Accelerator Systems

S.Peggs

Tune Feedback

Luminometer

Abort Gap Monitor/LDM

Phase I Collimation Studies

Electron Cloud

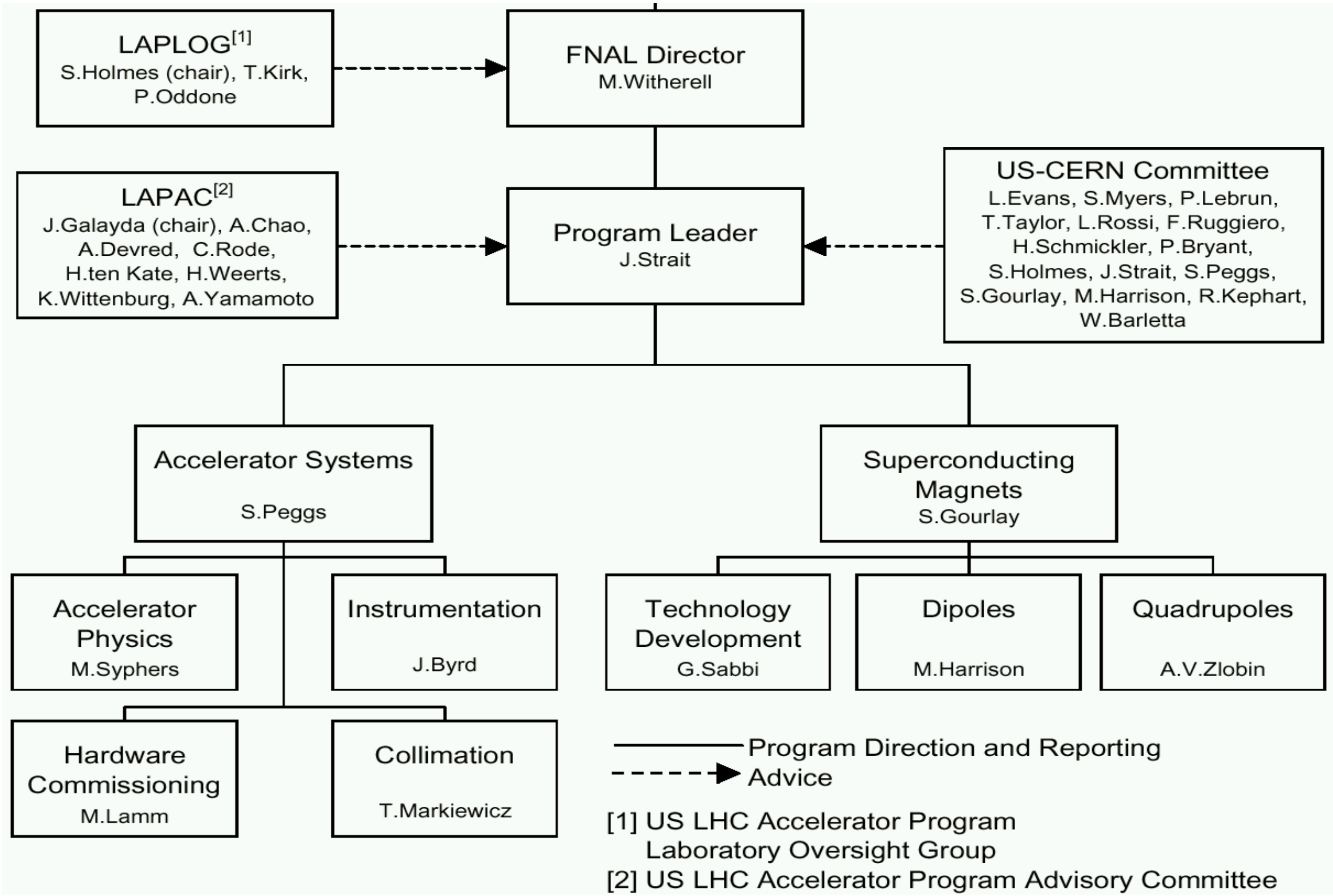
Interaction Region & Beam-Beam

Beam Commissioning

Phase II Collimators

Hardware Commissioning

Organization Chart



How to make Luminosity

Engineering

$$L = F_{coll} \left(\frac{N_1 N_2}{4\pi\ \sigma^2} \right)$$

Protons/bunch in beams 1 & 2

Collision frequency

Beam size (round)

Physics

Number of bunches

Angular beam size

$$L = M\ (\xi_1 \xi_2)\ \sigma'^2 \times \left(\frac{4\pi\gamma^2}{r_p^2} \right) F_{rev}$$

Beam-beam parameters

Tevatron Comparison

		Tevatron [Apr 04]	LHC ["ultimate"]
Luminosity [$cm^{-2}s^{-1}$]	L	6×10^{31}	1×10^{34}
Magnet style		1-in-1	2-in-1
Beam-Beam parameter	ξ_1	0.008	0.004
	ξ_2	0.001	0.004
Number of bunches	M	36	$\sim 3,600$
BUT unfortunately ...			
Beam stored energy [MJ]		1	350
Chromaticity snap-back	$\Delta\chi$	~ 30	~ 300

Making Luminosity – Tasks (1)

Put in lots of bunches, but worry about

Stored energy

- Phase I Collimation Studies
- Abort Gap Monitoring

Bunch spacing and impedances

- Electron Cloud
- Phase II Collimators

Provide skilled US resources for early luminosity ...

- Luminometer
- Beam Commissioning
- Hardware Commissioning

Making Luminosity – Tasks (2)

... while leveraging early beam lessons for future development at LHC and in the US

Snapback will be ferocious
- Tune Feedback

Collision dynamics and performance
- Interaction Regions and Beam-Beam

It is vital that LARP Accelerator Systems supports LARP Superconducting Magnets, in the “long row to hoe” towards the Interaction Region upgrade

LARP Accelerator System Tasks

TASK	LEAD AUTHOR	CO-AUTHOR(S)	EDITOR
INSTRUMENTATION			
Tune Feedback	Cameron	Sen	Byrd
Luminometer	Byrd	-	Peggs
AGM/LDM	De Santis	Pordes	Byrd
ACCELERATOR PHYSICS		-	
Phase I Collimation Studies	Drees	Sen	Syphers
Electron Cloud	Furman	Drees	Syphers
IR and Beam-Beam	Sen	Furman	Syphers
Beam Commissioning	Harms	Drees, Furman	Syphers
Phase II Collimators	Markiewicz	Mokhov	Peggs
Hardware Commissioning	Lamm	Wanderer, Rasson	Peggs

Table 1: LARP Accelerator Systems Task sheets: Task/Author/Editor matrix.

LARP Acc Sys Summary Budget

TASK	FY04 $k	FY05 $k	FY06 $k
Phase Lock Loop	138	200	405
Lumimonitor	162	420	550
Abort Gap Monitor/LDM	80	80	305
Phase I Collimation Studies	0	80	200
Electron Cloud	100	120	440
IR and Beam-Beam	60	320	360
Beam Commissioning	60	20	120
Phase II Collimators	120	230	620
Hardware Commissioning	110	390	710

Table 2: LARP Summary budget for constructing the Accelerator Systems Task Sheets.

