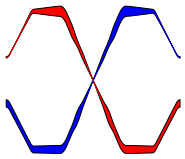
LHC Crab Scheme: Overview & Status

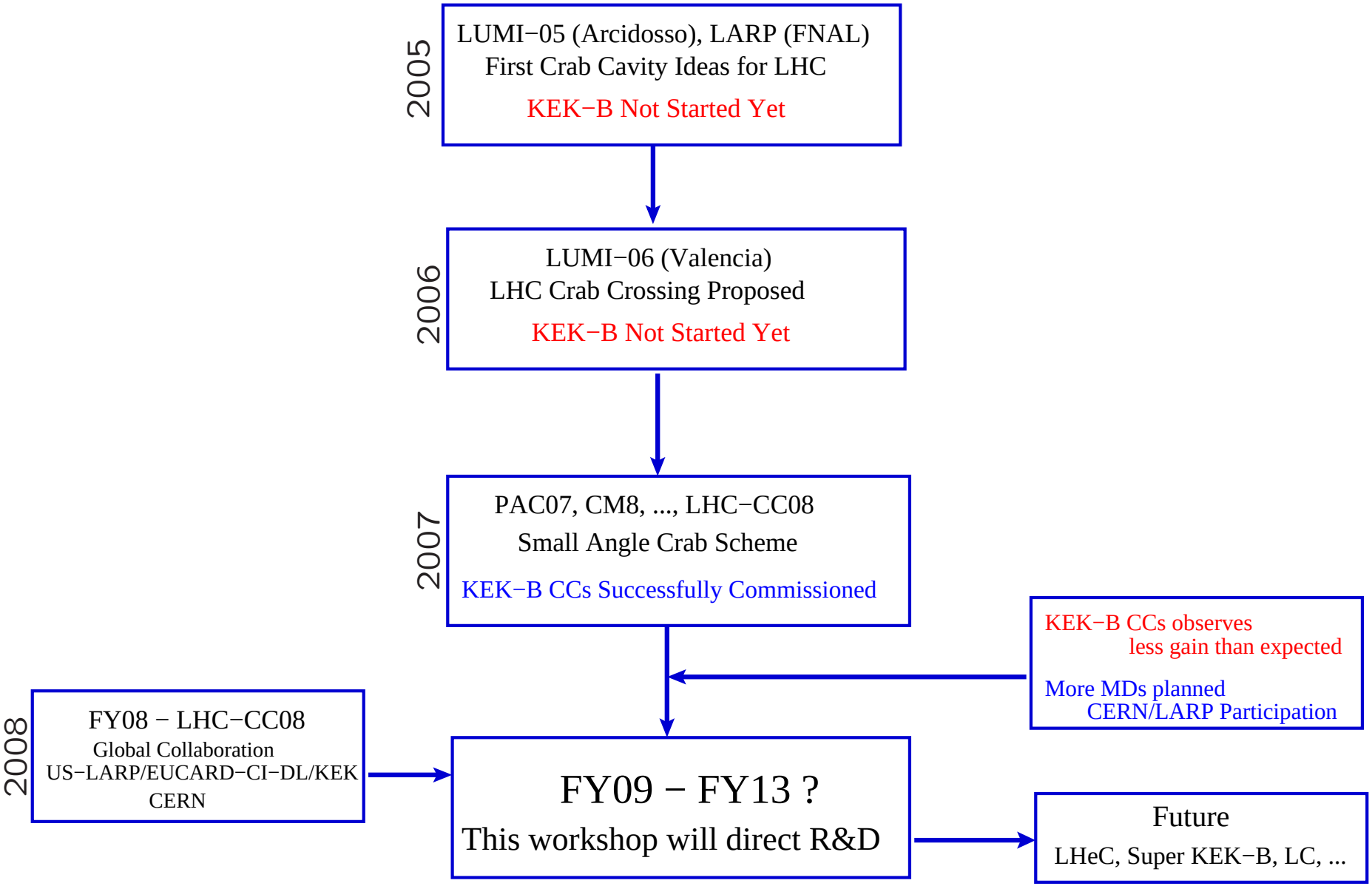
Rama Calaga
BNL/LARP, Aug 21, 2008



CARE-HHH: LHC Crab Cavity Validation

Ack: R. Tomás, F. Zimmermann & CC-Team

Brief Chronology



Collaboration: Spanning 3 Continents

US–LARP | CERN | KEK | EUCARD/CI–DL | OTHERS

Points of Contact:

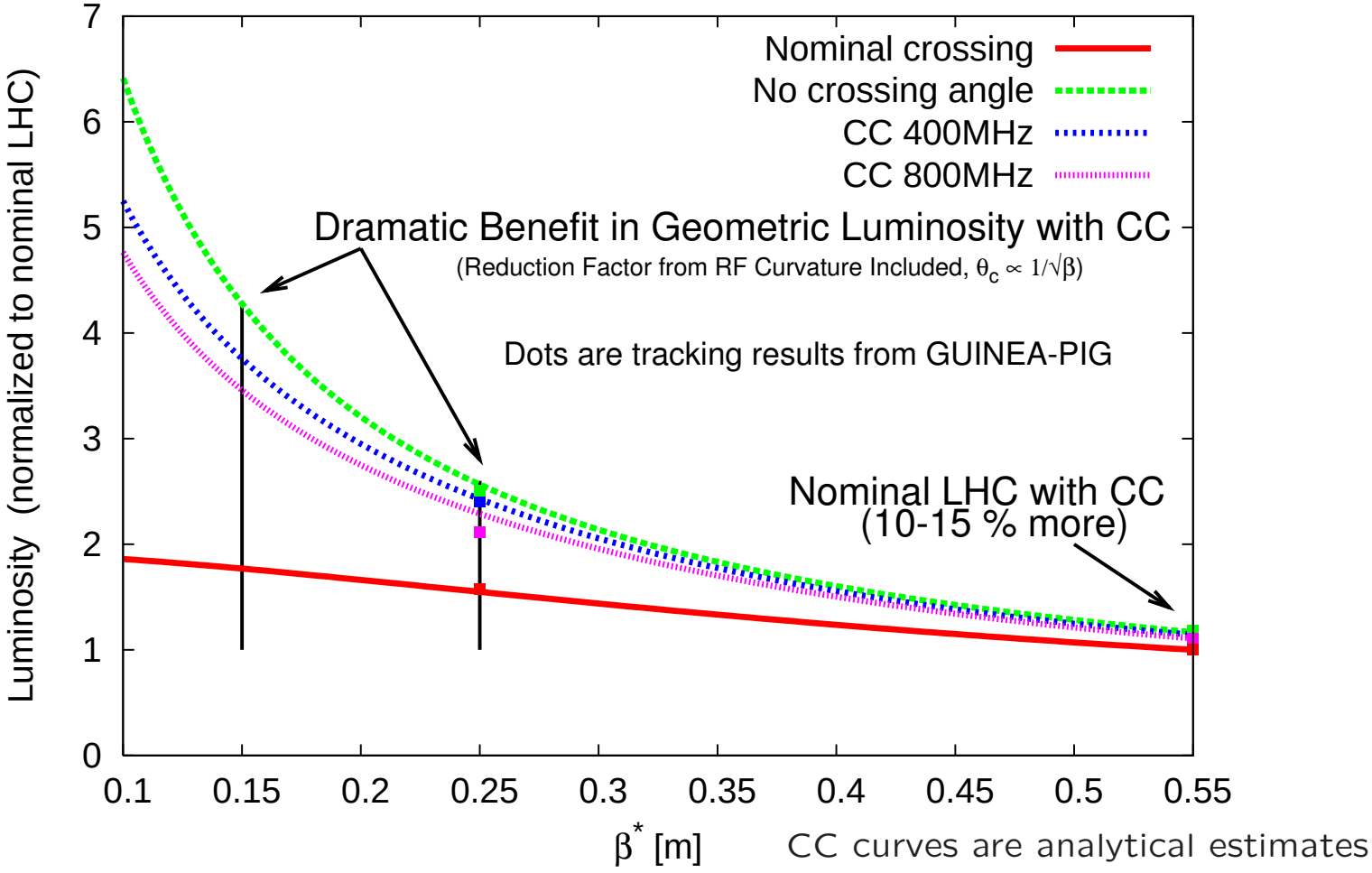
- US-LARP
  - BNL: R. Calaga, FNAL: N. Solyak, LBNL: J. Byrd , SLAC: A. Seryi
- EUCARD/Cockcroft Institute: P. McIntosh
- KEK: K. Oide

