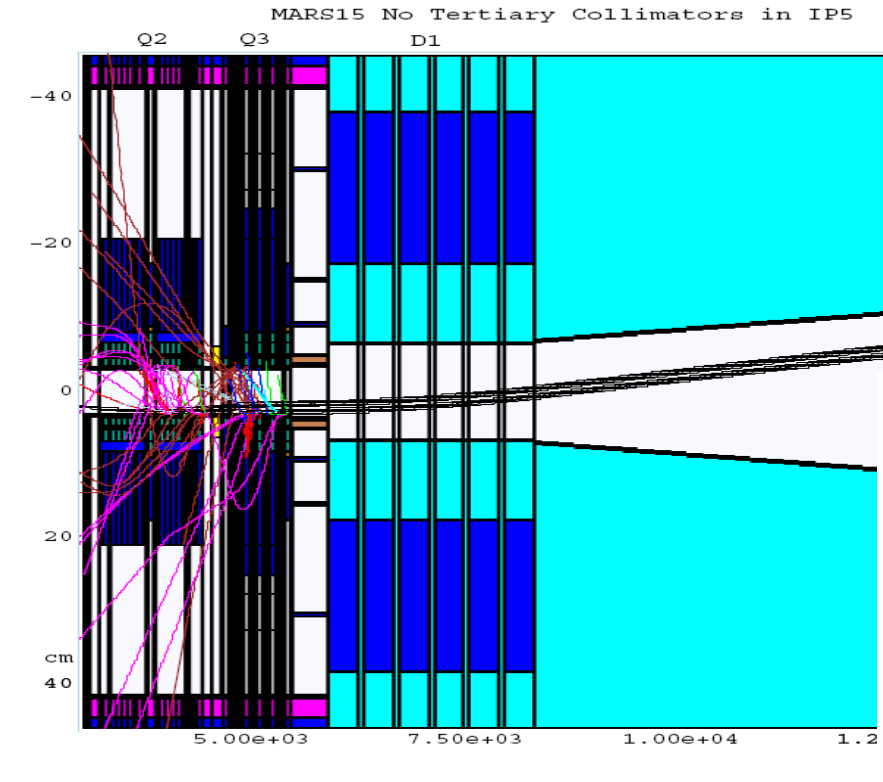
LHC@FNAL Status

- Committee's work complete
- Endorsement received fro
  - Fermilab Directorate
  - Affected Fermilab Divisions/Sections (AD, PPD, CD, FESS)
  - LARP management
  - CMS management
- Construction plans in development
- Funds set aside/awaiting DOE approval
- Center planned to be open in September 2006