Task Milestones (1)

Accelerator Systems Milestones

	FY04				FY05												FY06
	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10
Tune Feedback				**1**				**2**				**3**				**4**	
Luminometer				**1**		**2**											
Abort Gap Monitor/LDM							**1**										
Phase I Collimation Studies				**1**					**2**			**3**		**4**			
Electron Cloud	**1**				**2**						**3**		**4**			**5,6**	**7**
IR and Beam-Beam			**1**						**2**		**3**				**4**		
Beam Commissioning				**1**	**2**			**3**									
Phase II Collimators	**1**							**2**			**3**					**4**	
Hardware Commissioning				**1**		**2**					**3**	**4**					

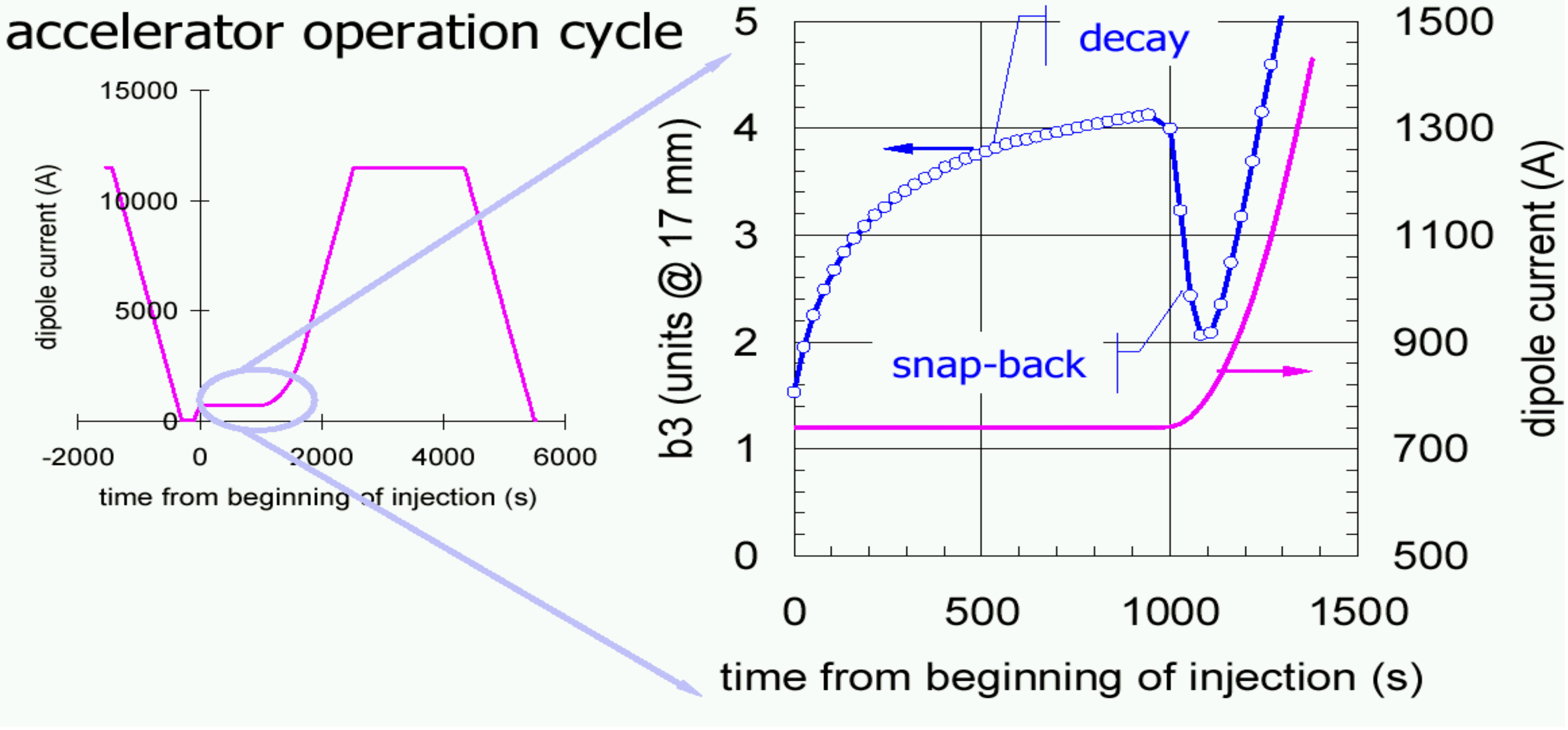
KEY:

Tune Feedback	1) Evaluate data from PLL protoype studies in SPS
	2) Cost and Technical review in early CY05
	3) Conclude coupling study, write coupling correction report
	4) Design, fabricate, test, & operate prototype baseband PLL electronics & software in RHIC
Luminometer	1) 40 MHz performance demonstrated, with required accuracy & sensitivity
	2) Commitment definition (how many & which IPs?) at Technical and Cost review
	2005) Evaluate options for performing a radiation hardness test
	2005) Deliver an engineering design of the entre installation (no production)
	2007) Commission lumimonitoring in the LHC control room
Abort Gap Monitor/LDM	1) Deliver AGM engineering feasibility study white paper end of CY04 (FY04?)

Task Milestones (2)

Phase I Collimation Studies	1) Define code bench marking tests 2) Report on bench-marking of collimation codes with RHIC beam data loss 3) Test LHC collimator set-up procedures with RHIC collimation system 4) Report on accuracy of “cleaning efficiency” simulations, and lessons for LHC
Electron Cloud	1) Participate in SPS EC experiments and studies (when?) 2) Install cold EC detector in RHIC 3) Report on simulated reproduction of measured spectrum & spatial distribution of SPS ECs 4) Report first cut at defining optimal LHC conditioning scenario 5) Report on applicability of map simulation technique to LHC 6) Report on cold EC in RHIC 7) Report on simulated EC at IR4 diagnostic bench
IR and Beam-Beam	1) Participate in beam studies of wire-based BBC at SPS 2) Report on BEAMBEAM3D strong-strong simulations (sweeping beam, emittance growth rates) 3) Report on dipole & quad first layouts (field quality, beta star limits, energy deposition) 4) Report on impact of beam-beam on IR design (quad/dipole first, performance limits, BBC)
Beam Commissioning	1) TI-8 tests begin 2) Reduced level of activity in FY05 3) Define how LARP BC fits into the LHCOP commissioning plan, at Chamonix '05 2006) Participate in LHC Injection Test, 2 weeks in 2006 with beam 2007) Several long-term postings to CERN for machine commissioning
Phase II Collimators	1) Phase II collimator meeting, CERN 2) Present status report at Chamonix '05 3) Phase II collimator review, go/no go decision 4) Set up lab & test RC0 (existing prototype)
Hardware Commissioniong	1) Deliver a hardware commissioning report for FY05 and beyond 2) Warm fit-up of inner triplet (D1/DFBX/Q3/Q2/Q1) 3) Participate in installation of 3 IRs, and TAS/TAN in IR1 4) Begin hardware commissioning efforts (room temp, vac, alignment, initial cool-down) 2006) Participate in injection/sector test

Tune Feedback (1)



"Snap-back" is not SO fast,
but the chromaticity jump is huge ~ 300 units!

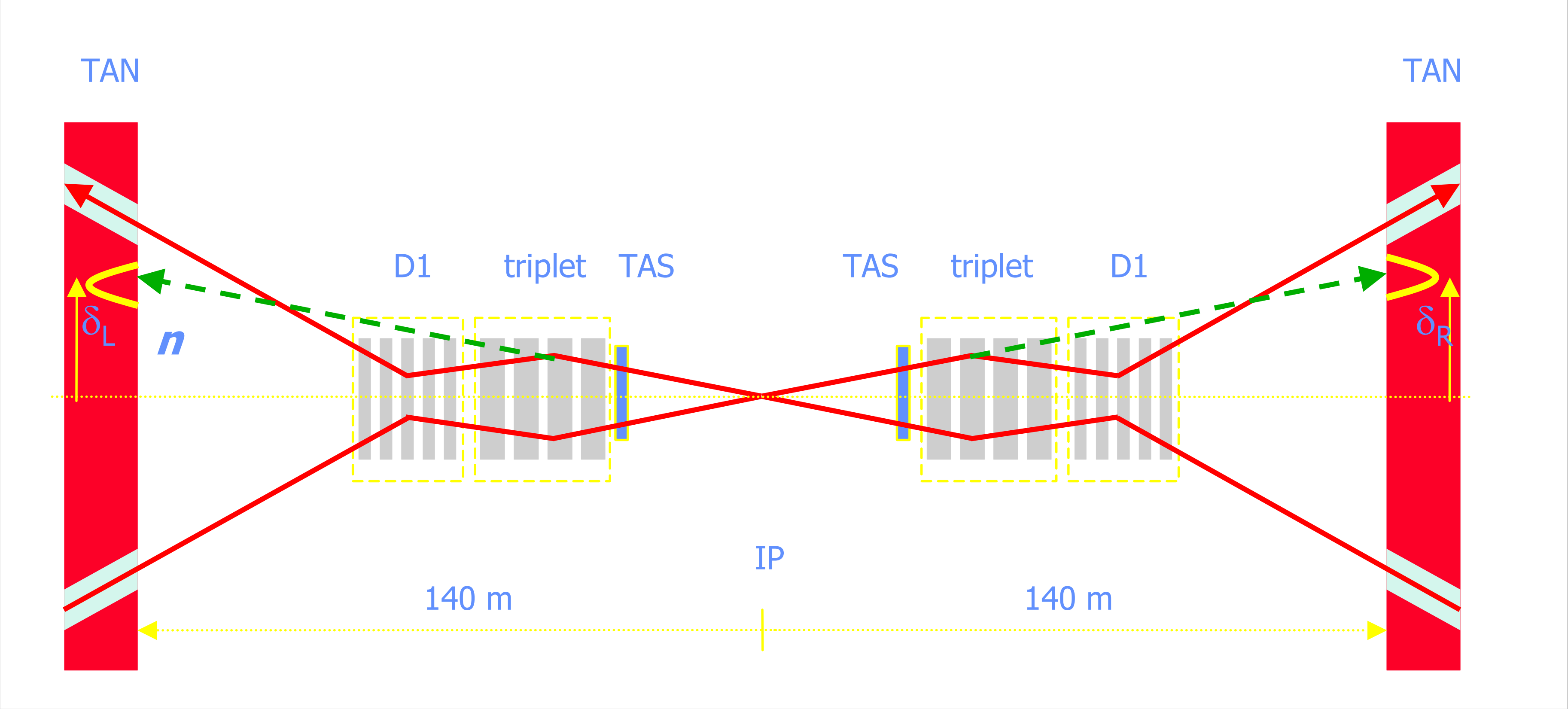
Tune Feedback (2)

