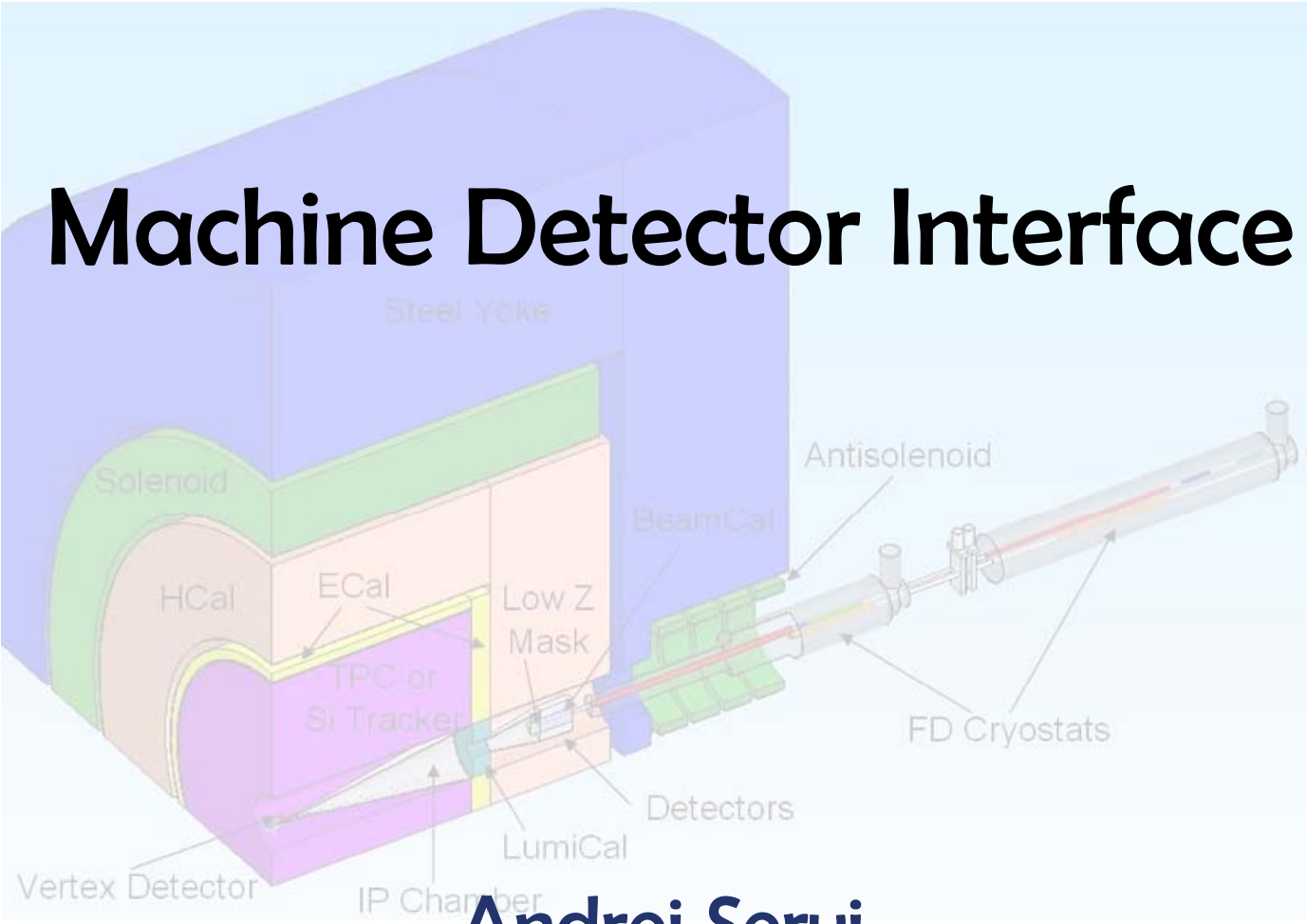
Machine Detector Interface



Andrei Seryi
SLAC

ILC PAC Review
20 October 2008

Plan of the presentation

- Outlook of Beam Delivery System plans in TDP
- Brief overview of ILC IR design and MDI challenges
- Recent (Sept 2007-Oct 2008) progress in MDI work
  - IRENG07 workshop
  - Establish MDI work plans toward LOI
  - Work on "Interaction Region interface document"
  - Design studies by detector groups
- (New) Directions of MDI activity
  - IR design, Final Doublet (FD), and its tests at ATF2
  - Support search for optimal IP parameters for min machine
  - New collaboration on beam dump (neutrons to IP=> also MDI item)
  - Exploration of ideas & tests for more performing machine

Bema Delivery Systems strategy in TDP

In TDP I & II plan, the scope of work changed, and the focus is shifted

→

- Focus on a few critical directions. Selection criteria:
  - –Critical impact on performance versus cost;
  - –Advanced ideas promising breakthrough in performance;
  - –Broad impact and synergy with other worldwide projects

→

- Three critical directions:
  - –General BDS design
  - –Test facilities, ATF2
  - –Interaction Region optimization

beam dump
photon collider
crystal collimation
crab cavity
MDI diagnostics …

ATF2 commissioning & operation
Develop methods to achieve small beam size
Diagnostics, Laser Wires, Feedbacks …

IR interface document & design
SC FD prototyping and vibration test
ILC-like FD for ATF2 …

BDS five year plan

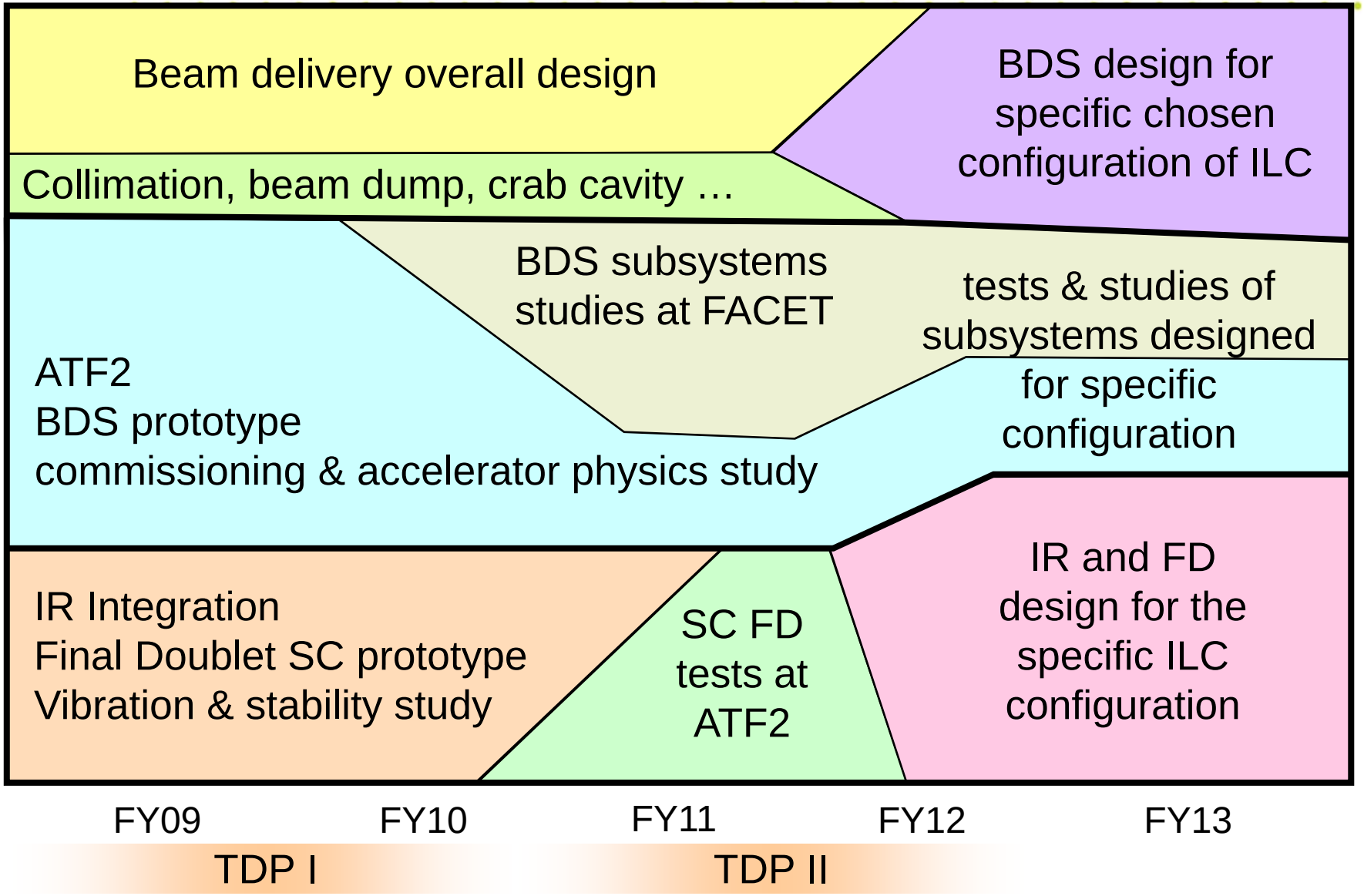


Table 3.4: TD Phase Beam Test Facilities Deliverables and Schedule.