E.Harms/E.Gotschalk

TERTIARY Collimators at CMS

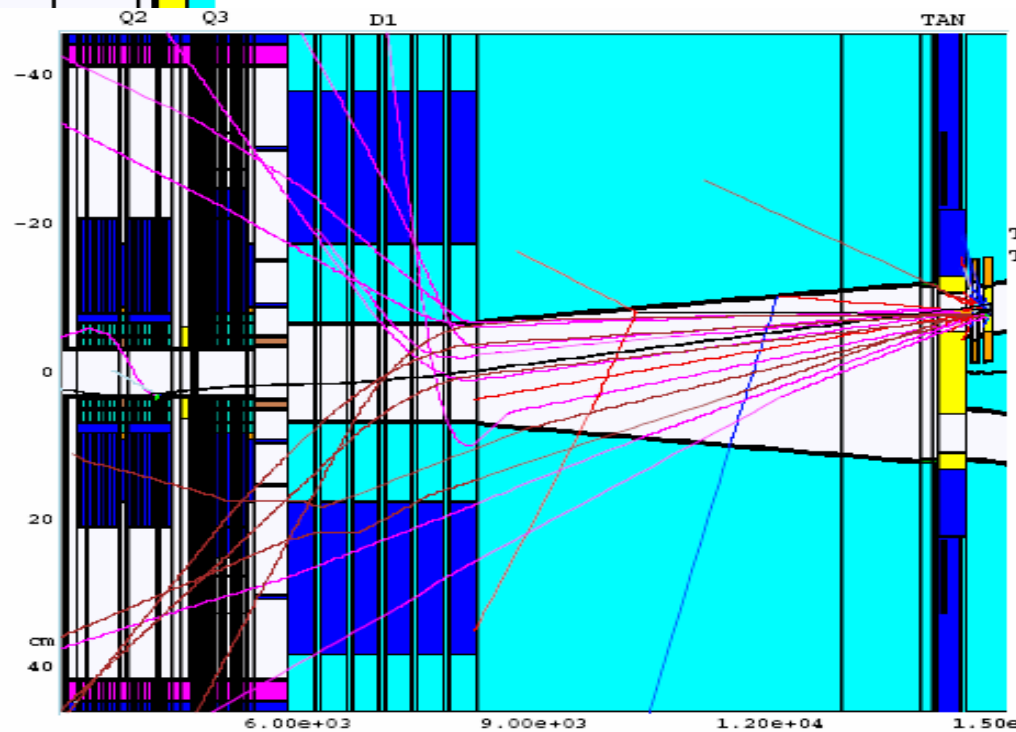
LARP



article tracks E>10 GeV for a few 7-TeV protons at > 8.4

N.Mokhov/M.Monville

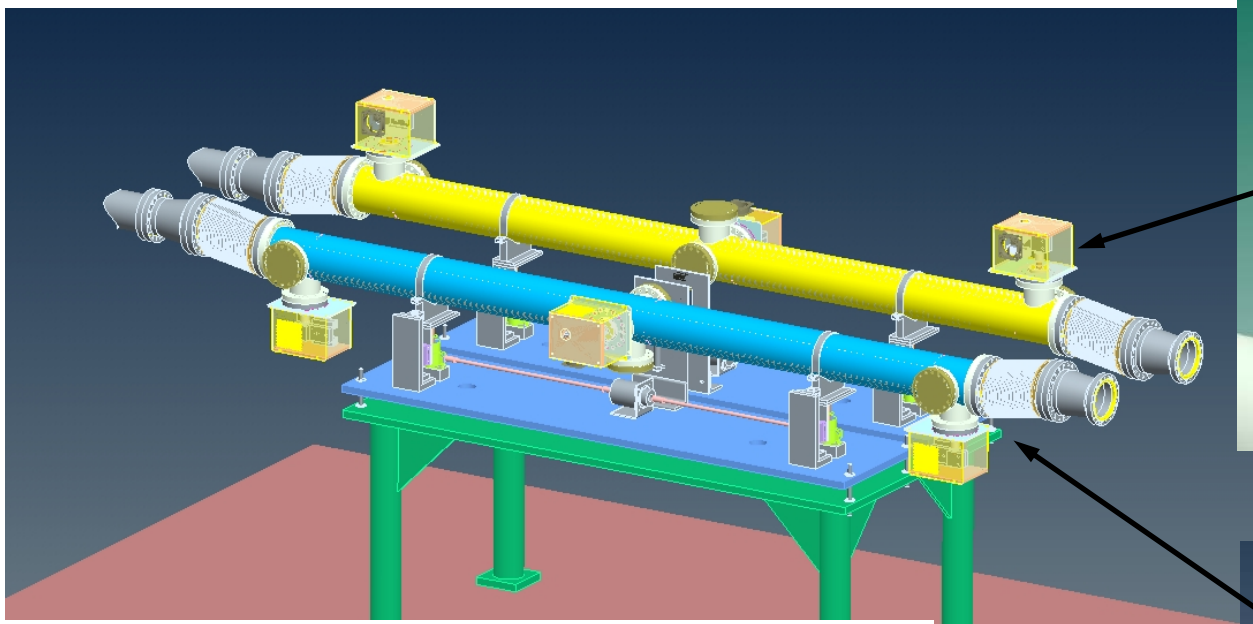
Primary	**6 sigma**
Secondary	**7 sigma**
Inner Triplets	**8.5 sigma**
Arcs	**30 sigma**

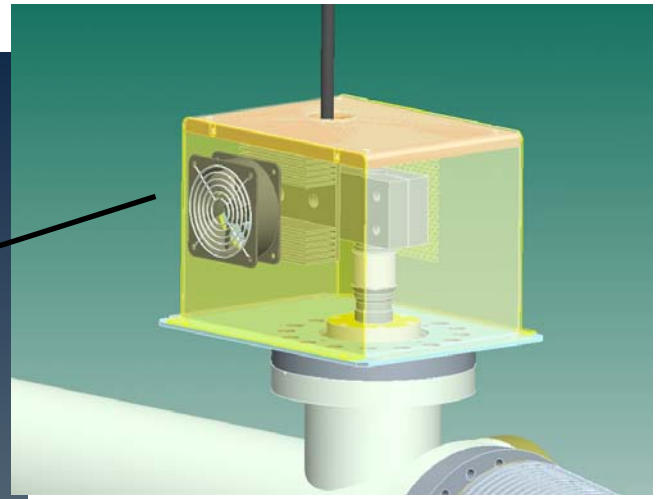


- Simulations of Detector protection against beam losses at secondary collimators, due to beam-gas and unsynchronized aborts
- Two 1m long copper jaws H,V at 7-8 sigma from beam, 145 m from IP

Particle tracks E>10 GeV for a few 7-TeV protons on TCTs

RHIC long-range beam-beam compensator design





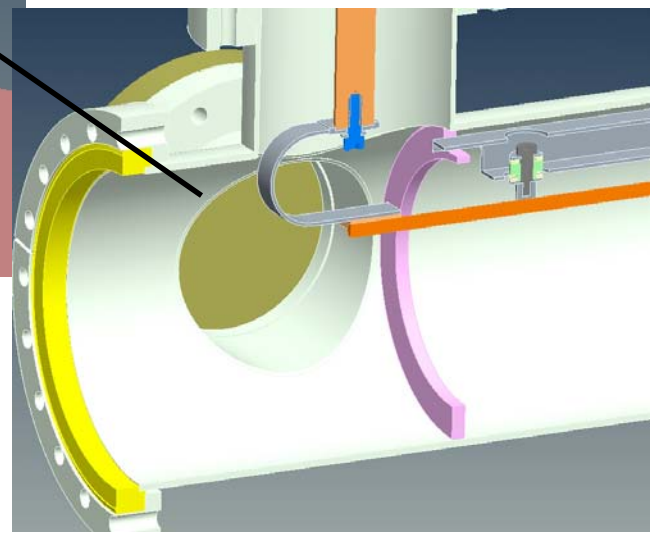
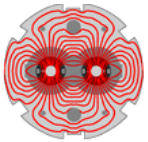


Table 3: Main parameters for RHIC long-range beam-beam compensators.

quantity	unit	value	comment
integrated strength (IL), single interaction	Am	9.6	
maximum integrated strength $(IL)_{max}$	Am	125	
length of wire L	m	2.5	
radius of wire r	mm	3.5	
number of heat sinks n	...	3	at both ends and in middle
electrical resistivity ρ_e	Ωm	1.72×10^{-8}	Cu (at 20°C)
heat conductivity λ	$Wm^{-1}K^{-1}$	384	Cu (at 20°C)
density ρ_g	kg/m^3	8.96×10^3	Cu (at 20°C)
thermal expansion coefficient	K^{-1}	1.68×10^{-5}	Cu (0 to 100°C)
melting temperature	K	1083	Cu
radius of existing beam pipe r_p	mm	60	
current in wire I, single interaction	A	3.8	
maximum current in wire I_{max}	A	50	
electric resistance R	mΩ	1.12	
maximum voltage U_{max}	mV	55.9	
maximum dissipated power P_{max}	W	2.8	
maximum temperature change ΔT_{max}	K	15	
maximum change in length ΔL_{max}	mm	0.4	
vertical position range	mm	65	
vertical position range	σ_y	10.6	for $\gamma = 107$, $\beta^* = 1$ m, and $\epsilon_n = 20$ mm·mrad
weight of wire G	kg	0.9	

T.Sen/W.Fischer

In CY06 – construct and install a wire compensator in RHIC, downstr. of Q3 in IR6



Beam-beam experiments, simulations

- **RHIC beam-beam experiments in April 2006**

  Motivation: Test of wire compensation in 2007

  Determine if a single parasitic at top energy causes beam losses that need to be compensated. Similar experiment done last year at injection energy - found strong effects at separations ≤ 6σ.