Tune Feedback strictly only addresses the tunes

But experience shows that linear coupling must be taken into account for robust tune feedback

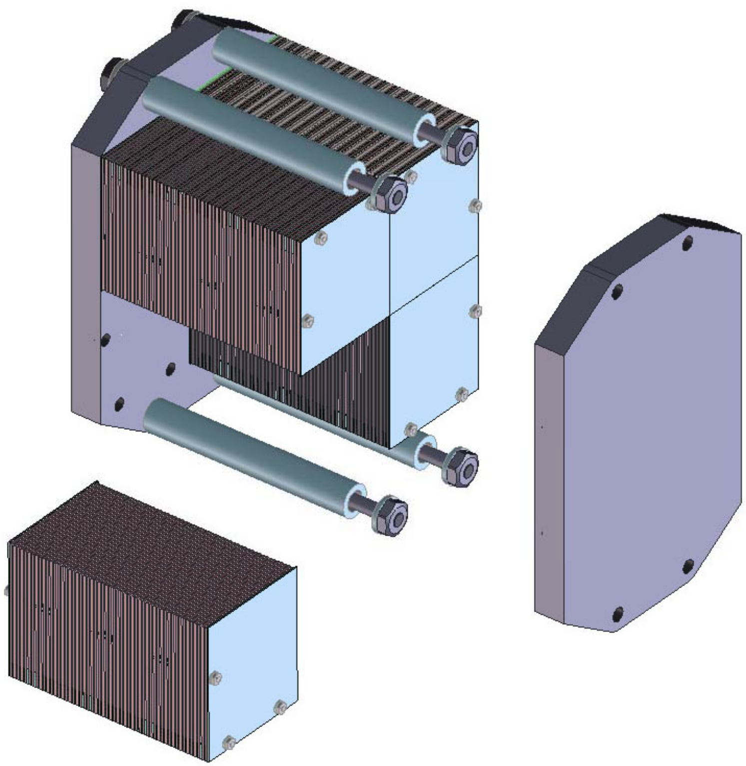
Both tunes and linear coupling must be under control to get a good handle on the (snap-back) chromaticities

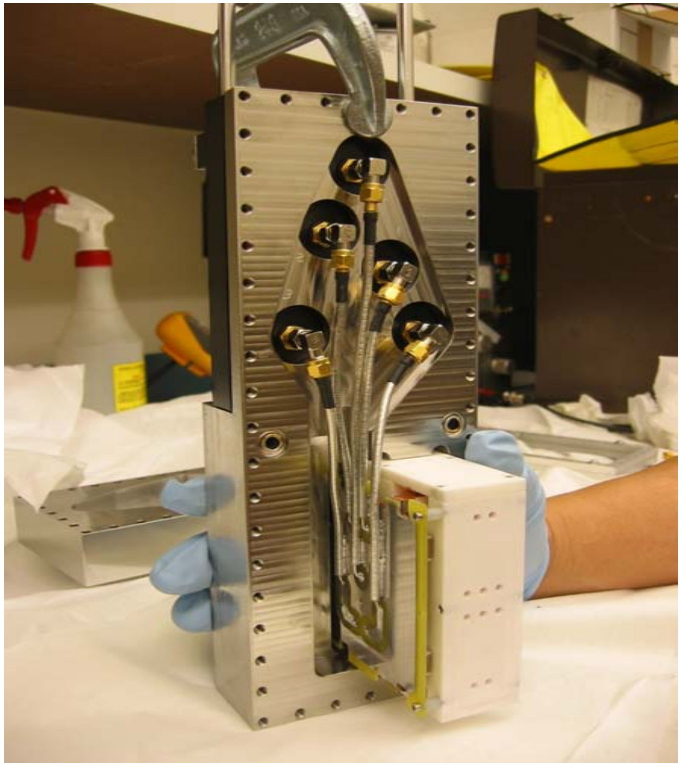
Luminometer (1)



Luminometer (2)

How many gas Luminometers? Which IPs?
Technical and Cost review, ~ Nov 04





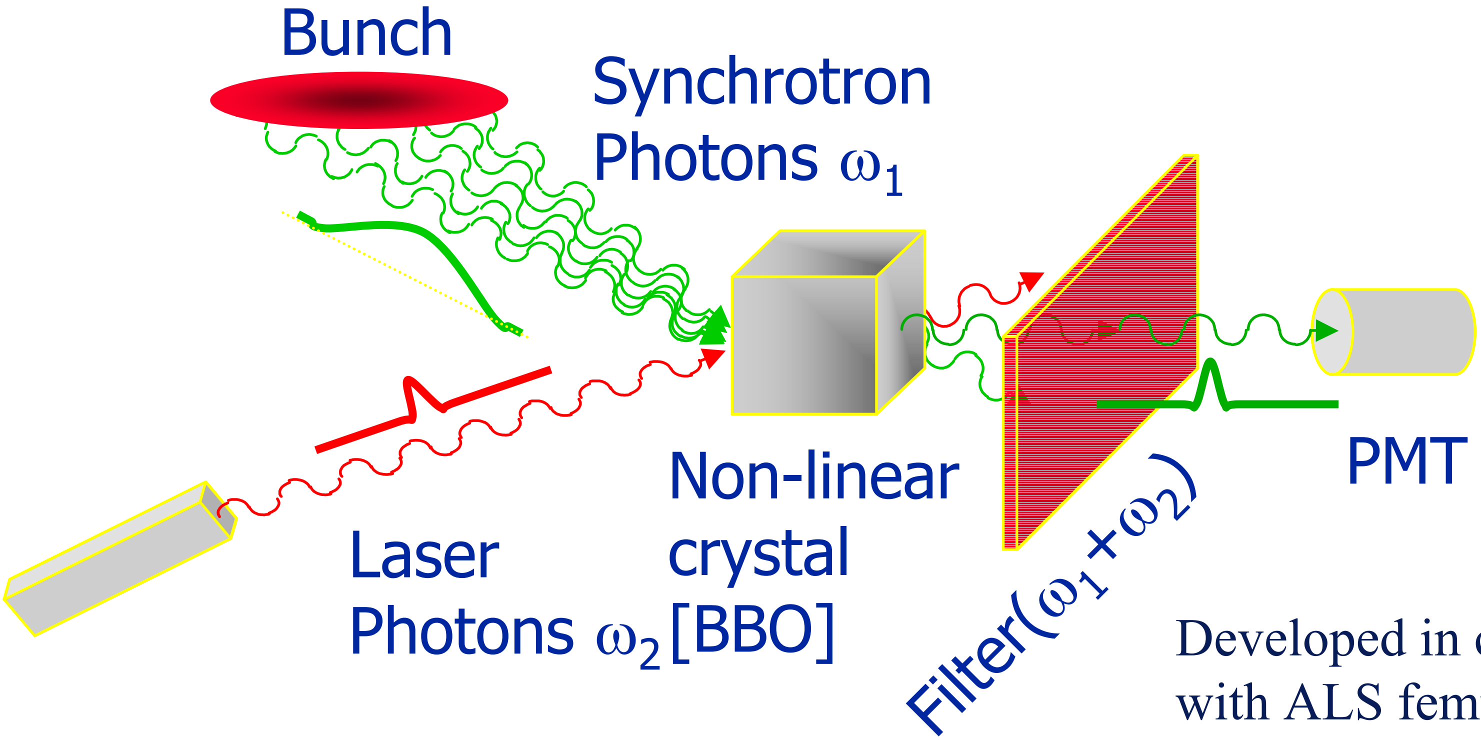
Abort Gap Monitor/LDM (1)