Test Facility	Deliverable	Date
Optics and stabilisation demonstrations:		
ATF	Generation of 1 pm-rad low emittance beam	2009
ATF-2	Demonstration of compact Final Focus optics (design demagnification, resulting in a nominal 35 nm beam size at focal point).	2010
	Demonstration of prototype SC and PM final doublet magnets	2012
	Stabilisation of 35 nm beam over various time scales.	2012

3.3.5 Beam Delivery System

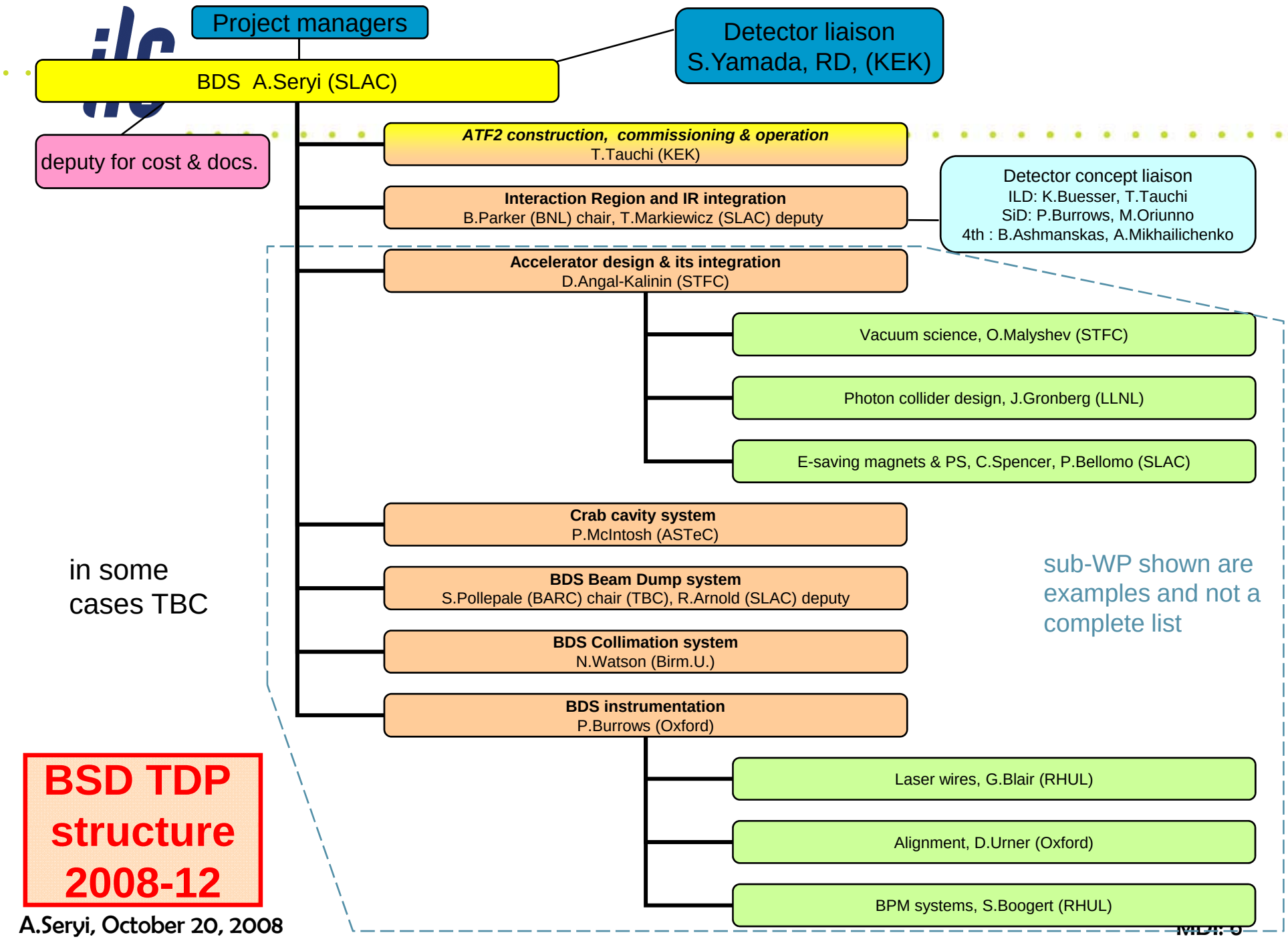
The main R&D focus for the BDS is the ATF-2 programme at KEK which will allow demonstrations of many of the key BDS components and design concepts, the Machine-Detector activity for optimization of the Interaction Region, and design for those BDS subsystems which are critical for system performance or which may expand the physics capabilities of the collider. Examples of R&D are:

- Development of instrumentation (e.g. laser-wires), algorithmic control software, beam-based feedback systems and emittance-preservation techniques to achieve the small beam-size goals (2010)
- Developing of IR Interface Document defining MDI specifications and responsibilities (2010) and design or optimised IR (2012)
- Development of the prototype of the Interaction Region SC Final Doublet (2012)
- Development of Interferometer system for FD stability monitoring (2012)
- Design of the beam dump system (2012)
- Tests of SC and PM Final doublet at second stage of ATF2 (2012)
- Design studies for the photon collider option (2012)
- Collimation and dump window damage tests at ATF2 (2010)
- Development and demonstration of the SCRF crab-cavity system (2010)

BDS in GDE Technical Design Phase plan

MDI-related.

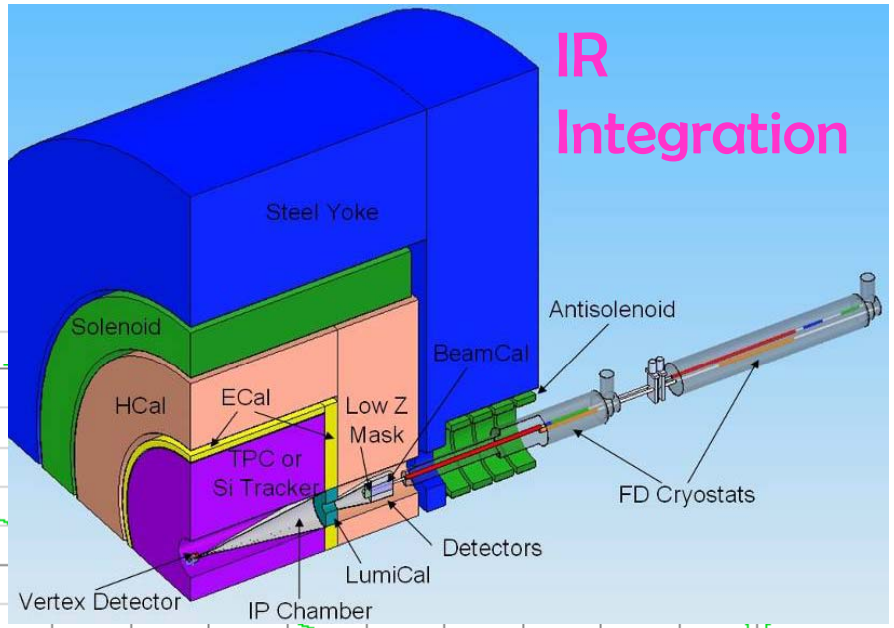
Will discuss in this talk.