  2 experiments done so far – April 5th, April 12th

- **Beam-beam simulations of 2006 experiments**

  Motivation: Tests and improvements of codes, predictions of observations in 2006 and of wire compensation

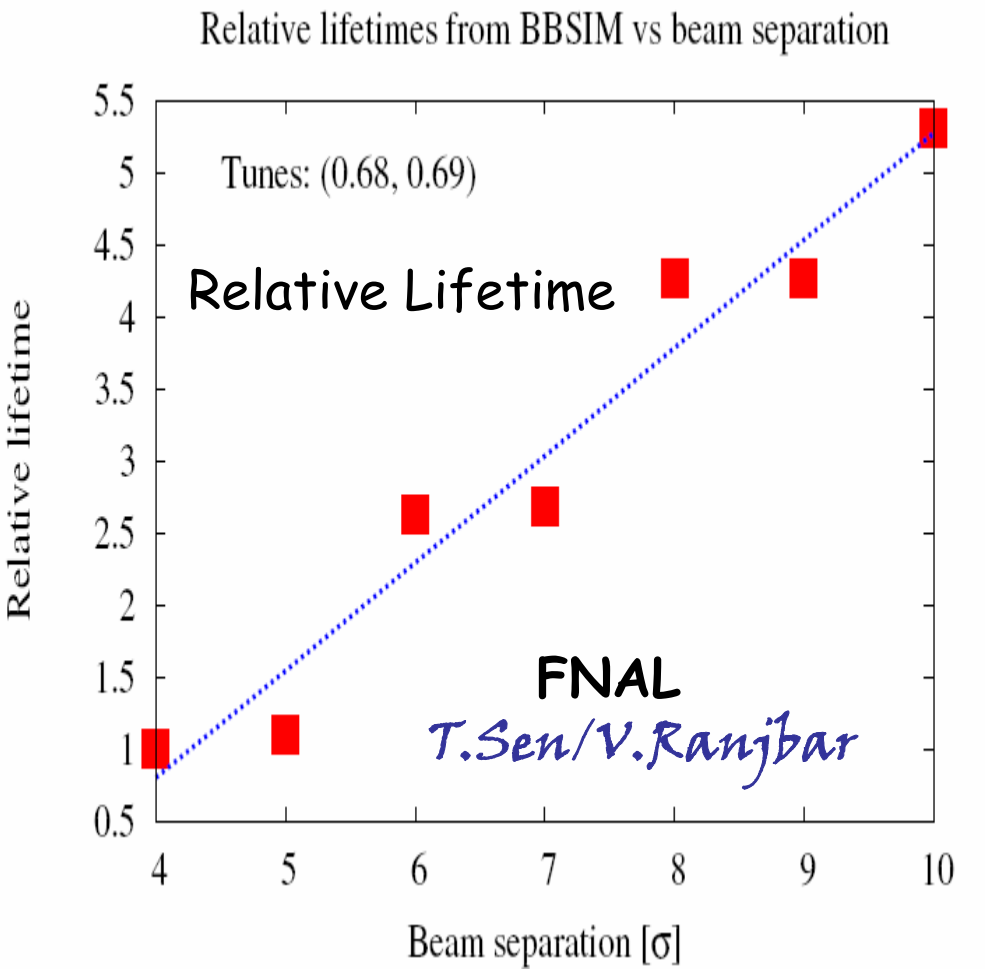
  Four groups

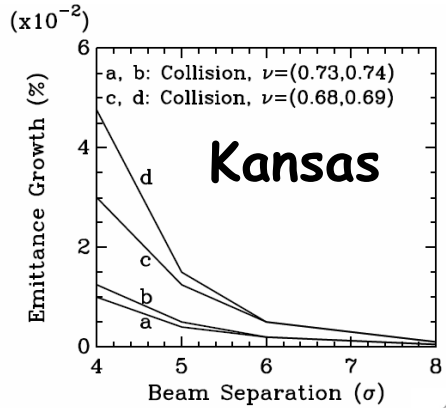
  FNAL: V. Ranjbar, T. Sen; SLAC: A. Kabel; LBL: J. Qiang; University of Kansas: J. Shi