CERN Points of Contact:

- CERN RF: J. Tuckmantel, T. Linnecar
- CERN AB: O. Brüning, F. Zimmermann, R. Tomás
- EUCARD: J. P. Koutchouk

What does LHC gain ?

Lumi Reduction Factor: $\frac{L}{L_\circ} \approx \left[1 + \left(\frac{\sigma_z}{\sigma_x^*} \tan\left(\theta_c/2\right)\right)^2\right]^{1/2}$

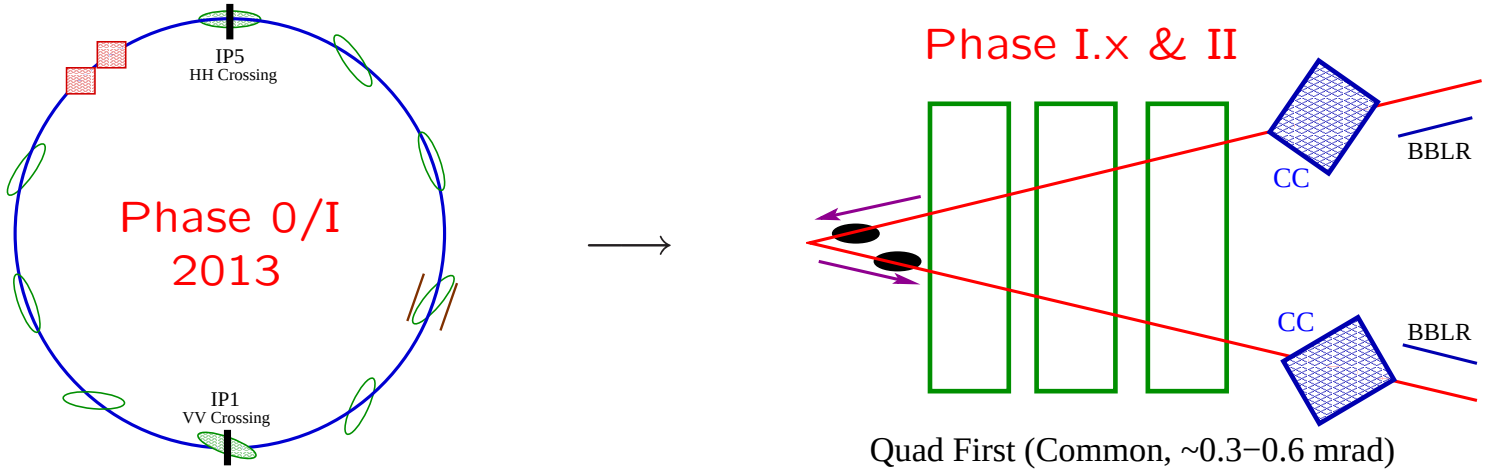


CC curves are analytical estimates

https://twiki.cern.ch/twiki/bin/view/Main/LHCCrabCavities

Phased Upgrades

- Phase 0/I (Nominal LHC/Phase I):
  - One crab structure/beam (global cavities @IP4, circa 2013)
    - Bare minimum scenario is only ONE cavity for ONE beam
  - SRF limits in deflecting mode & crab crossing with hadron beams
- Phase I.x (β^* IR Upgrade, after 2013)
  - Modified IR to accommodate local cavities (Global $\rightarrow$ Local)
  - VV crossing scheme (elliptical) -OR- compact cavities
- Phase II (Complete IR Redesign,circa 2017 or beyond)
  - Larger beam separation -OR- compact cavities -OR- perhaps separate quad channels ?