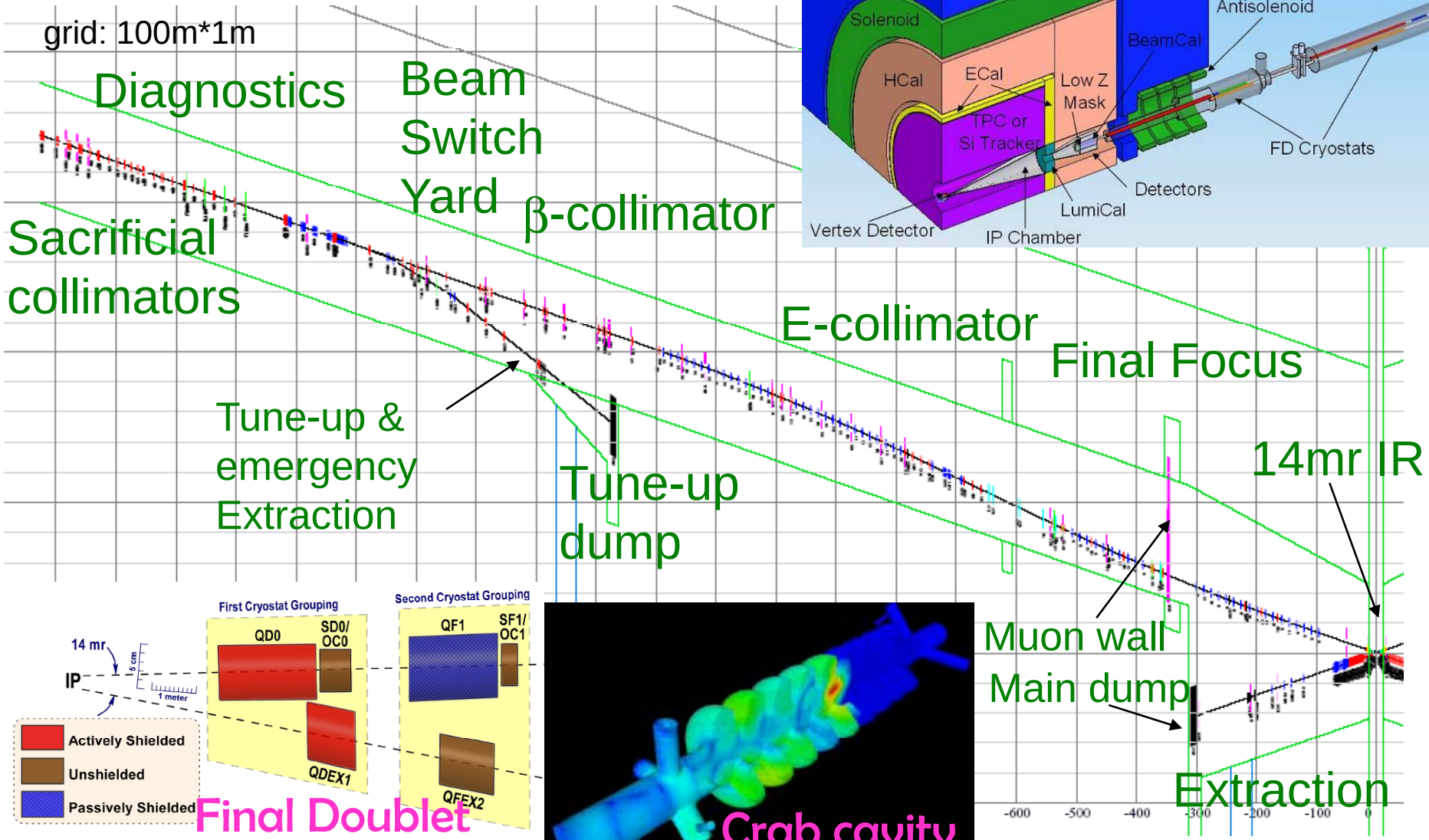


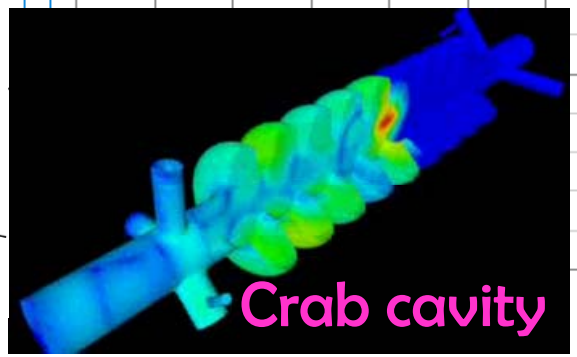
BSD TDP structure 2008-12

BDS RDR design

1TeV CM, single IR, two detectors, push-pull



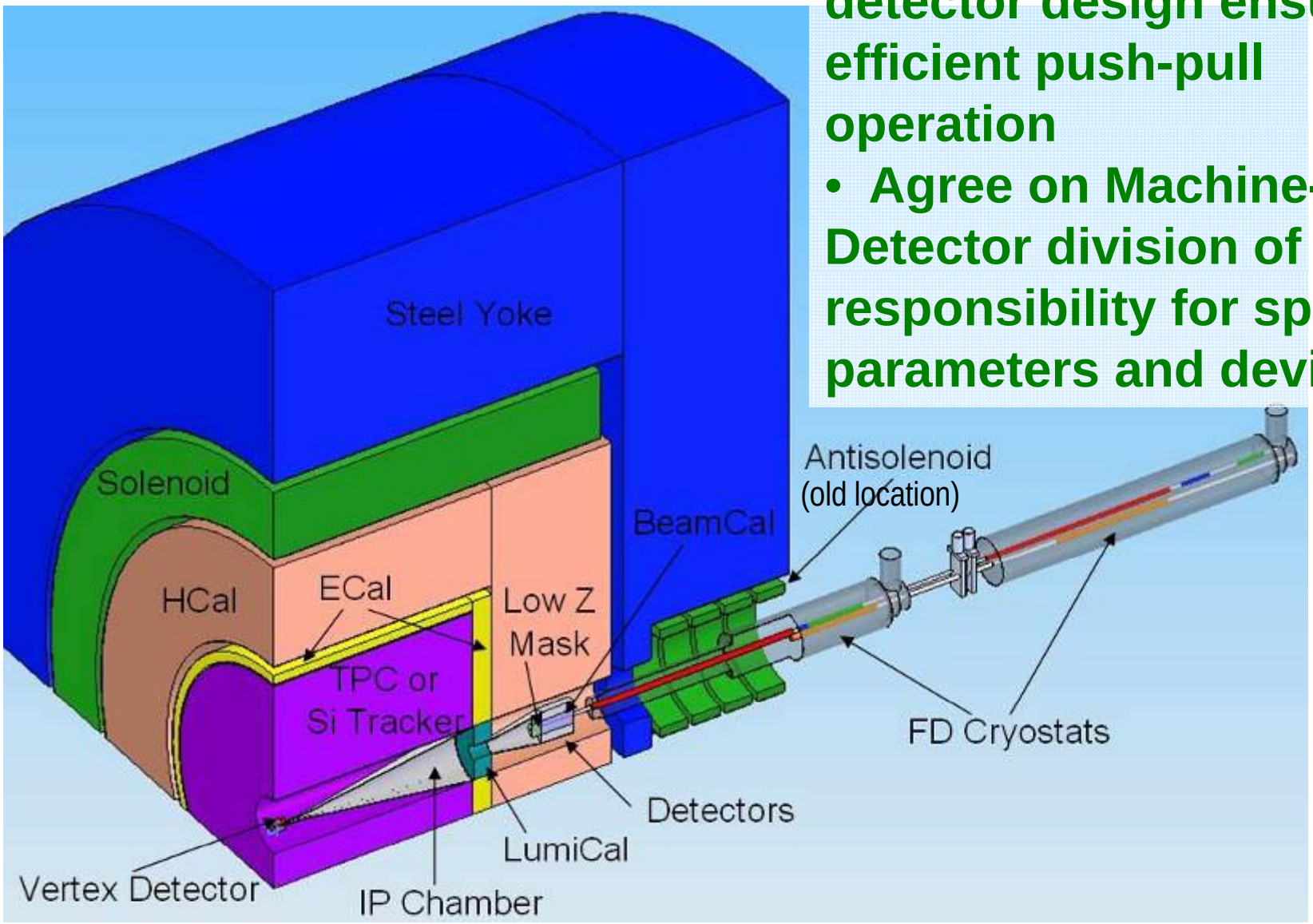




IR integration

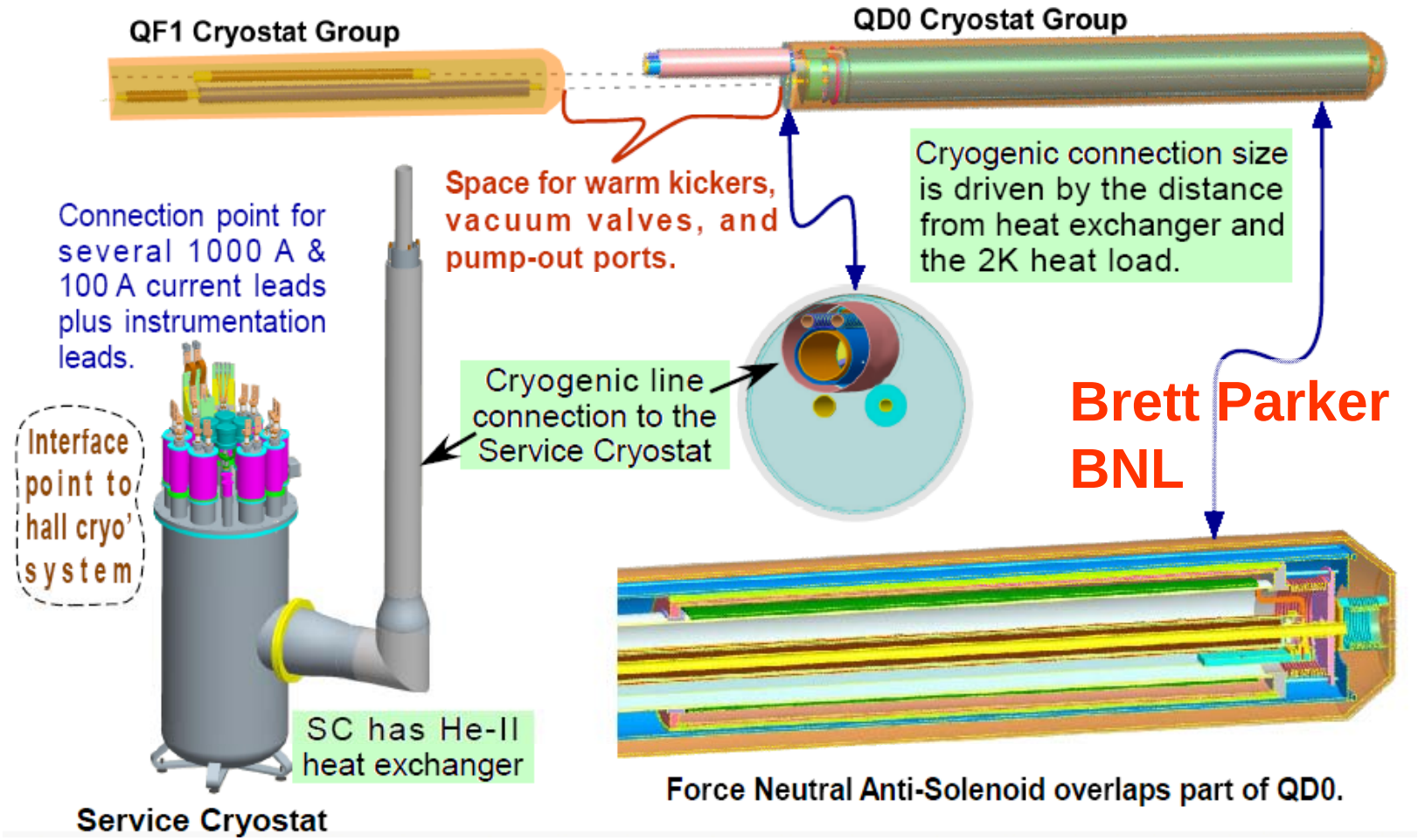
Challenges:

- **Optimize IR and detector design ensuring efficient push-pull operation**
- **Agree on Machine-Detector division of responsibility for space, parameters and devices**



SC final double & its cryo system

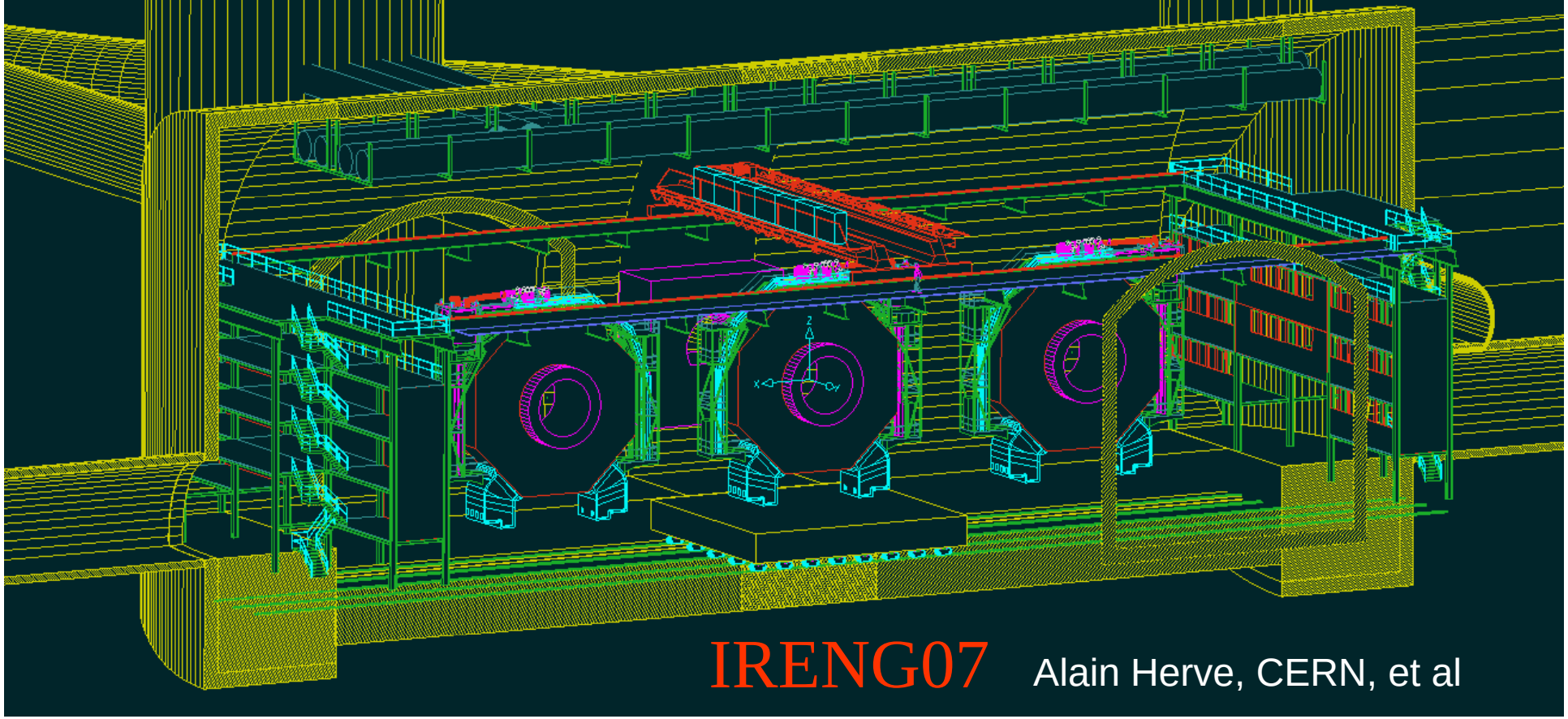
Significant progress (2007) on consistent design of the SC Final Doublet, suitable for push-pull operation ("IR Eng. workshop, IRENG07")



Brett Parker et al BNL

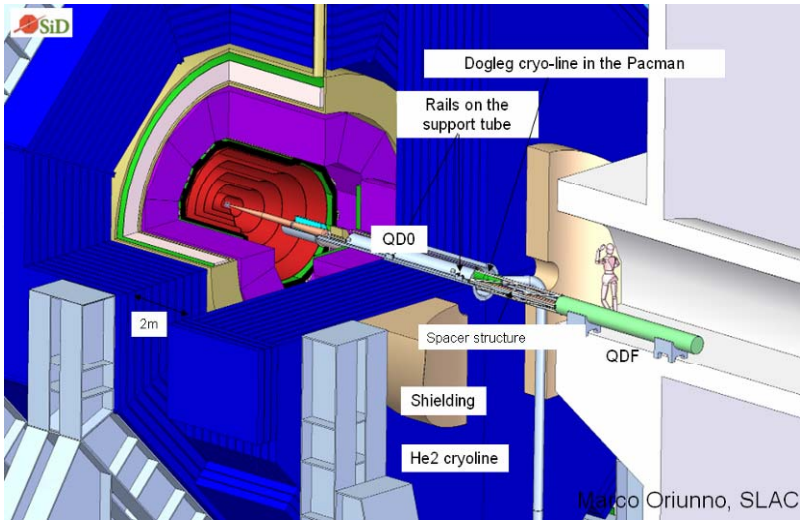
Optimization of Push-Pull design

Optimized IR hall and motion system with auxiliary interface platform that provide clear interface and reduce detector distortion during push-pull operation (IR Eng. workshop, IRENG07, September 2007)



IRENG07 Alain Herve, CERN, et al

IR integration



- Machine – Detector work on Interface issues and integration design is a critical area and a focus of efforts
- IR integration timescale
  - EPAC08 & Warsaw-08
    - Interface document, draft
  - LCWS 2008
    - Interface doc., updated draft
  - LOI, April 2009
    - Interface document, completed
  - Apr.2009 to ~May 2010
    - design according to Interface doc.
  - ~May 2010: LHC & start of TDP-II
    - design according to Interf. doc and adjust to specific configuration of ILC

EPAC08

CHALLENGES AND CONCEPTS FOR DESIGN OF AN INTERACTION REGION WITH PUSH-PULL ARRANGEMENT OF DETECTORS – AN INTERFACE DOCUMENT*

B.Parker (BNL), A.Herve, J.Osborne (CERN), A.Mikhailichenko (Cornell Univ.), K.Buesser (DESY), B.Ashmanskas, V.Kuchler, N.Mokhov (Fermilab), A.Enomoto, Y.Sugimoto, T.Tauchi, K.Tsuchiya (KEK), J.Weisend (NSF), P.Burrows (Oxford Univ.), T.Markiewicz, M.Oriunno, A.Seryi, M.Sullivan (SLAC), D.Angal-Kalinin (STFC), T.Sanuki, H.Yamamoto (Tohoku Univ.)

Abstract

Two experimental detectors working in a push-pull mode has been considered for the Interaction Region of the International Linear Collider [1]. The push-pull mode of operation sets specific requirements and challenges for many systems of detector and machine, in particular for

The speed of push-pull operation is the first defining assumption. We set as the goal that hardware design should allow the moving operation, reconnections and possible rearrangements of shielding to be performed in a few days, or less than a week.

The range of detector sizes considered in the design

http://accelconf.web.cern.ch/accelconf/e08/papers/mopp031.pdf

IR Interface Document

- Minimal functional requirements:
  1. Two detectors in a single collider hall, able to work in turns, in push-pull mode.
  2. Hardware should allow the moving operation, reconnections & possible rearrangements of shielding to be done in a few days, or less than a week.
  3. The IP to start of QD0 (L*) in the range of 3.5-4.5 meters (different L* is allowed for different detectors); distance from IP to the QF1 fixed to 9.5 m.
  4. The range of detector sizes considered in the design include detectors with half size of 6-7 meters
  5. The off-beamline detector is shifted in transverse direction to a garage position, located 15m from the IP.
  6. The radiation and magnetic environment, suitable for people access to the off-beamline detector during beam collision, are to be guaranteed by the beam line detector using their chosen solution.
  7. The IR and detector design is to satisfy all the beam parameters defined in the RDR including nominal, Low N, Large Y and Low P parameter sets.