Abort Gap Monitoring for machine protection
- Required on day 1
- Independent of beam dynamics functionality (LDM)
- Requires assessment for LHC (Report, Dec 04)

Longitudinal Density Monitor (LDM)
- Propose to shift from AGM to LDM, end of FY04
- White paper at end of FY05: branch point
- Fermilab interest in AGM and LDM functionality
- BUT level of CERN interest in what technology/performance is uncertain ...

AGM/Longitudinal Density Monitor (2)

- One solution: use nonlinear mixing of synchrotron radiation with a short laser pulse to sample longitudinal bunch profile



Developed in collaboration with ALS femtoslicing program.

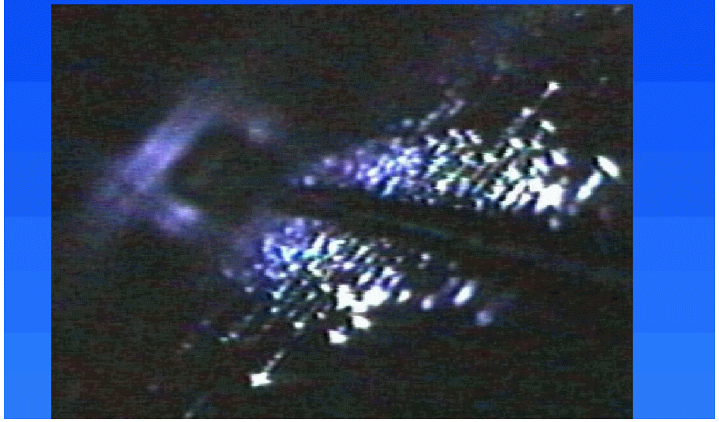
US LARP

Phase I Collimation Studies (1)

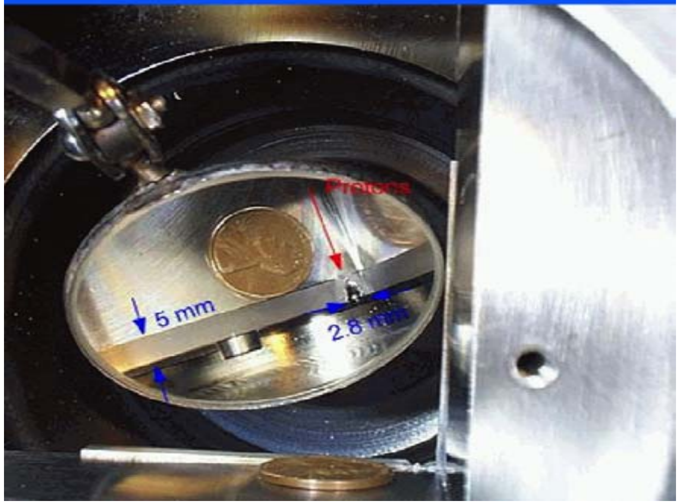
Less than 1 MJ does a lot of damage in the Tevatron !

How about 350 MJ in LHC?

Secondary tungsten collimator



Primary tungsten collimator



Helium leak in spool piece

Phase I Collimation Studies (2)

The "complexity of the system is also worrying for (the) operations (group)" with more than 100 jaws to adjust

Introduction: Movable aperture restrictions

Number of movable elements: 112-155

Acronym	Movable	Material	Length [m]	Number	Locations	Purpose
Scrapers						
TCSP	yes	tbd	tbd	6-8	IR3, IR7	Beam scraping
Collimators						
TCP	yes	C/C-C	0.2	8-9	IR3, IR7	Primary collimators
TCSG	yes	C/C-C	1.0	30-44	IR3, IR7	Secondary graphite collimators
TCSM	yes	tbd	1.0	30-44	IR3, IR7	Hybrid metallic secondary collimators
TCT	yes	Cu	1.0	12-16	IR1, IR2, IR5, IR8	Tertiary collimators
TCDI	yes	C	3.0	10-18	Transfer lines TI2, TI8	Injection collimation
Diluters						
TCLI	yes	tbd	tbd	4	IR2, IR8	Injection protection
TCDQ	yes	sandwich	9.5	2	IR6	Protection against irregular dump
TCDS	no	sandwich	5	2	IR6	Dump septum protection
Absorbers						
TDI	yes	Sandwich	4.0	2	IR2, IR8	Injection protection
TCDD	no	Cu	1.0	2	IR2, IR8	Injection shielding upstream D1
TCLP	yes	Cu	1.0	8	IR1, IR5	Secondaries from IP
TAS	no	Cu	1.8	4	IR1, IR5	Secondaries from IP
Dumps						
TDE	no	Sandwich	7.7	2	UD62, UD68	Dump for ejected beam

Phase I Collimation Studies (3)

Control systems thrive in the face of complexity if the physical system (eg closed orbit) is

- linear (response matrix)
- hysteresis free
- fast

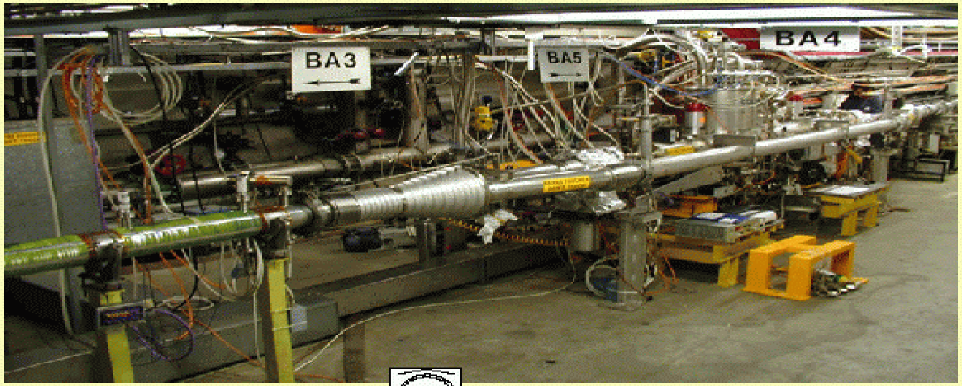
Score 0 (?) out of 3 for the collimator control problem, whether the task is

- machine protection
- quench avoidance
- background reduction

Electron Cloud (1)

Accelerator Technology Department

...COLDEX (principle)...