  Website: http://www-ap.fnal.gov/~tsen/RHIC

  for information exchange and results

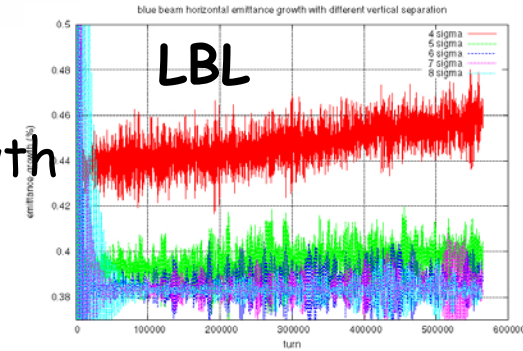
Beam-beam simulation results

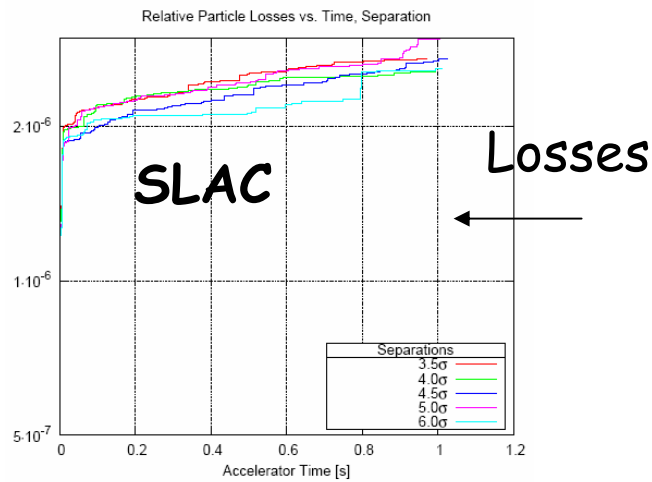




No sextupoles

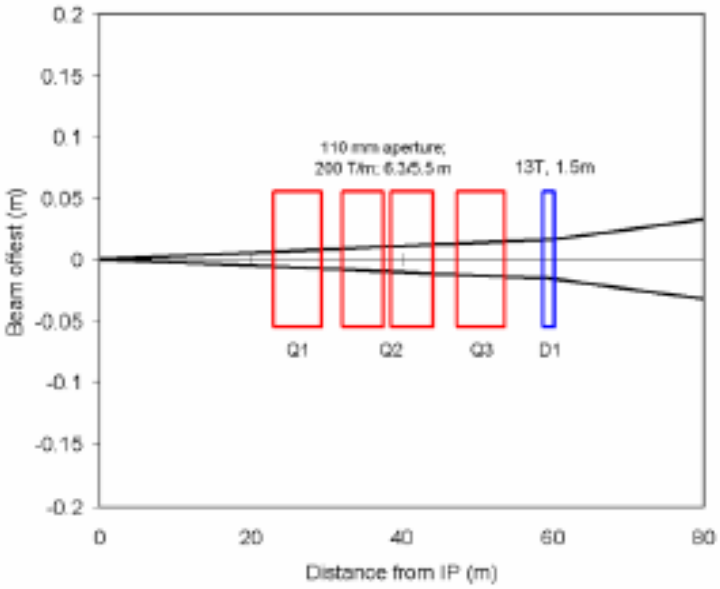
Emittance growth





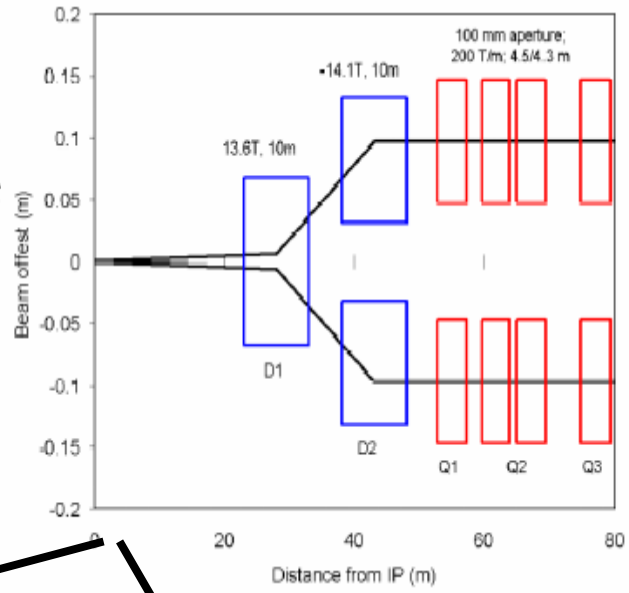
BBSIM (VR, TS) simulations for lifetime show **a linear dependence on separation**

IR Layouts



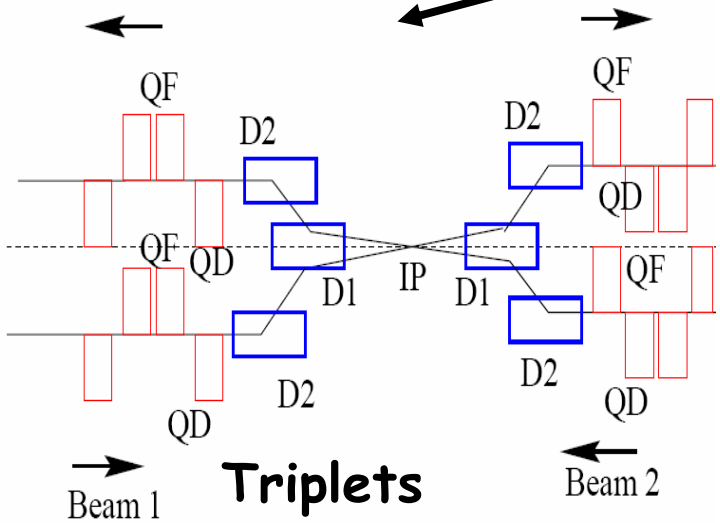
Baseline Layout
Quads first
Too many parasitics

Dipoles first layout

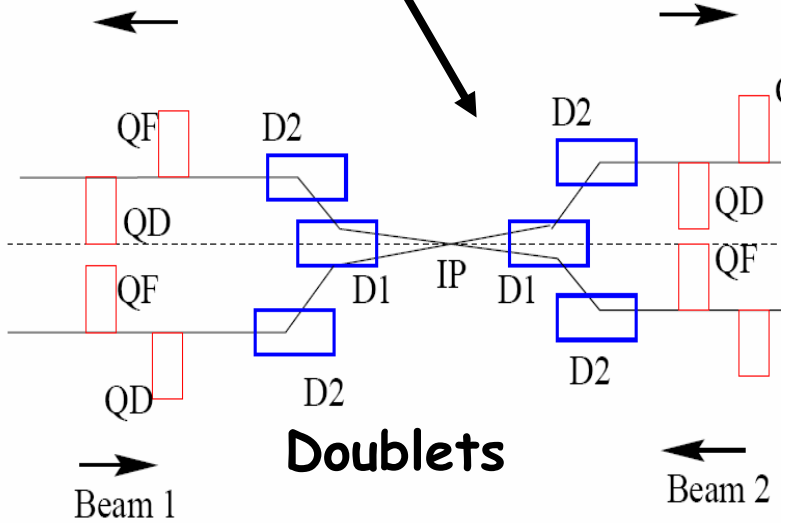


Early separation
but ....

J.Johnstone/T.Sen



Dipole first layout: triplet focusing



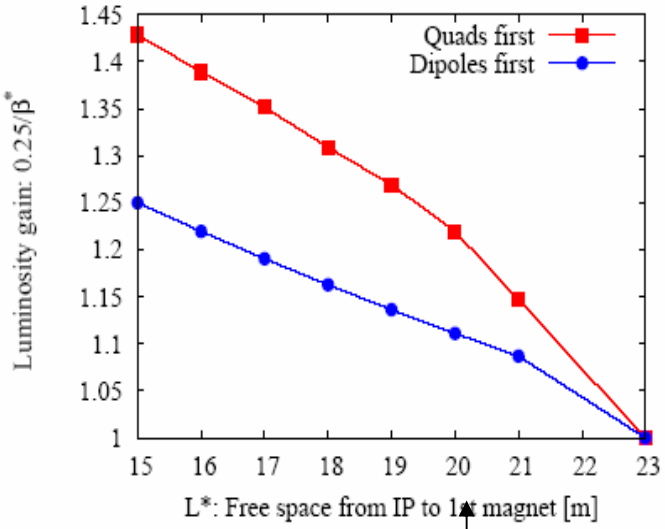
Dipole first layout: doublet focusing

IR Upgrade Optics Issues

LARP

IR Magnet apertures and fields

	Pole tip field [T]	Aperture [mm]
Quads 1st	10	101
Dipoles 1st: triplets	11	107
Dipoles 1st: doublets	10	104



Energy Deposition

Major issue in all optics, but dipole designs more challenging.

Beam-beam interactions

Demonstration of wire compensation would favor quads 1st.

Chromaticity and Nonlinear Correctors

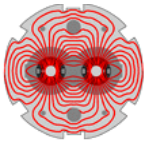
Corrector strengths lower with quads 1st but independent control of 2 beams with dipoles 1st.

Luminosity gain with lower L*

Larger gain with quads 1st.