IR Interface Document, examples 1

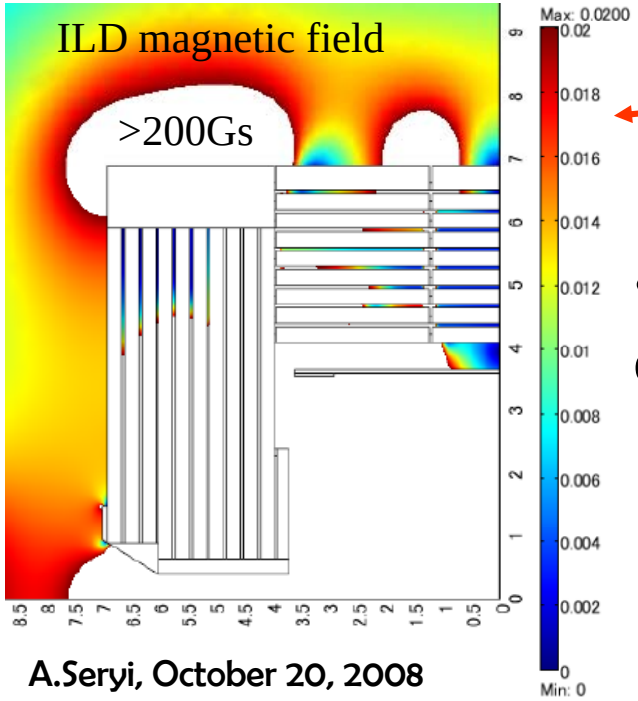
- Interface specifications and responsibilities ("marriage contract"). Examples (some are actively debated now):
  - Definition of push-pull operation –from the switch-off until when luminosity is restored to 70% level and at the same energy, after the detector exchange
  - Any possible calibration of detector, at nominal or lower E, is not included in the time of push-pull operation and is up to detector collaboration
  - Design should allow 2m opening of detector on the beamline. Responsibility for operation: detector collaboration
  - Assembly of detectors for assumed deep site configuration: on surface
  - Alignment: ±1mm precision detector repositioning after the move;
    ±2mm QD0 mover range;
    ±0.2mm FD to VX alignment before beam start;
    detector is to provide to machine info on VX position;
    four channels in the detector for interferometer path to QD0;
    responsibility to align QD0: machine group

IR Interface Document, examples 2

- Interface specifications and responsibilities ("marriage contract"). Examples (some are actively debated now):
  - Detector motion system: use of 20*20*2m platform (working assumption, actively debated); Responsibility for motion operation: machine group
  - radiation criteria: normal (< 0.05mrem/h) and accident (<25rem/h for max credible beam); detector responsible for its (self or additional)-shielding
  - Fire safety: no flammable gases underground; halogen free cables; smoke detectors inside the sub-detectors...
  - stability of detector surface supporting FD: < 50nm; responsibility: detector
  - Vacuum requirements: 10ntorr near IR; detector responsible for providing space for pumps near IR, not relying on QD0 cold bore for pumping
  - magnetic field criteria: assume no access for people with pacemakers; field on any external surface of on-beamline detector < 2kGs; field in non-restricted area (including near the off-beamline detector) is < 100Gs; cross distortion of on-beam-line detector field < 0.01% ...

Iterations on IR Interface specs, example

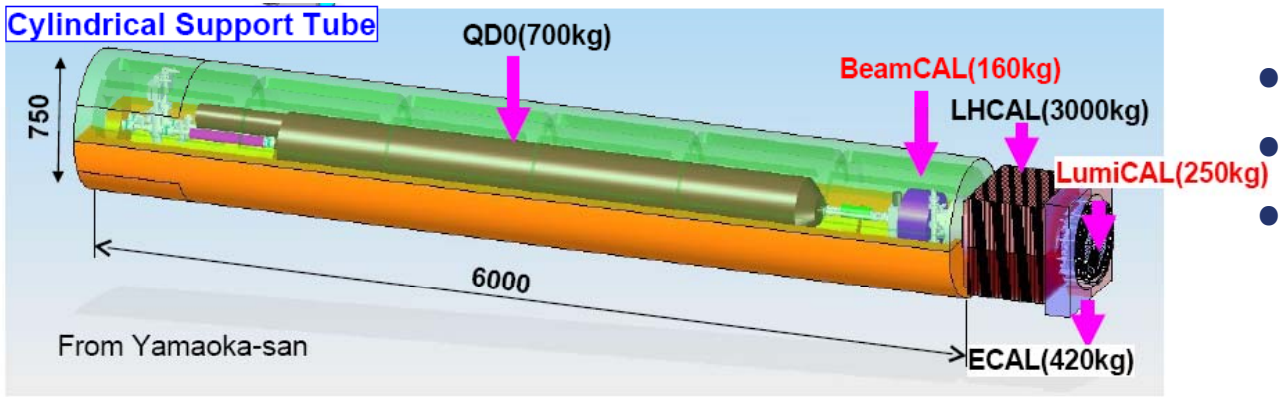
- Magnetic fields requirement evolution:
  - Few years ago: < 50 Gs anywhere outside of detector
  - Recently: < 200 Gs at 0.5m
  - Latest in IR Interf. Doc: < 2kGs on detector surface, < 100Gs in accessible area; no pacemakers; < 0.01% cross-field distortion
    - » Assumptions: any static field effects on the beam can be corrected, and high frequency field fluctuations are small. Thus the limiting factors are only safety for people, operability of hardware, and field cross-distortion



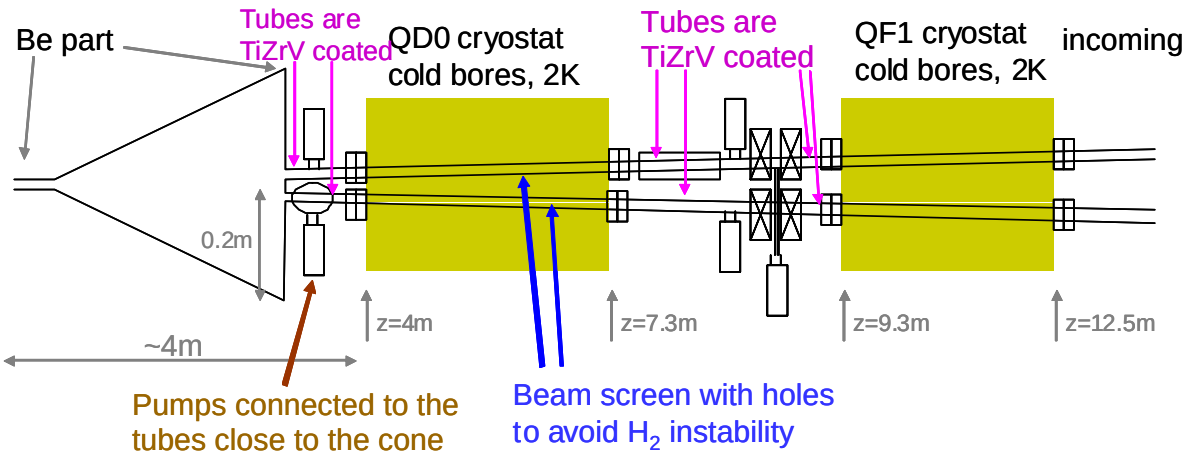
ILD detector would require +60cm of steel to meet <200Gs requirement

- Within ILC detector study, CERN/CMS colleagues are planning to test:
  - possibility to perform mechanical operations in 50-100Gs field;
  - model distortion of detector field due to external field

Hot MDI issues, examples



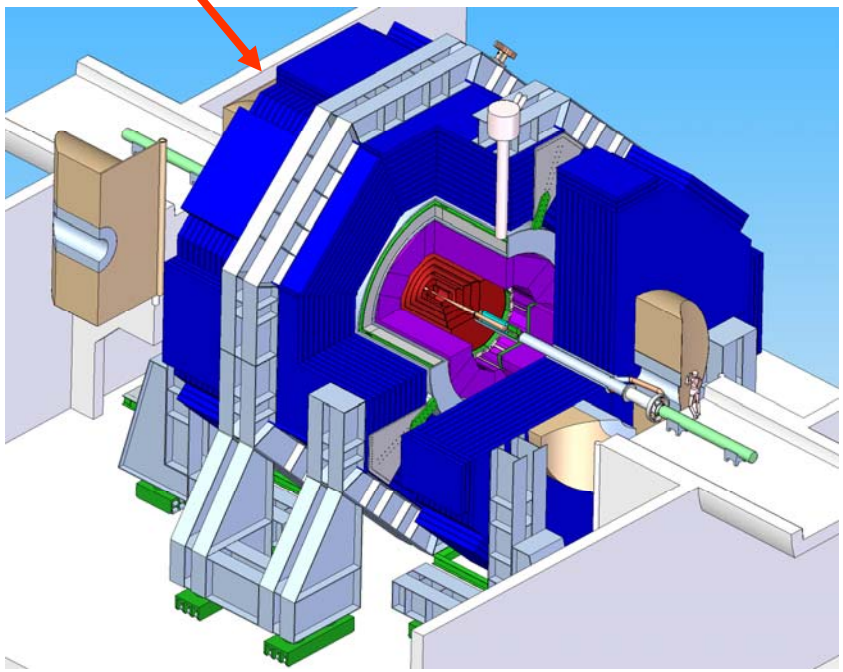
- < 50nm for QD0 stability
- compact movers for QD0
- support ~3t LHCAL mass such that it does not adversely affect the QD0 dynamics