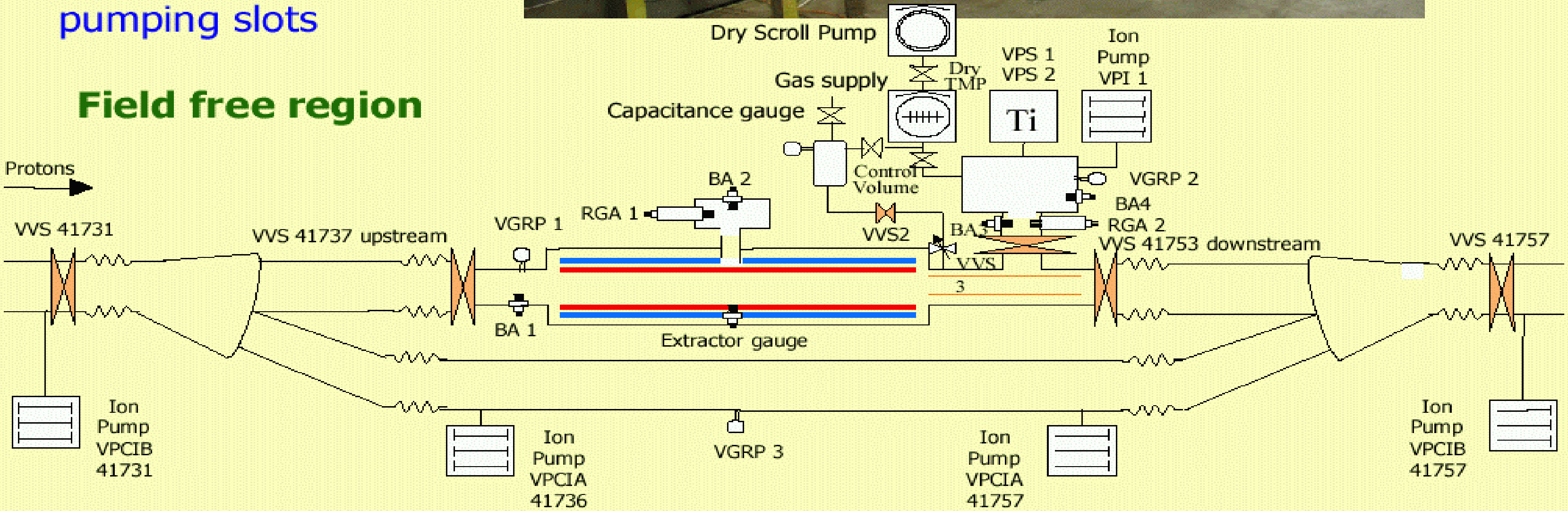


Cold bore at 3K

Cold copper beam screen:

- length: 2.2 m, ID=67 mm,
- temperature controlled
  - between 5 and 150K,
- 1% BS area with shielded
  - pumping slots

Field free region



Electron Cloud (2)

RHIC performance is limited by the pressure rise due to electron clouds regularly observed in WARM regions

LHC cares about heat load due to EC in COLD region

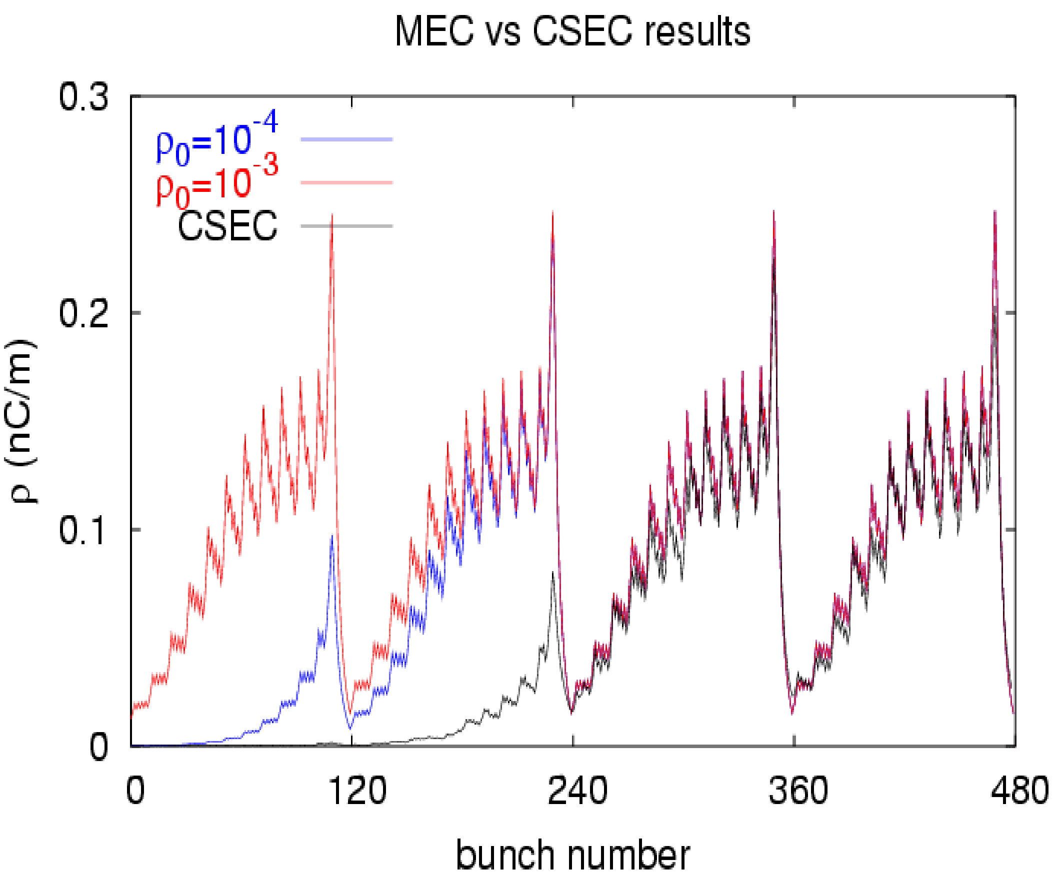
Simulations need benchmarking against reality

Possibility of much faster simulations, through maps?

Prepare for LHC IR4 diagnostic bench

Electron Cloud (3)

Bunch pattern:(3,2,0)(6,4,0)

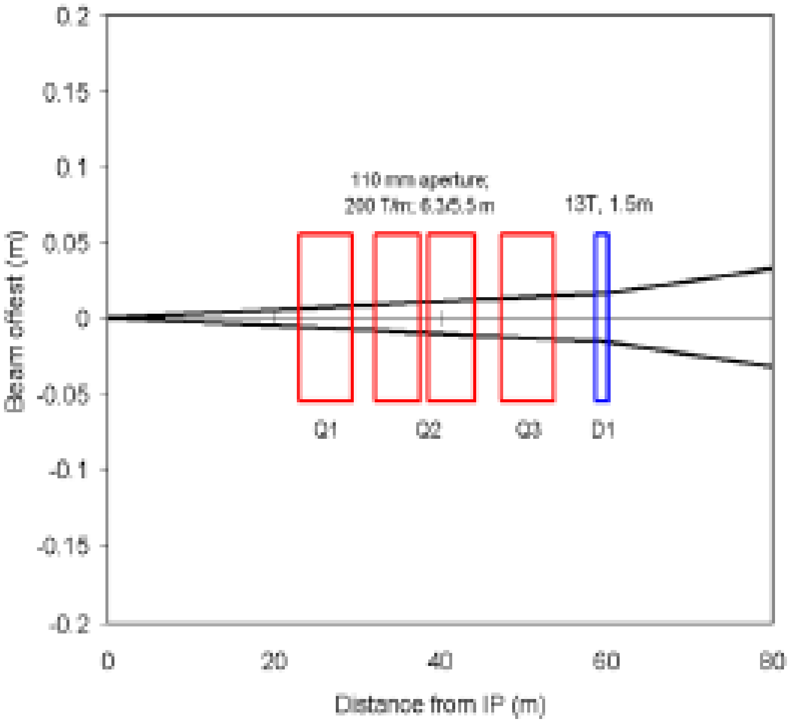


LEFT: A map based simulation (MEC) mimics a conventional simulation (CSEC)

With about 6 orders of magnitude speed up

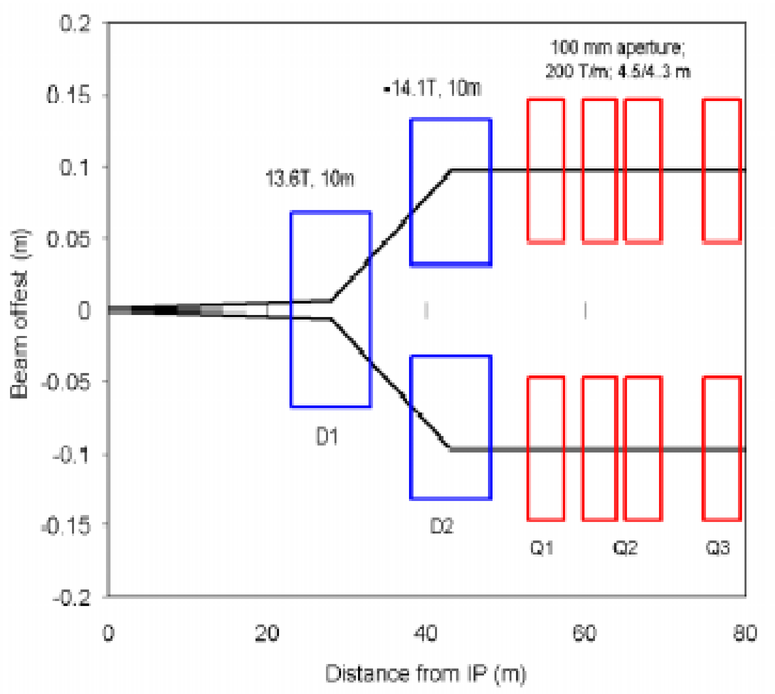
Applicable to LHC?