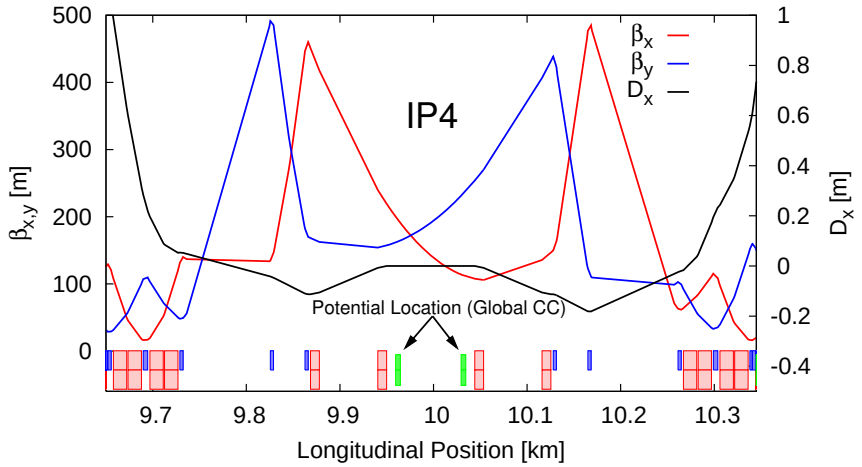
2007-08 Progress

Pre & Post LHC-CC08

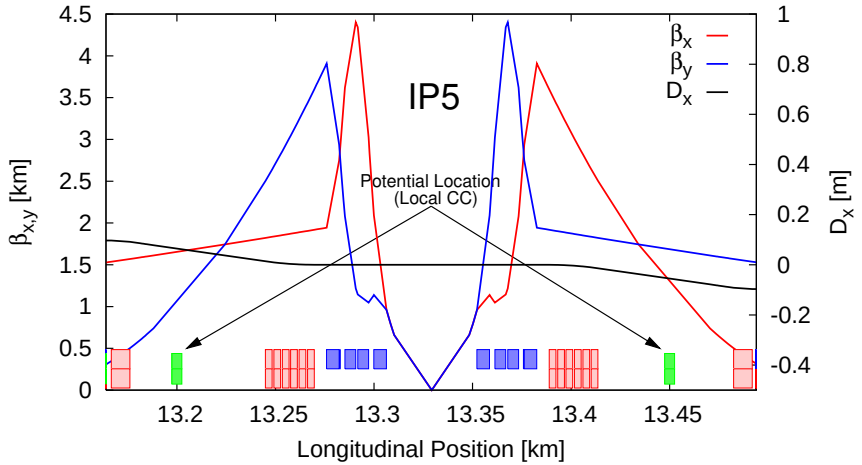
- Establish coordinates, preliminary optics & apertures
- Cavity-Cryomodule R&D
- Beam-beam (Ohmi) & impedance simulations
- Define task distribution and 5 yr plan to be ready for beam testing

Where do they go ?

Global Cavities @IP4 $\pm$ 35 m:



Local IR Cavities (Between D_1 & D_2):