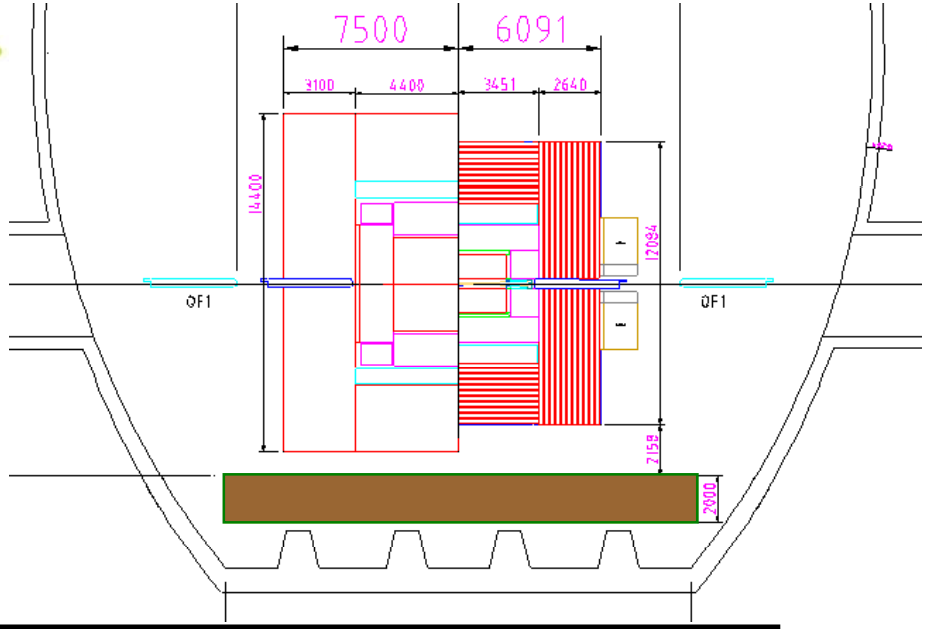


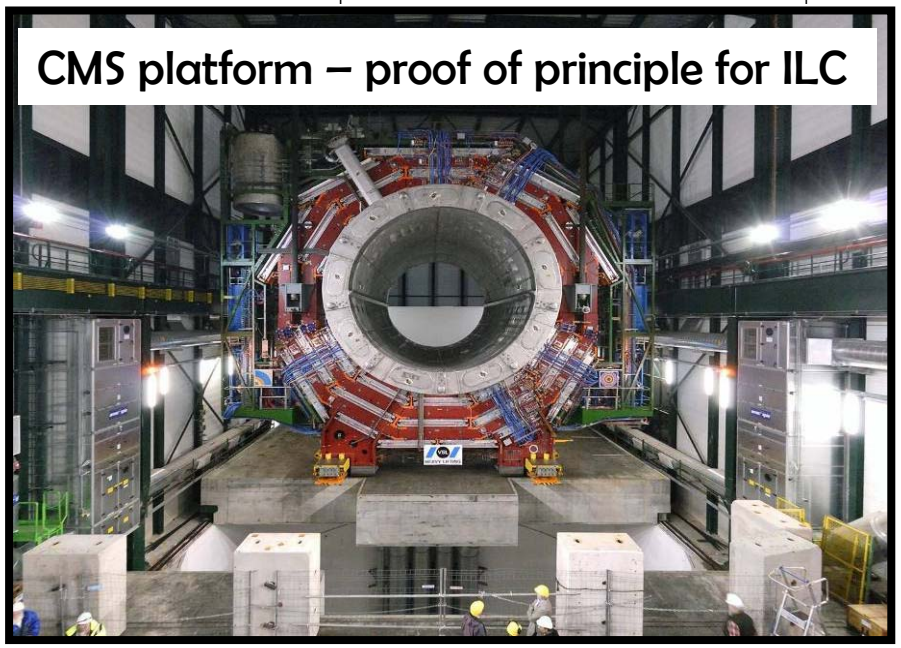
- May need pump close to IP
- Do not rely on QD0 cold bore cryo-pumping
- High Order Modes
- Support and alignment of IR chamber and VX
- Assembly, flanges...

Hot MDI issues, examples

Detector motion system with
or without an intermediate platform



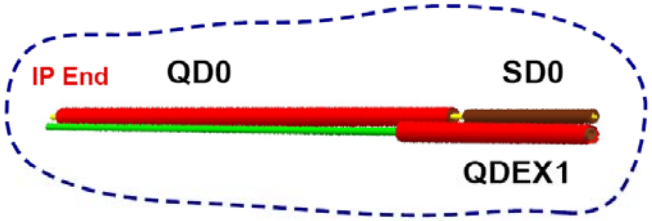




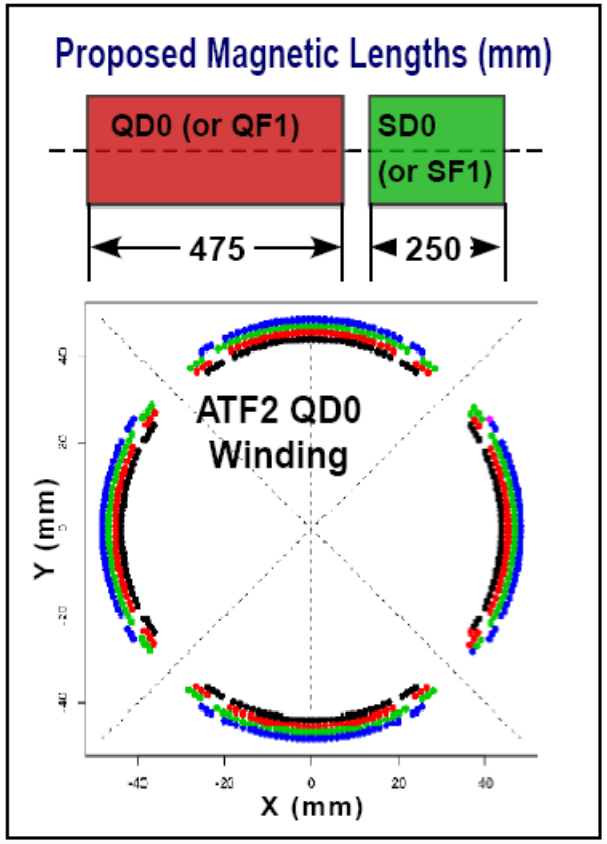
- Working assumption: use platform
- As detector design develops, a feasible and cost effective solution without a platform might be found

SC FD modified plans and ATF2 tests

QD0 Cryostat Design for L* = 4.5 m.



Earlier plan was to prototype ILC-like QD0 magnet with cryostat & study its stability

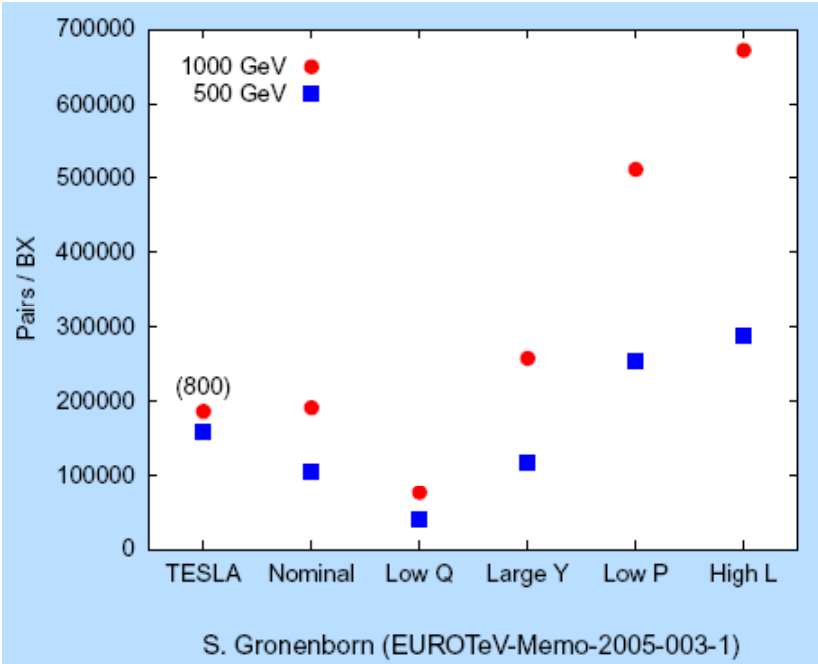


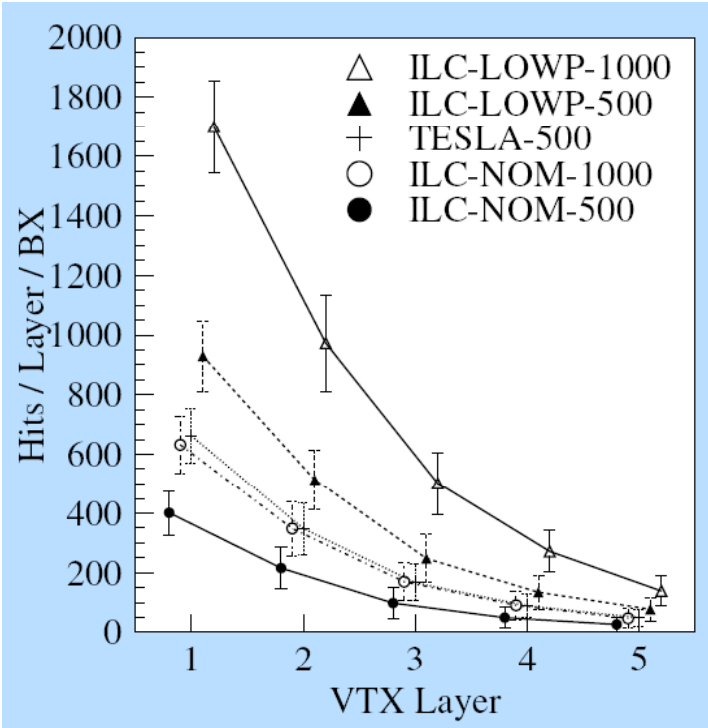
- In TDP, has adjusted the plans for SC FD prototype at BNL
  - reduce efforts on ILC-like FD prototype; make only long cold mass and perform its field & stability tests
  - enhance efforts on ILC-technology-like SC Final Doublet for ATF2 upgrade

- Only produce one quadrupole/sextupole magnet combination (in common cryostat).
- No self-shielding or anti-solenoid (simple).
- KEK Cryogenic system (major challenge).
- 50 mm aperture but with a warm bore (i.e. optimize to limit cold mass heat leak).
- Minimum degrees of freedom (correctors).
- Found it easy to match corrector coils and main coil magnetic lengths.