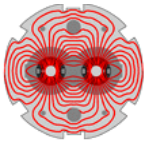
Flux jumps in IR magnets

Chromaticity jumps small (~2 units) with $\Delta b_3 = 1$ in both optics if spurious dispersion in IR is controlled to ~1cm at IP. Nonlinear effects need to be studied



Conclusions

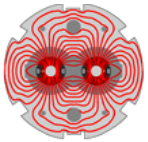
- US LHC Accelerator Research Program:
  - Collaboration of 4 US Nat'l Labs: FNAL, BNL, LBL, SLAC
  - FNAL serves as Host Laboratory
  - Budget ~11M$ in FY'06 and ~3 years ahead
- Activities led by FNAL Accelerator Division:
  - New instruments
    - 4.8 GHZ Schottky design and TuneTracker/TuneFB
  - Organization of Hardware and Beam Commissioning
    - 8 people for HC (long-term, 6 from FNAL), ~13+ for BC
  - Radiation effects studies
    - Tertiary colimators and radfields for IR upgrade magnets
  - Beam-beam and IR studies :
    - For IR Upgrade and for simulations of wire compensation
- FNAL scientists/eng's will be part of LHC start up:
    - Hardware Commissioning (>Oct'06) and SPS experiments (Fall'06), Sector test (Jan'07), 1st beam and beyond (Dec'06)



BackUp Slides

Communication/Coordination

- Communication within LARP:
  - VideoConf of all AS L2s+Steve ~once/mos
  - One-on-one meetings (site visits, reviews, etc) ~once/qrtr
  - Collaboration meetings ~twice/year
- Communication with CERN
  - First “long-termers” (P.Limon et al)
  - Visits (HC, BC, Instr, etc) >1/mos
  - Workshops (e.g. TAN) and reviews (e.g. RC) ~once/qrtr
  - US-CERN meetings ~ once/yr
- LARP Doc DB is functioning:
  - ~250 docs uploaded from Oct’05-Apr’06



New Initiatives

- AC dipole
- dB/B measurements
- Crystal collimation
- Super-SyncLite
- e-lenses for Head-on B-B Compensation
- Crab cavities
- 1.5TeV Injector in LHC tunnel LER-LHC
- Optical Stochastic Cooling

Counting ...

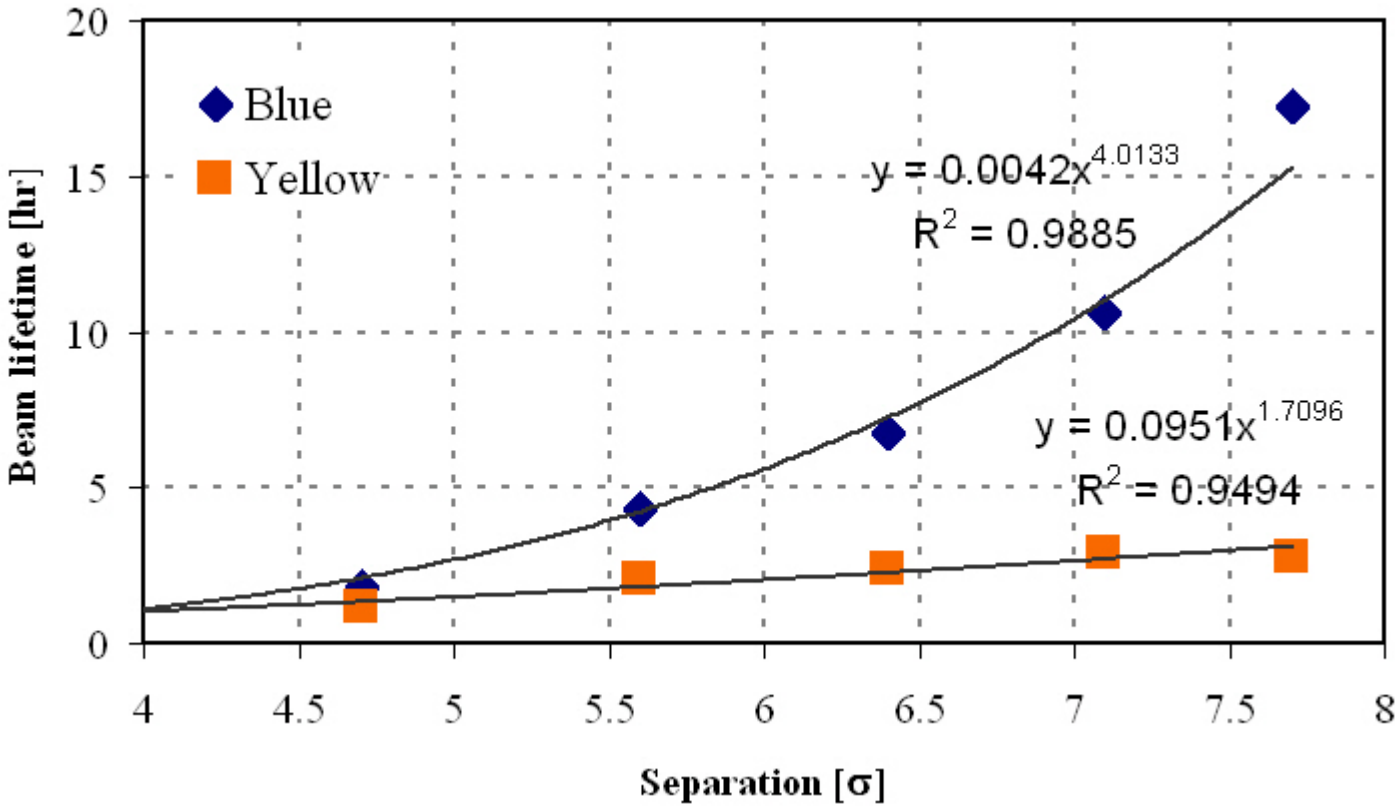

TIME REMAINING
DAYS
HOURS
MINUTES
SECONDS
LHC
FIRST COLLISION

Long Range Beam-Beam

SPS : $\tau \sim d^5$ [measured 11/09/04]

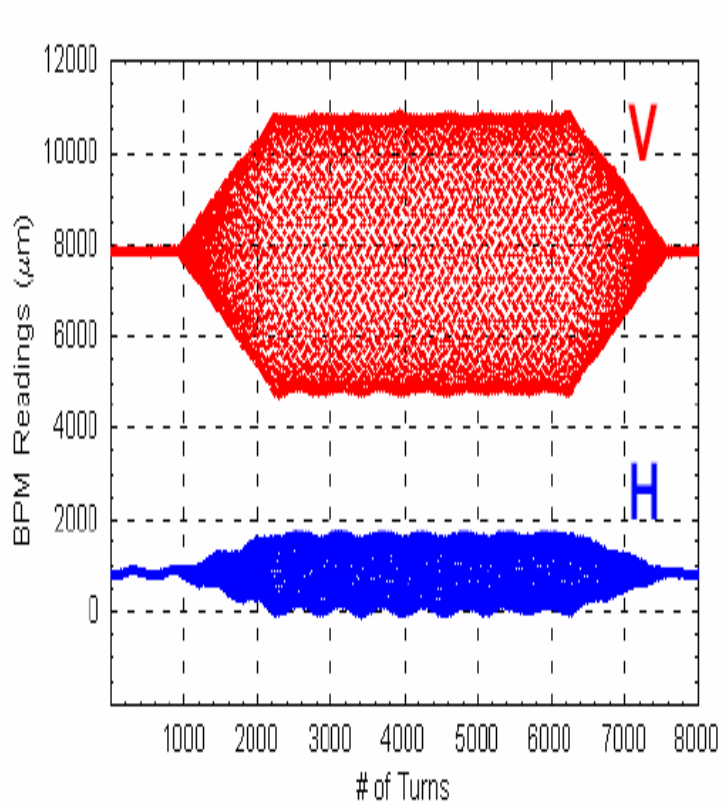
Tevatron: $\tau \sim d^3$ [measured in HEP stores, TEL]