Prelim Aperture Specs

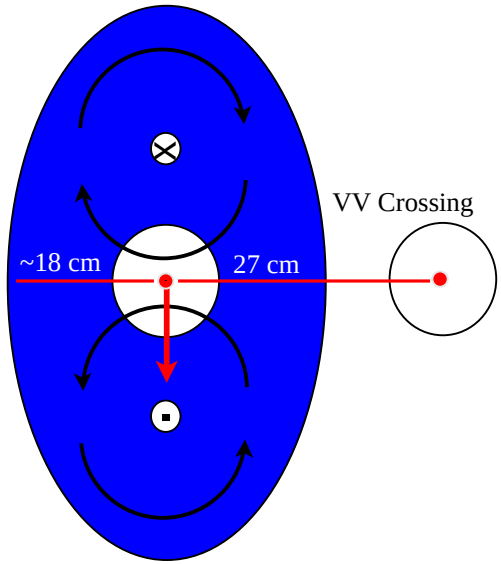
LHC prelim beam-pipe aperture:

Magnet	Ap-H[mm]	Ap-V[mm]	Tesla	L [m]
D1	134	110	7	10
D11	106	70	7	10
Crab Cav	**84** (>110 preferred)		-	-
D12	78	60	4	10
D2 (present)	69	53	3.85	10

Can D_1 be RHIC DX modules ? (being checked by R. Tomás & R. De-Maria)

Cavity Size (units in mm):

	Global (IR4)	Local (IR1-5)
Beam-Beam	420	270
Beam pipe	50	
Avail Space	340-360	190-210
Crab cavities	230	180 (VV)



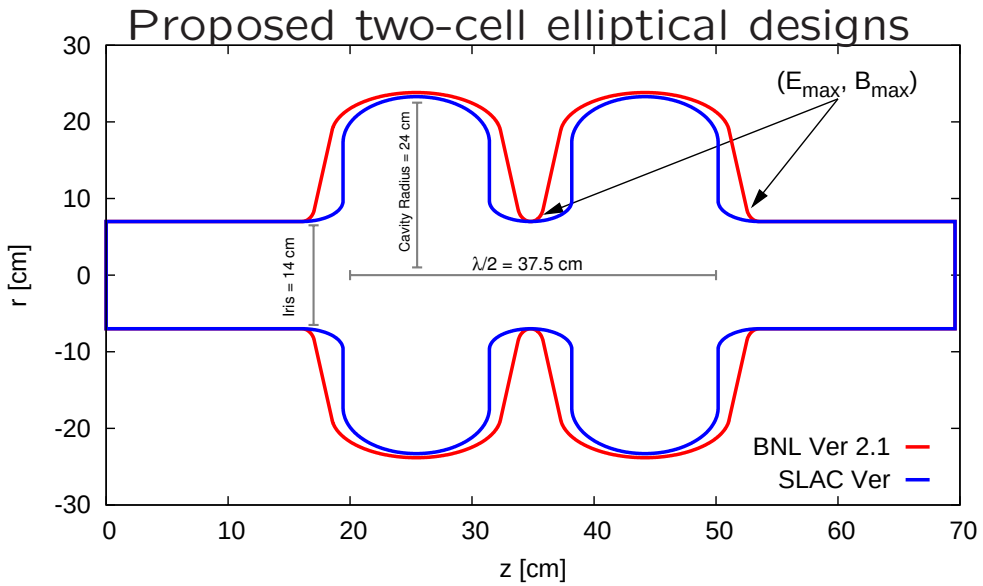
Cavity Frequency & Design

Two conflicting LHC constraints:

- Bunch length (7.55 cm) $\Rightarrow \leq$ 800 MHz (400 MHz preferred)
- Transverse beam-to-beam separation $\Rightarrow$ 800 MHz or higher

Based on bunch length, transverse size, aperture & SRF constraints:

- Two-cell squashed cavity at 800 MHz optimum choice
- Easily fits in IR4 section for prototype tests



Frequency	800 MHz
# of Cells	2
CC Voltage	2.5 MV
E_{peak}	$<$ 40 MV/m
B_{peak}	$<$ 100 mT
$R_\perp/Q$	$\sim$ 120 Ω

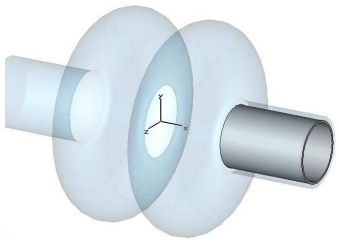
Couplers R&D

Strategy for coupler development:

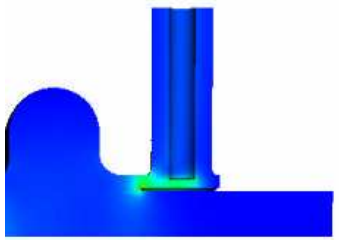
- Learn from KEK-B experience (excellent damping but delicate)
- Explore similar damping range with robust design

FY08 Progress:

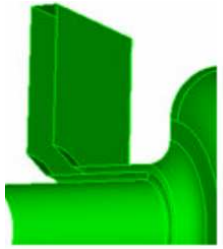
- Several ideas proposed to reach the strong damping requirements
- Converge to single or hybrid design during next year
- Tests on warm cavity to explore robustness & manufacturing issues



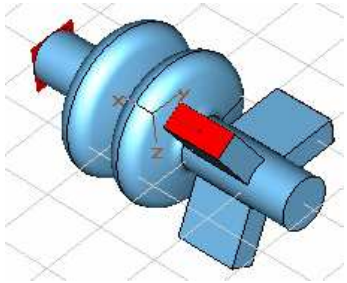
BP-Coax
(KEK-B)



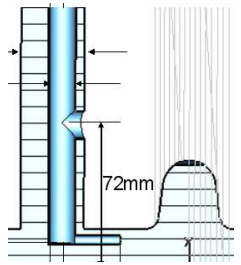
Coax-Coax
(L. Xiao)



Coax-Waveguide
(L. Xiao)

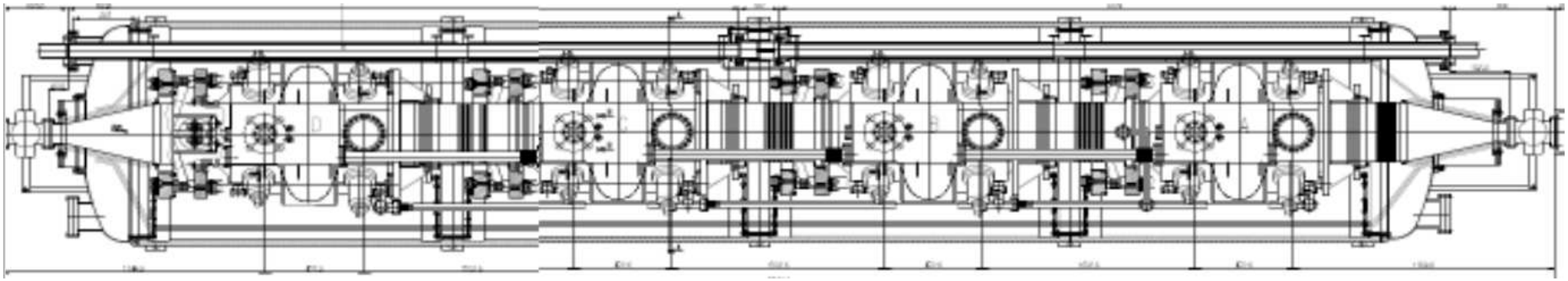


Waveguides
(G. Burt)