Interaction Region & Beam-Beam (1)



- Quads first followed by separation dipoles
- Beams go off-axis in the quadrupoles
- Correction algorithm acts on both beams
- 16 long-range Beam-Beam interactions on either side of IP

Interaction Region & Beam-Beam (2)



Dipoles first layout reduces long-range Beam-Beam interactions 3 fold

Independent nonlinear correction for each beam

BUT

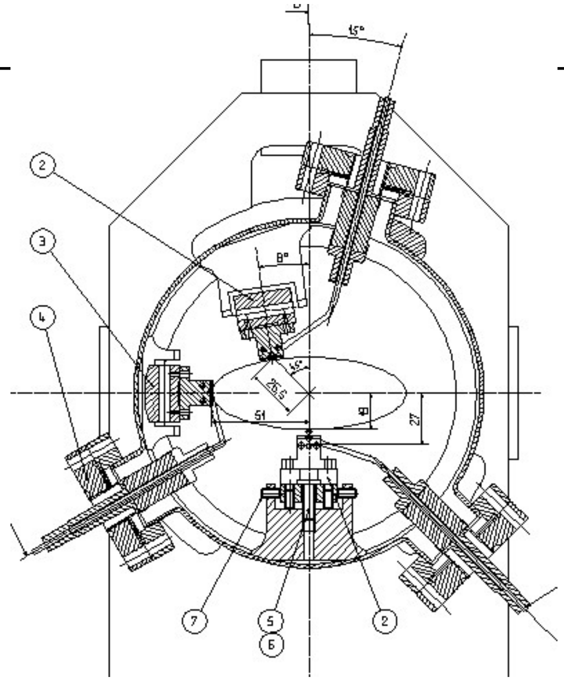
Larger β* at fixed βmax

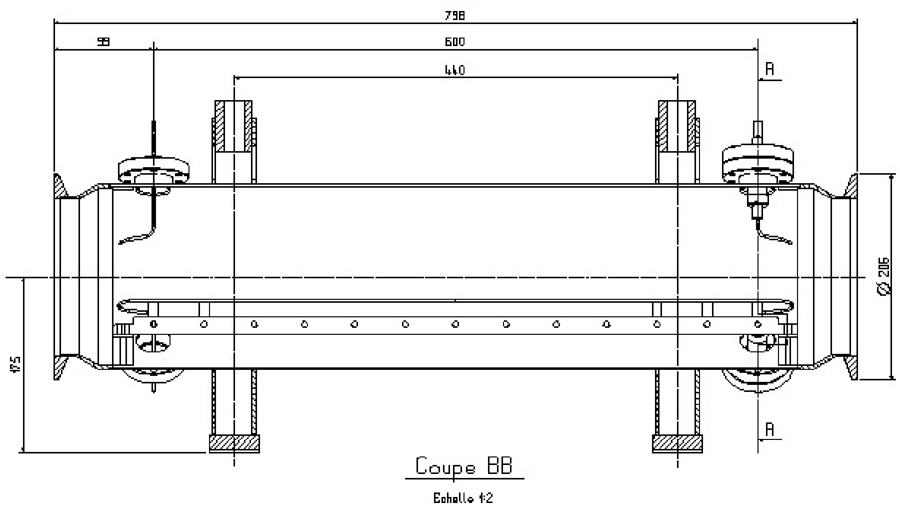
Higher energy deposition in D1 from charged particles

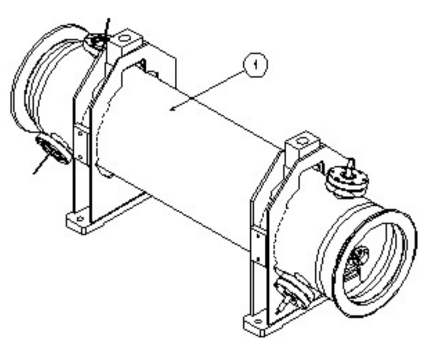
Interaction Region & Beam-Beam (3)

Beam-Beam Correction?

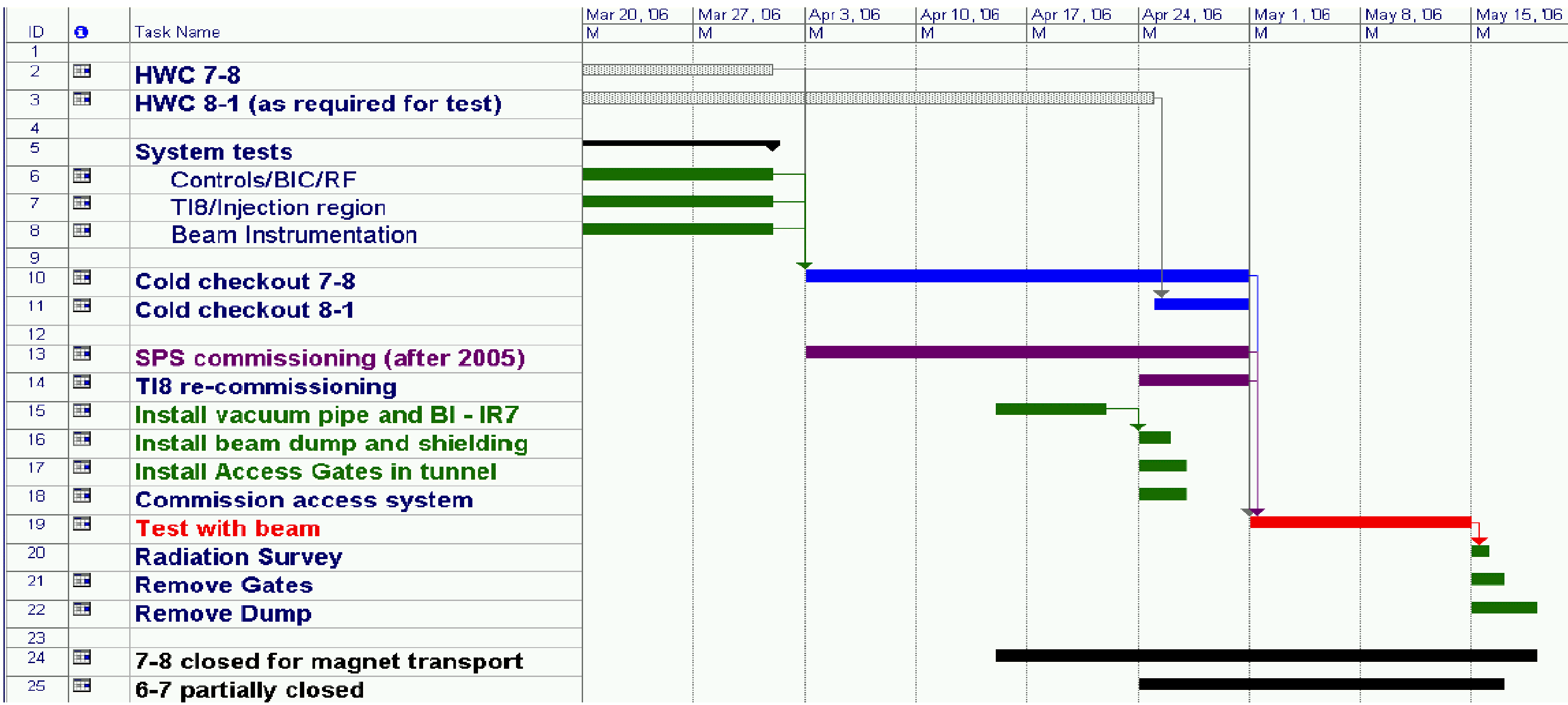
Recent tests with single BBC wire in SPS were successful (“next step” shown here)