RHIC : $\tau \sim d^4$ or d^2 [measured 04/28/05, scan 4]



AC dipole

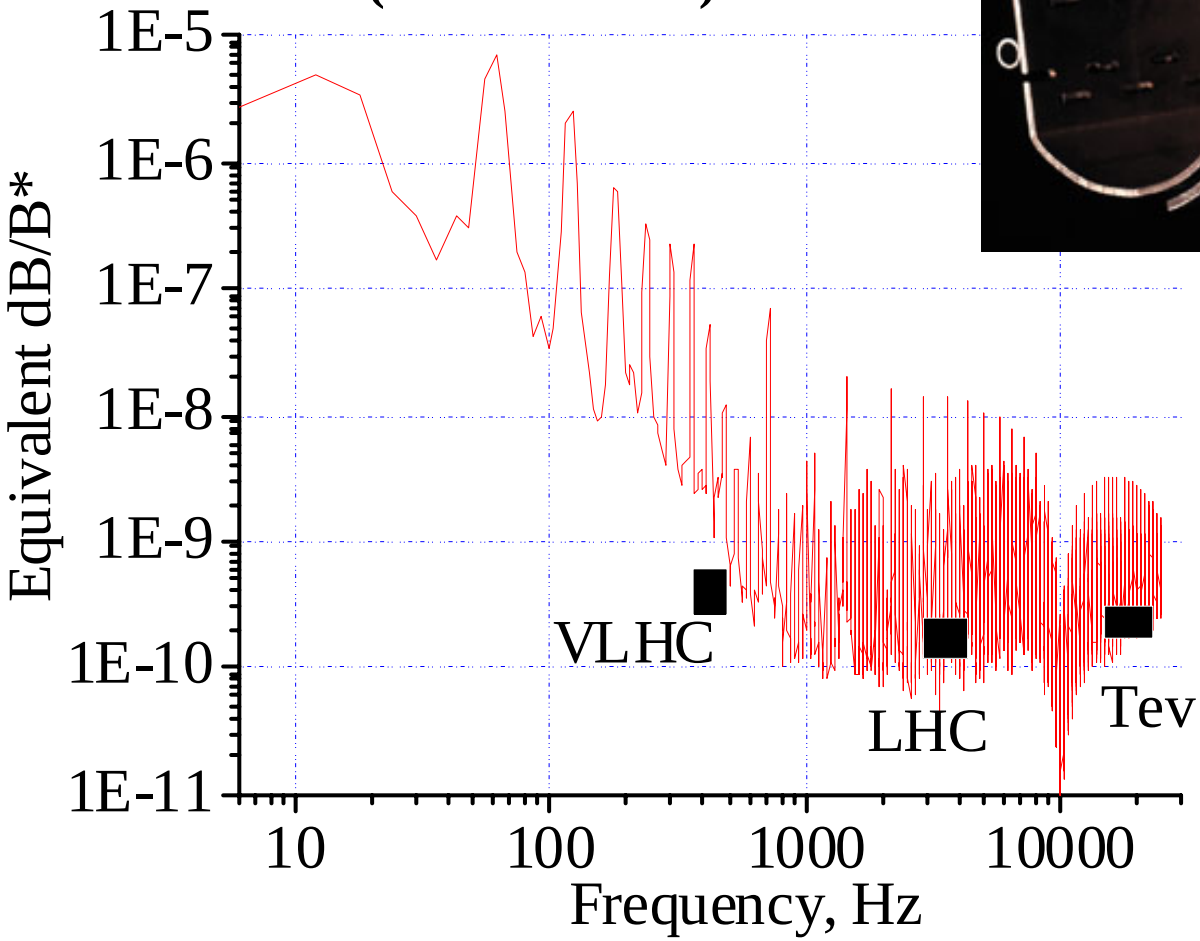
- Recent results from the Tevatron
- Collaboration formed including Fermilab, BNL and CERN.
- Formal proposal for LHC at this meeting

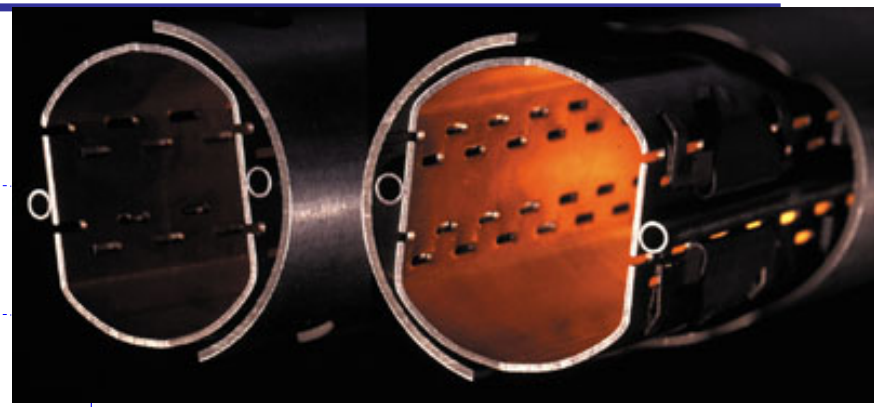


First AC dipole data in the Tevatron

New Initiatives: dB/B Fluctuations

Tevatron Stand-Alone Dipole measurements (Proc. PAC'01)