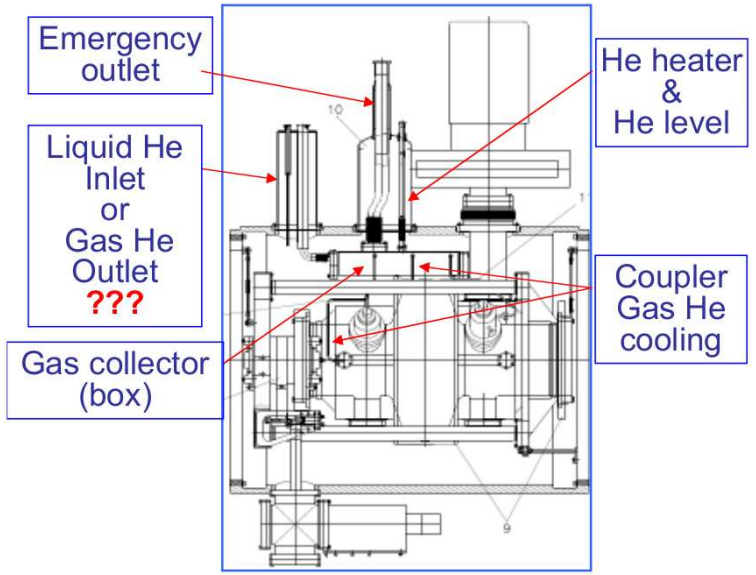


Coax-Hook Idea
(G. Burt)

Adapt CERN RF Cryostat



- Multiple large ports in frame offers easy access for cavity assembly
- Single He inlet and outlet circuit for 4 modules (modification for single module)
- Same mechanical tuner can be adapted to crab cavity if needed
- Availability of cryostat end cups ?
- Shielding sufficient for 4K (400 MHz) but may need more for 2K (800 MHz)
- Support/alignment inside cryostat can be adapted from the main RF