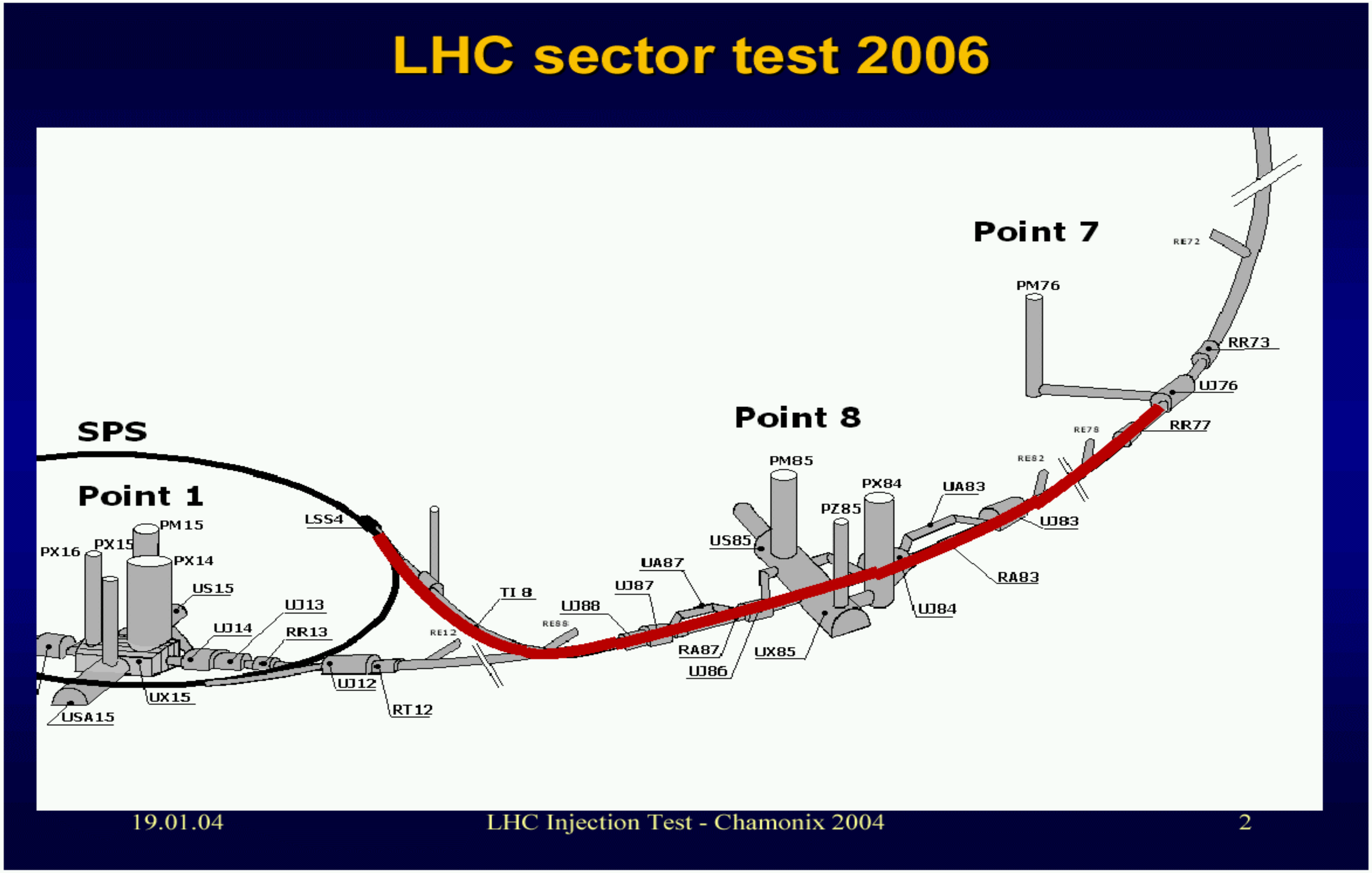




Beam Commissioning (1)



Beam Commissioning (2)



Beam Commissioning (3)

Resulting proposal for year 1 (Chamonix 03)

Start high energy operation at 6.5TeV or even 6TeV
Move to 7TeV whenever machine stability permits it (1 step)

Phase 1 : Establish colliding beam operation with 43 on 43

- Machine de-bugging without / with crossing angle
- Parasitic physics, limited by event pileup, low luminosities

Phase 2 : Establish multi-bunch operation with 75ns spacing and relaxed machine parameters

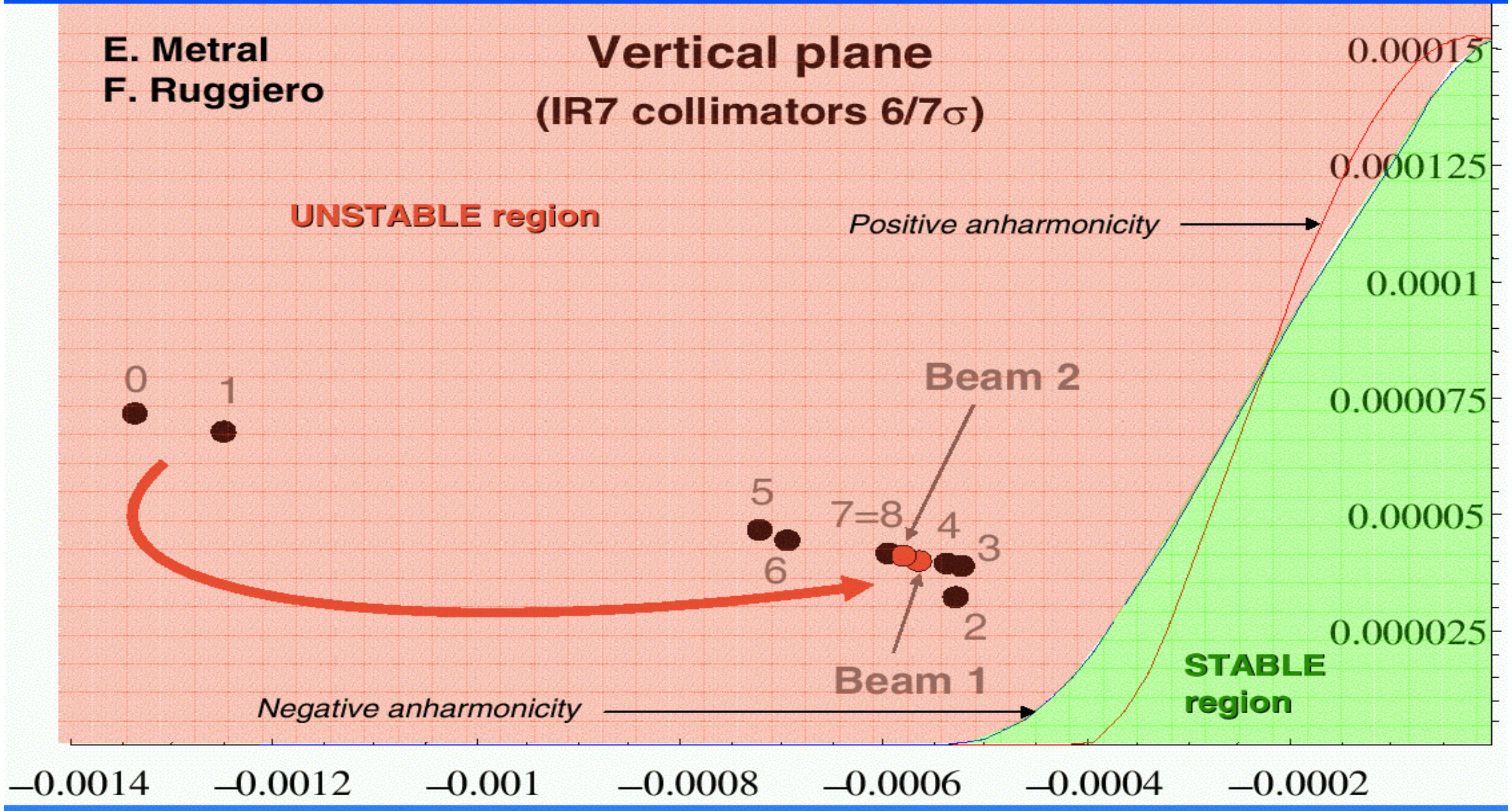
- Luminosity tuning, limited by event pileup, may reach 5 10^{32} $cm^{-2}s^{-1}$
- Establish routine operation in this mode
- Move to nominal squeeze and crossing angle (lower emittance ?)