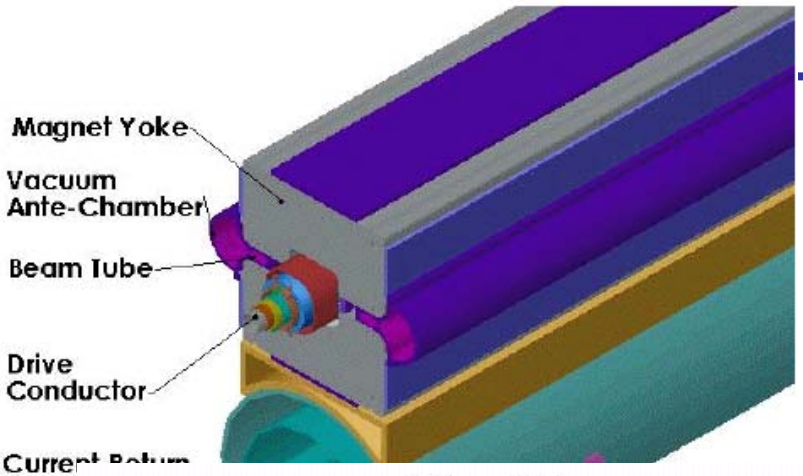


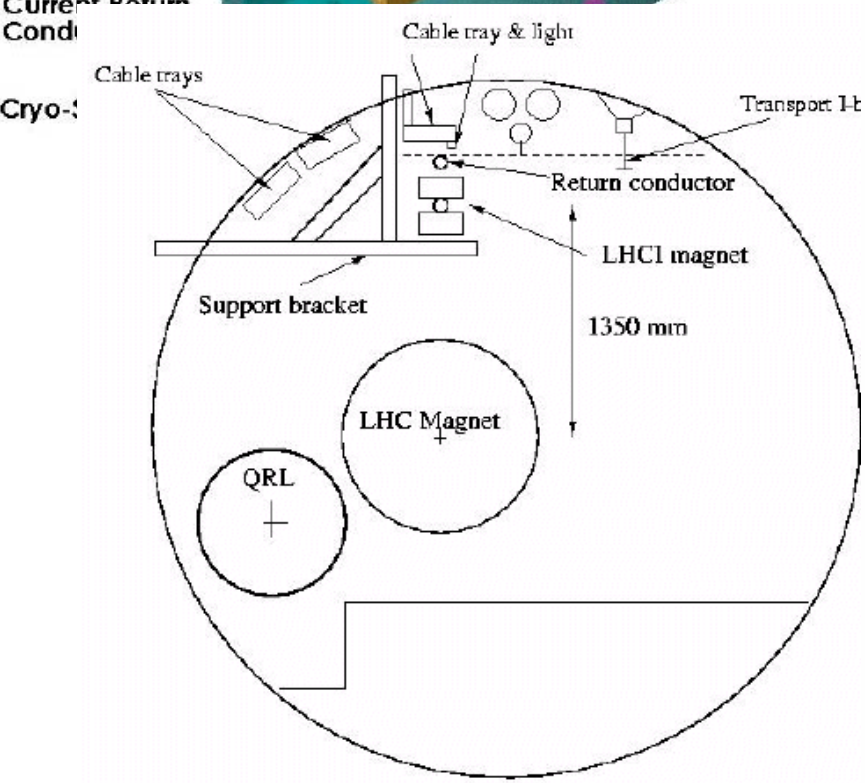
LHC screen: light and feels 20 K He flow turbulence; B-flux is constant at 3kHz →dB/B ~ dR/R → need dR < 1A to blow horizontal emittance

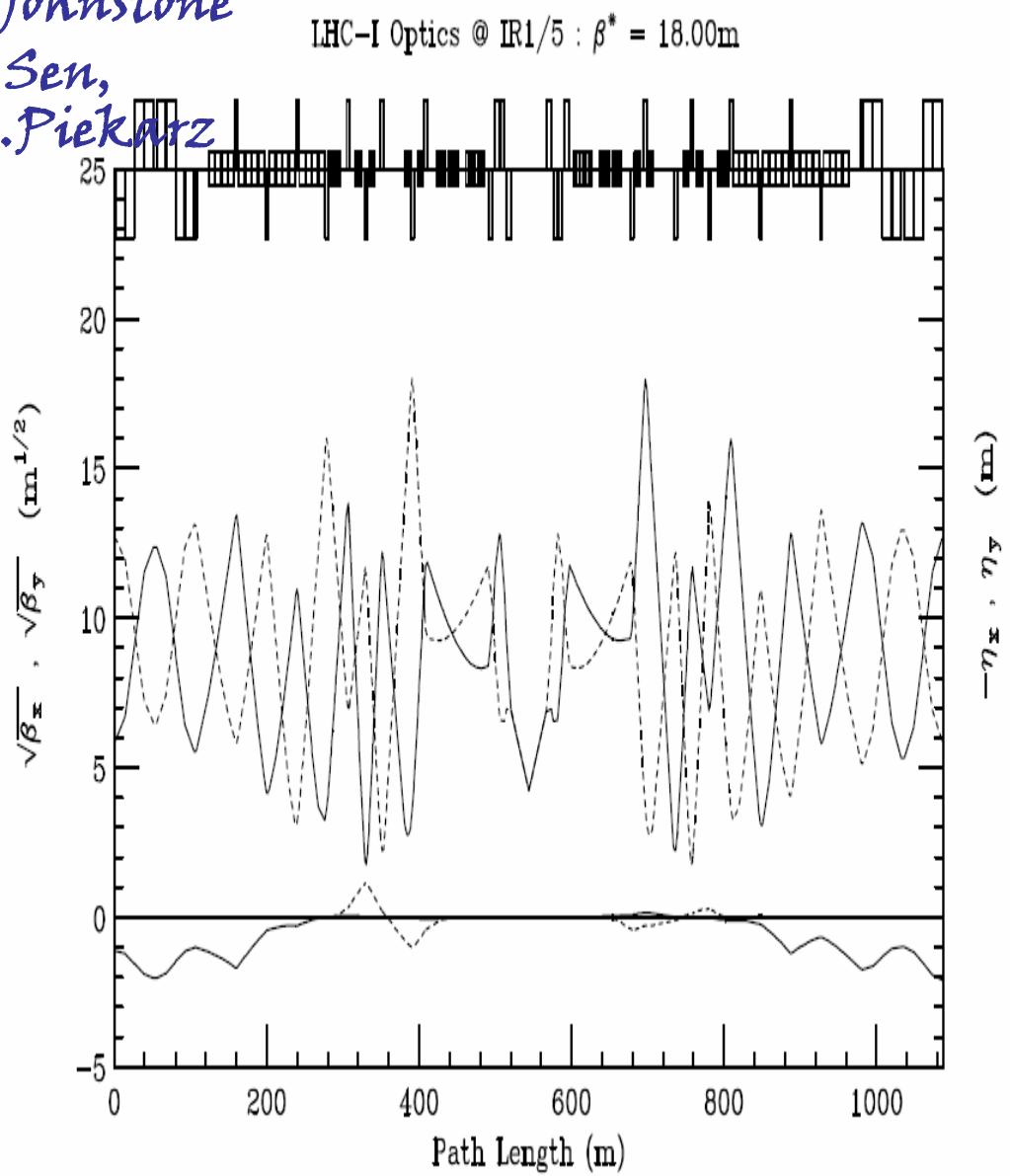
Can be measured at CERN MMF and in Tev

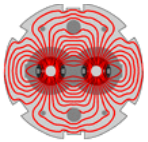
1.5 TeV SuperFerric Injector in LHC tunnel