He circuit 1 Cavity

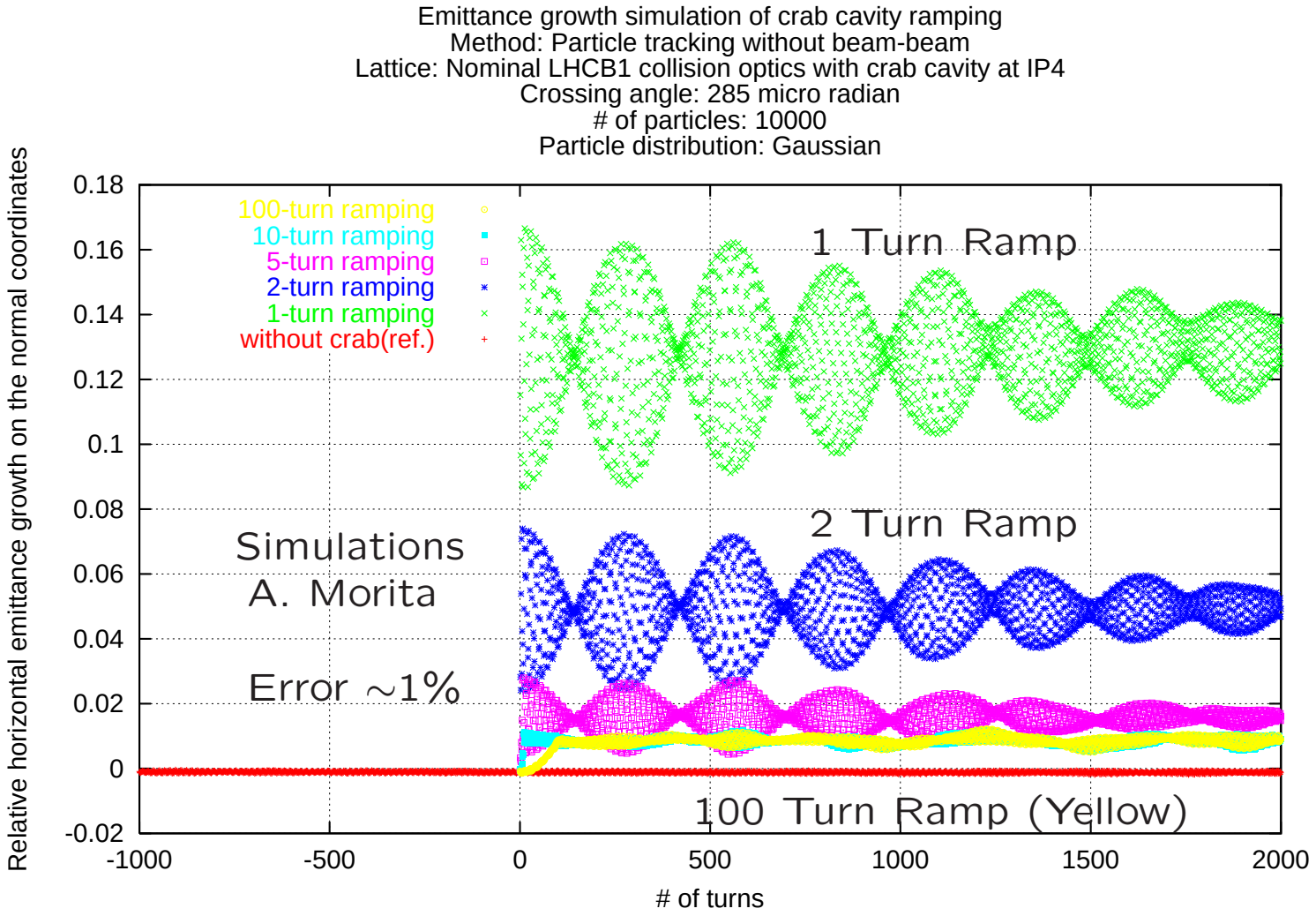
— FNAL + CERN

LHC Operation with Crabs

- Operational Scenarios
  - Turn-on cavities with or w/o beam (KEK-B test ?)
  - Beam transparency at injection & ramp
    - De-tune the cavity by several MHz (no overlap with 40 MHz bunch-rep)
  - Adiabatic voltage ramping of crab cavities
    - Stable orbit similar to collimators ($\sim$200 μm, natural feedback)

- KEK-B Experiments
  - Understand & solve KEK-B drop in specific luminosity
  - Use KEK-B as LHC crab-cavity testbed
  - LHC studies might help for KEK-B problem and vice versa

Adiabatic Ramping V_{crab}



- Cavity Q is very high ($\sim 10^6$), naturally slow ramping
- Ramping over several sync-periods should have negligible emittance growth

Tasks & Coordination

Near Term							
	US-LARP				EU-DL/CI	KEK	CERN
POC	BNL/AES Calaga	FNAL Solyak	LBNL Byrd	SLAC Seryi	Koutchouk McIntosh	Oide	Tuckmantel Tomás
Coordination	X						
Cavity	X						
Couplers			(X)	X		O	
LLRF			X		X	O	
Cryostat		X				O	
Cryogenics		(X)					X
Power Systems							X
Optics	X						X
Collimation			(X)				X
BB Tracking	(X)					(X)	X
Impedance Est.	(X)						X
Controls							X
Warm Model	X		X		X		
Fabrication		X			(X)		
Cav. Treatment		X				O	
Bench Testing		X			X		(X)
Beam Testing		(X)					X
OP Scenarios						O	X

RF

Simulations

Fabrication

X: Lead role, (X): Supporting role, O: Proposal

Parallel R&D on compact cavities (US-LARP/EUCARD/KEK(?))

Next 6-12 Months

- Outcome of this workshop
  - Establish/agree (CERN $\leftrightarrow$ Collaborators) on the 5 yr R&D plan, detailed WBS to follow
  - Commitment towards the 2013 goal
- FY09-12 funding will determine the R&D pace
  - Strong support from LARP & EUCARD expected
  - KEK contribution to cryomodule (?)
- Rapid progress in 2008-09 towards a preliminary CDR ready for review

Next 5 Yrs

- Preliminary review (2nd LHC-CC workshop) mid-2009
  - Technical design of cavity, couplers, cryostat, controls
  - Simulation studies,Operational scenarios and beam transparency
  - Warm model fabrication $\rightarrow$ testing
- A comprehensive review $\sim$2010 (T. Linnecar's talk)
- Cryo-module fabrication and testing $\sim$2010-12
  - Hardware procurement, fabrication of components, assembly
  - Rigorous bench testing (RF & operational scenarios)
- LHC Integration and commissioning $\sim$2012-13