Phase 3 : Move to 25ns operation for standard physics running

- Production physics running, limited by electron cloud and beam dump
- Luminosity should be > 10^{33} cm^{-2} s^{-1} , pileup OK with 4 10^{10} / bunch
- Scrubbing run needed to go higher (1 week studies in any case)

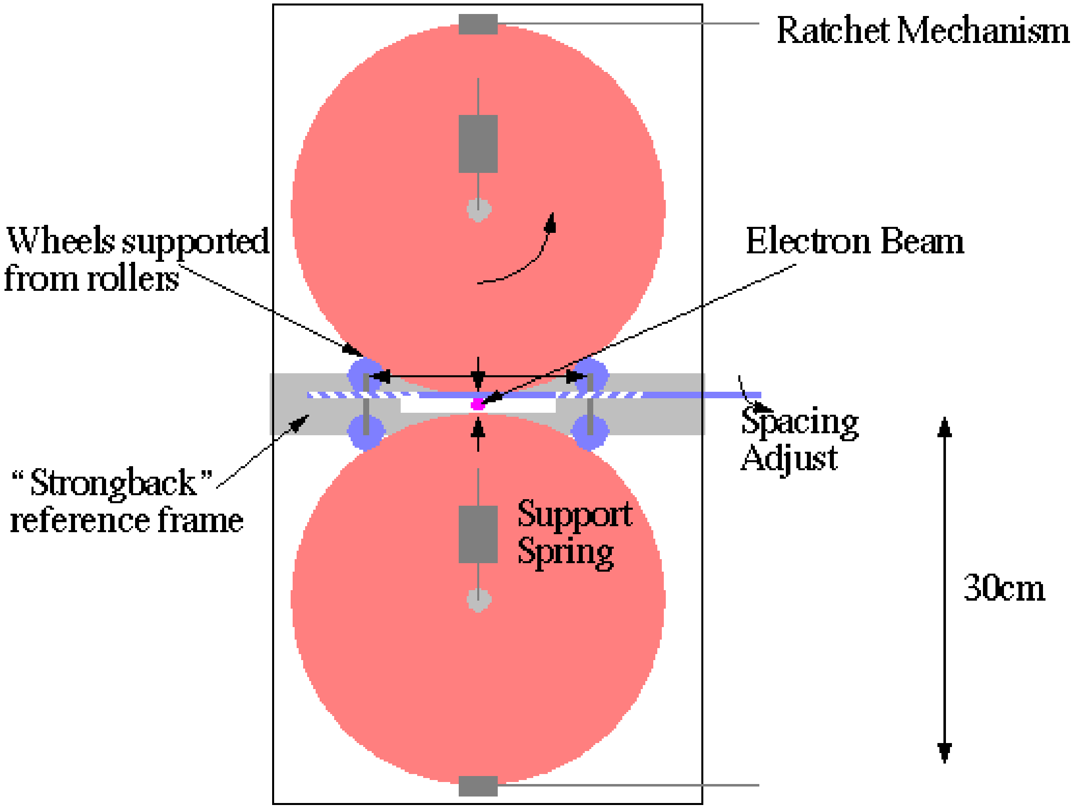
Phase II Collimators (1)

Impedance: Stable and unstable regions



Impedance limit → Reduce beam current until we are in stable regime (performance limit)

Phase II Collimators (2)



Phase II Collimators (3)

Dimensions, mass, & DC heat load of Phase II Colls. are VERY DIFFERENT than those of NLC design

Deliver a Phase II Collimator CDR in about April 05

Accelerator Physics

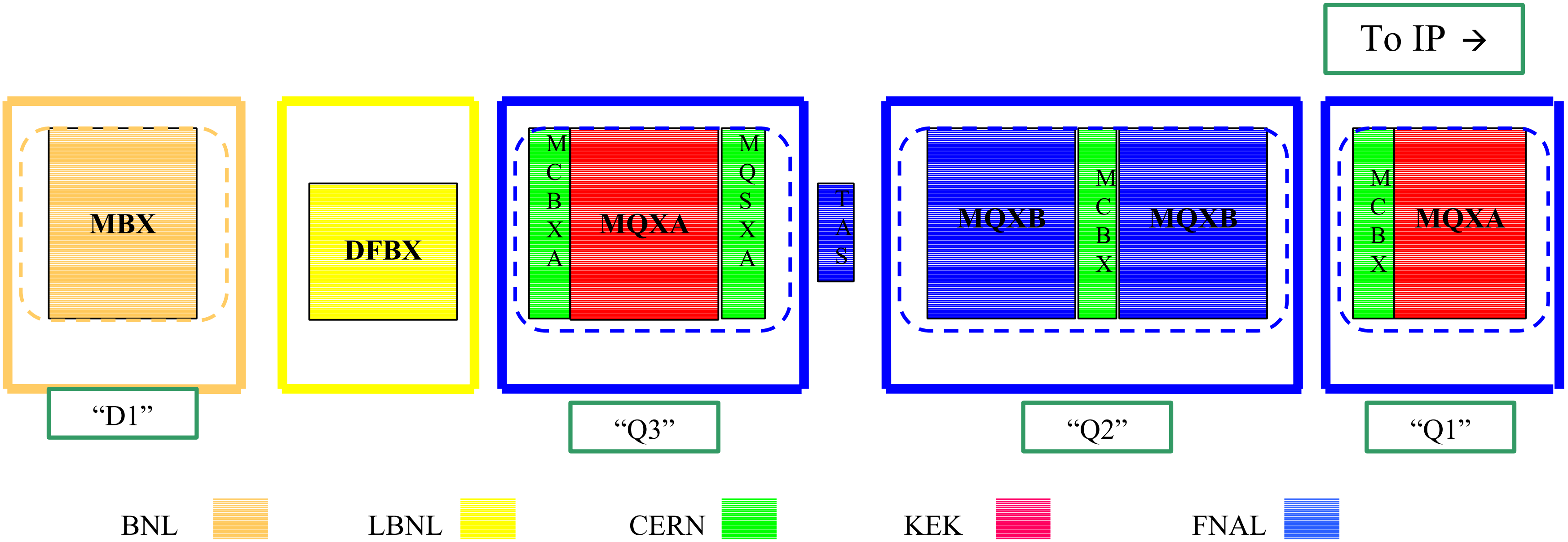
Conceptual engineering

Different paths beyond then, if

1) specs are a "reasonable extension" of the NLC rotating collimator concept, or

2) device is too "LHC-Specific"

Hardware Commissioning



Other important hardware to commission:

- Absorbers for high luminosity region(LBNL)
- Other separation dipoles (BNL)

Issues – Summary (1)

1) How to prioritize the Accelerator Systems tasks?

2) How do hardware tasks (Tune Feedback / Luminometer / AGM / Phase II Colls) proceed to

- full prototyping
- production

3) How to weigh/integrate wetware tasks (Phase I Coll Studies / EC / IR & BB / BC / HC) against/with other tasks?

4) How should Accelerator Systems support Superconducting Magnet tasks?

Issues – Summary (2)

Critical hardware milestones (FY05):

Nov	Luminometer: Cost & Tech review
Dec	AGM: Engineering feasibility white paper
	LDM segue? Technology?
Jan	Tune Feedback: Cost & Tech review
Apr	Phase II coll: Review, go/no go decision

Critical wetware milestones (FY05):

Sep	HC: deliver hardware commissioning plan
Jan	BC: Define how LARP BC fits LHCOP plan
Apr	IR&BB: Report on dipole & quad first layouts
May	Phase I coll: Test set-up procedure in RHIC
Jun	EC: First cut at optimal conditioning scenario