J.Johnstone
T.Sen,
H.Piekarz







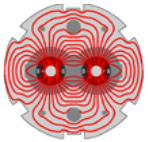


AD ManPower

Quantity	FTE	Amount	Fringe	Burdened Cost	Transaction Source	Job Name
856.88	5.22	42,481.43	25,055.55	67,536.98		APPLICATIONS PHYSICIST Total
739.96	4.54	39,069.36	23,043.11	62,112.47		APPLIED SCIENTIST Total
331.40	2.00	12,780.71	7,538.06	20,318.77		ASSOCIATE SCIENTIST Total
322.20	1.93	9,493.09	5,599.02	15,092.11		DESIGNER Total
644.08	3.96	35,650.03	21,026.39	56,676.42		ENGINEER Total
254.40	1.56	9,412.14	5,551.28	14,963.42		ENGINEERING ASSOCIATE Total
167.32	1.02	7,663.80	4,520.11	12,183.91		ENGINEERING PHYSICIST Total
281.28	1.77	9,813.86	5,788.21	15,602.07		GUEST SCIENTIST Total
405.36	2.41	11,838.04	6,982.08	18,820.12		RESEARCH ASSOCIATE Total
1482.16	9.05	73,093.26	43,110.40	116,203.66		SCIENTIST Total
65.28	0.42	2055.04	1,212.06	3,267.10		TECHNICAL SPECIALIST Total
5550.32	33.9	253350.76	149,426.28	402,777.04		Grand Total

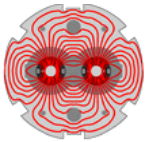
AD Man-Power

Task Number	Quantity	FTE	Amount	Fringe	Burdened Cost
20.12.1.1.9 Total	404.08	2.41	20,434.50	12,052.27	32,486.77
20.29.1.1.9 Total	1276.60	7.96	61,575.06	36,316.97	97,892.03
31.1.1.1.1 Total	303.32	1.84	11,678.19	6,887.80	18,565.99
31.1.1.1.4 Total	1311.32	8.02	57,528.95	33,930.57	91,459.52
31.1.2.1.1 Total	404.28	2.48	20,531.28	12,109.35	32,640.63
31.1.3.2.2 Total	217.68	1.36	11,853.43	6,991.15	18,844.58
31.1.4.1.2 Total	651.28	3.91	32,461.29	19,145.67	51,606.96
31.1.4.1.3 Total	576.96	3.37	20,966.69	12,366.15	33,332.84
31.2.1.3.3 Total	404.8	2.55	16321.37	9,626.34	25,947.71
Grand Total	5550.32	33.9	253350.76	149,426.28	402,777.04

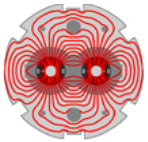


AD Man-Power

Period	Quantity	FTE	Amount	Fringe	Burdened Cost
OCT05-06 Total	514.28	3.06	25,865.54	15,255.50	41,121.04
NOV05-06 Total	494.72	3.09	23,998.58	14,154.36	38,152.94
DEC05-06 Total	759.80	5.00	33,807.95	19,939.93	53,747.88
JAN-06 Total	921.72	5.76	42,026.15	24,787.02	66,813.17
FEB-06 Total	879.76	5.50	42,544.91	25,092.99	67,637.90
MAR-06 Total	1097.88	5.97	43,948.71	25,920.95	69,869.66
APR-06 Total	882.16	5.51	41,158.92	24,275.53	65,434.45
Grand Total	5550.32	33.9	253,350.76	149,426.28	402,777.04



PROJ #	TASK #	TASK DESCRIPTION	EXP CATEGORY	OBL BUD	YTD OBL	YTD ACT
20	20.12.1.1.9	AD-LARP: US LHC ACCELERATOR RESEARCH PROGRAM	Materials & Services	0	0	0
			Total	0	0	0
	20.12.1.1.9	AD-LARP: US LHC ACCELERATOR RESEARCH PROGRAM	Personnel Costs	32	32	32
	20.29.1.1.9	LARP: US LHC ACCELERATOR RESEARCH PROGRAM		199	98	98
			Total	232	130	130
31	31.1.1.1.1	Tune Feedback	Materials & Services	0	4	0
			Total	0	4	0
	31.1.1.1.1	Tune Feedback	Overhead	0	6	6
	31.1.1.1.4	Schottky Monitor		0	28	28
	31.1.2.1.1	Beam Commissioning		0	10	10
	31.1.3.2.2	Tertiary Collimator Study		0	6	6
	31.1.4.1.2	Interaction Regions & Beam-Beam		0	16	16
	31.1.4.1.3	Beam-Beam Wires		0	10	10
	31.2.1.3.3	Radiation Heat Deposition		0	8	8
			Total	0	84	84
	31.1.1.1.1	Tune Feedback	Personnel Costs	0	19	19
	31.1.1.1.4	Schottky Monitor		0	91	91
	31.1.2.1.1	Beam Commissioning		0	33	33
	31.1.3.2.2	Tertiary Collimator Study		0	19	19
	31.1.4.1.2	Interaction Regions & Beam-Beam		0	52	52
	31.1.4.1.3	Beam-Beam Wires		0	33	33
	31.2.1.3.3	Radiation Heat Deposition		0	26	26
			Total	0	272	272
Total				232	492	488



DoE Reviews

• "The review committee was very pleased with the presentations on beam instrumentation and accelerator physics. In addition, they found the idea of participation in the development of a remote control room a very interesting possibility for enhancing interactions with CERN from afar via the Fermilab project "LHC@FNAL".

• Plans for commissioning of LHC hardware are already being implemented, with the first U.S. staff member (Peter Limon) already stationed at CERN. It was reported by management that U.S. laboratories will provide staffing for this effort, and, in fact, FNAL has committed seven persons to this task. LARP and CERN will cover costs of travel and additional living expenses in the Geneva area.

• Finally, the committee again emphasized its displeasure with the lack of formality in dealings of LARP, and strongly recommended a more effective bookkeeping system for managing expenses and progress on all active tasks, and a person who would be responsible for implementing such a system".