Support search for optimal IP parameters for min machine

- The "low power" option may be a **machine** "cost saving" set
- The RDR "Low P" is not a favorite set for detectors:





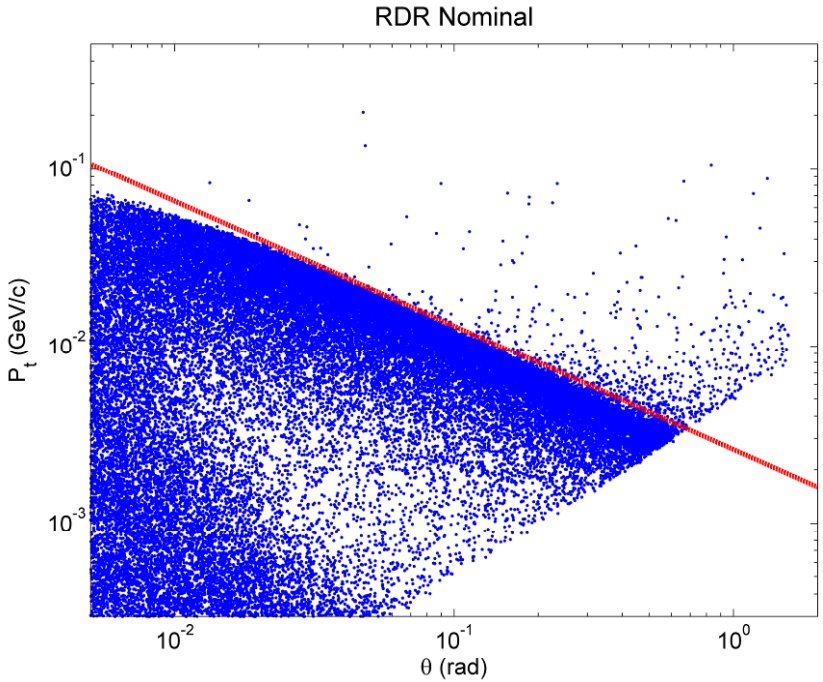
- Improved version of Low Power may require tighter IP focusing, and use of "travelling focus" [V.Balakin, 1990]

Candidates for new Low P parameter sets

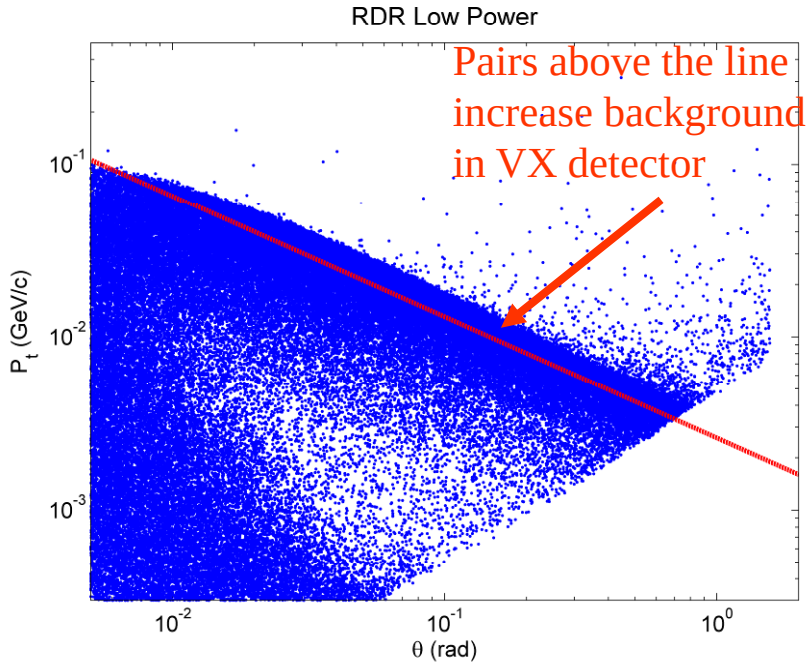
	Nom. RDR	Low P RDR	new Low P	new Low P	new Low P	new Low P
Case ID	**1**	**2**	**3**	**30**	**4**	**5**
E CM (GeV)	500	500	500	500	500	500
N	2.0E+10	2.0E+10	2.0E+10	2.0E+10	2.0E+10	2.0E+10
n_b	2625	1320	1320	1320	**1105**	1320
F (Hz)	5	5	5	5	5	5
P_b (MW)	**10.5**	**5.3**	**5.3**	**5.3**	**4.4**	**5.3**
$\gamma\varepsilon_x$ (m)	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05
$\gamma\varepsilon_y$ (m)	4.0E-08	3.6E-08	3.6E-08	3.6E-08	**3.0E-08**	**3.0E-08**
βx (m)	2.0E-02	1.1E-02	1.1E-02	1.1E-02	**7.0E-03**	**1.5E-02**
βy (m)	4.0E-04	2.0E-04	2.0E-04	**1.0E-04**	**1.0E-04**	**1.0E-04**
Travelling focus	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Z-distribution *	Gauss	Gauss	Gauss	**Flat**	**Flat**	**Flat**
σ_x (m)	6.39E-07	4.74E-07	4.74E-07	4.74E-07	3.78E-07	5.54E-07
σ_y (m)	5.7E-09	3.8E-09	3.8E-09	2.7E-09	2.5E-09	2.5E-09
σ_z (m)	3.0E-04	2.0E-04	**3.0E-04**	3.0E-04	**5.0E-04**	**2.0E-04**
Guinea-Pig $\delta E/E$	**0.023**	**0.045**	**0.036**	0.036	0.039	0.038
Guinea-Pig L ($cm^{-2}s^{-1}$)	**2.02E+34**	**1.86E+34**	**1.92E+34**	**1.98E+34**	**2.00E+34**	**2.02E+34**
Guinea-Pig Lumi in 1%	1.50E+34	1.09E+34	1.18E+34	1.17E+34	1.06E+34	1.24E+34

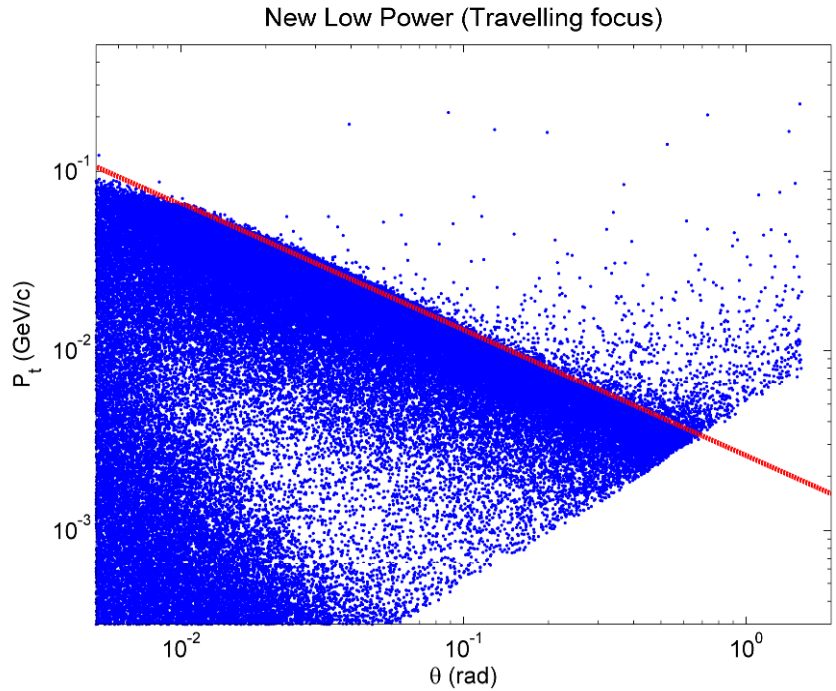
*for flat z distribution the full bunch length is σ_z*2*$3^{1/2}$

e+e- pairs



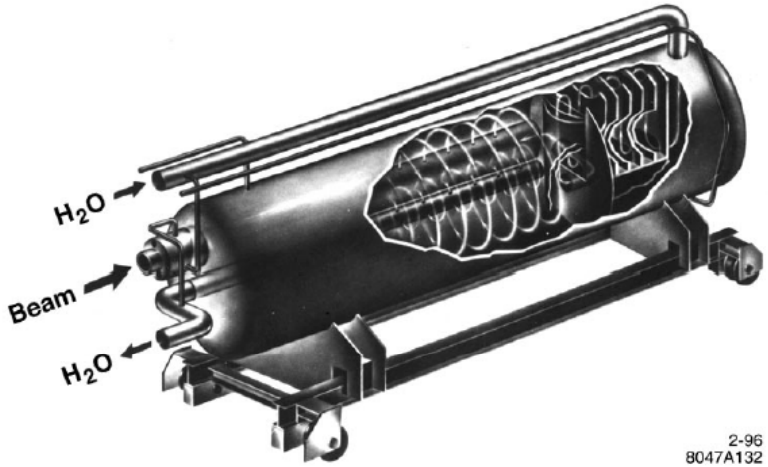
- Edge of pairs distribution in θ-P_t important for VX background
- RDR Low P: edge higher=> unfavorable for background
- New Low P: edge location similar as RDR Nominal





Beam dump design

Beam dump is MDI issue via neutrons coming back to IP which affect lifetime of VX detector



New collaboration with BARC, India, on 18MW beam dump design

SLAC/BARC critical expertise for beam dump project:

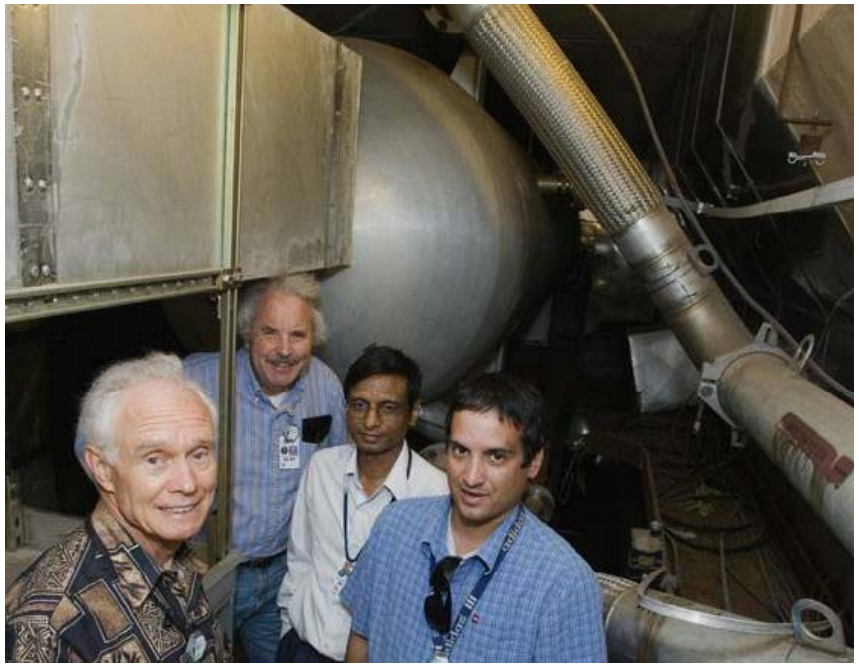
Satyamurthy Polepalle - expert in CFD and thermal hydraulic analysis with numerous successful projects in nuclear physics and power; large technical resources at BARC.

Dieter Walz - expert in beam dump design, materials performance and engineering for particle accelerator applications.

SLAC-BARC Dump Group

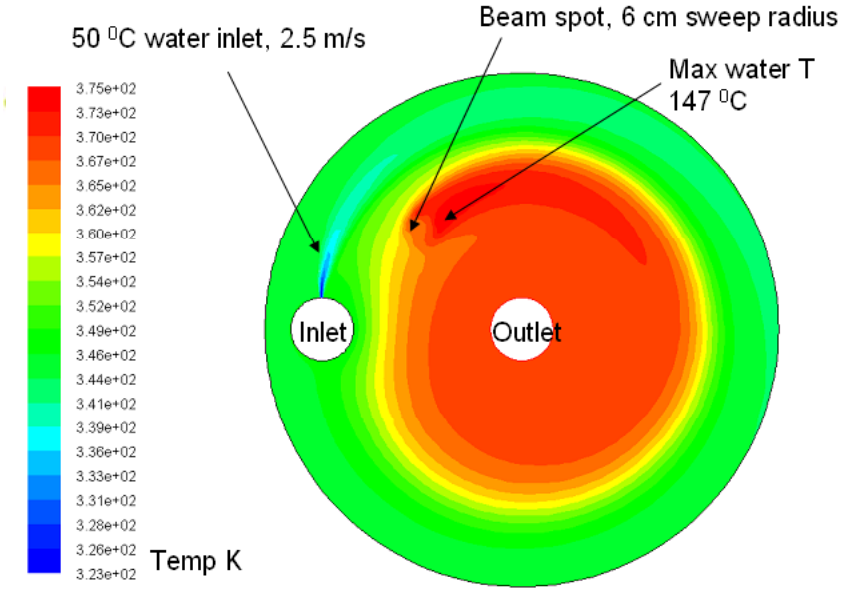
J. Amann, R. Arnold, D. Walz
Stanford Linear Accelerator Center
Stanford CA

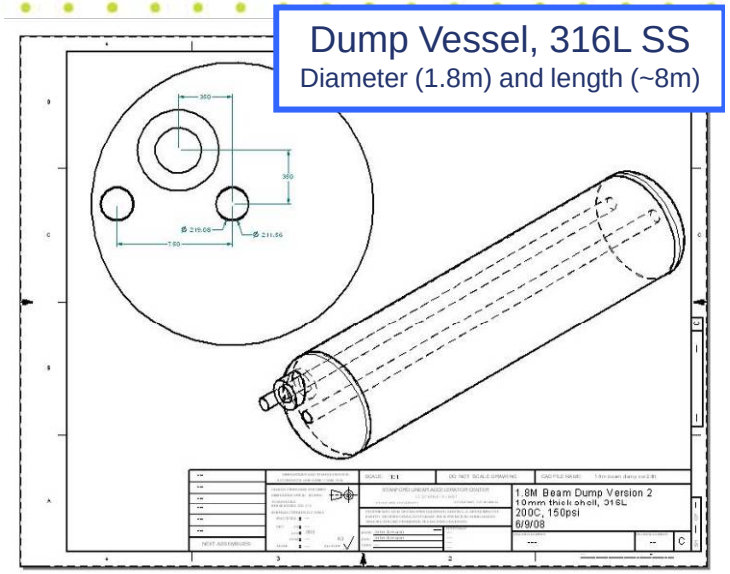
P. Satyamurthy, S.Pal, P. Rai, V. Tiwari
Bhabha Atomic Research Centre
Mumbai, India

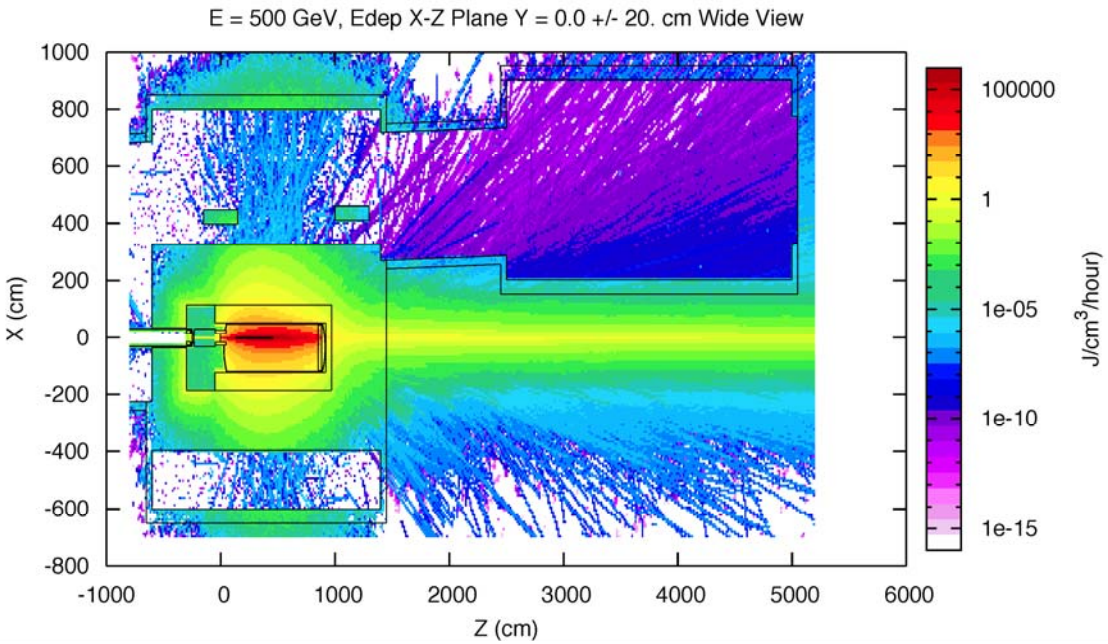


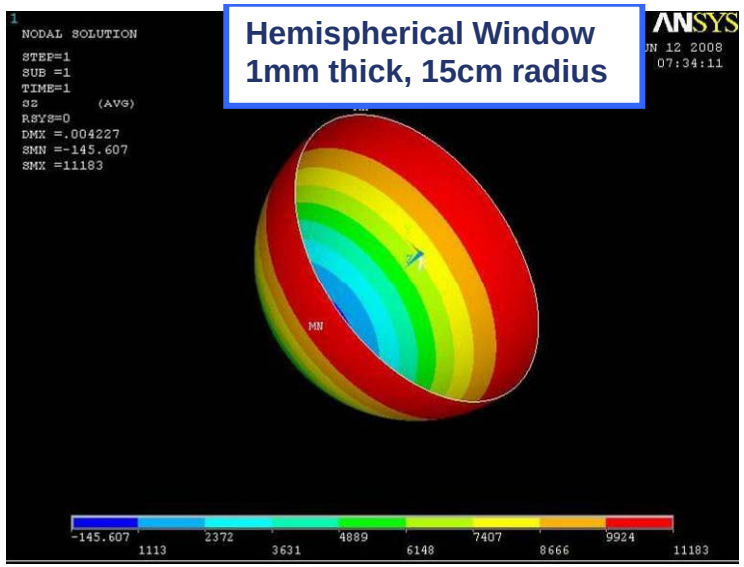
Dieter Walz, Ray Arnold, Satyamurthy Polepalle (BARC, India), John Amann, at SLAC beam dump area (February 2008)

Beam dump design progress







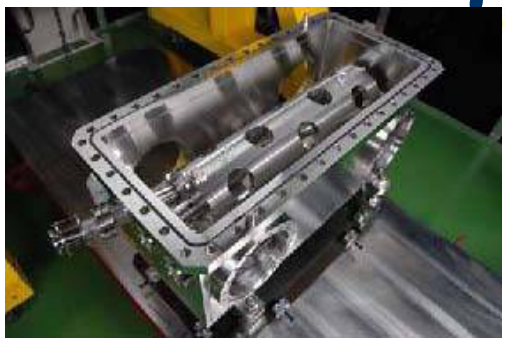


R&D plan for γγ

Public Note / ACCDT / BDS LLNL-TR-403955 ILC-NOTE-2008-043

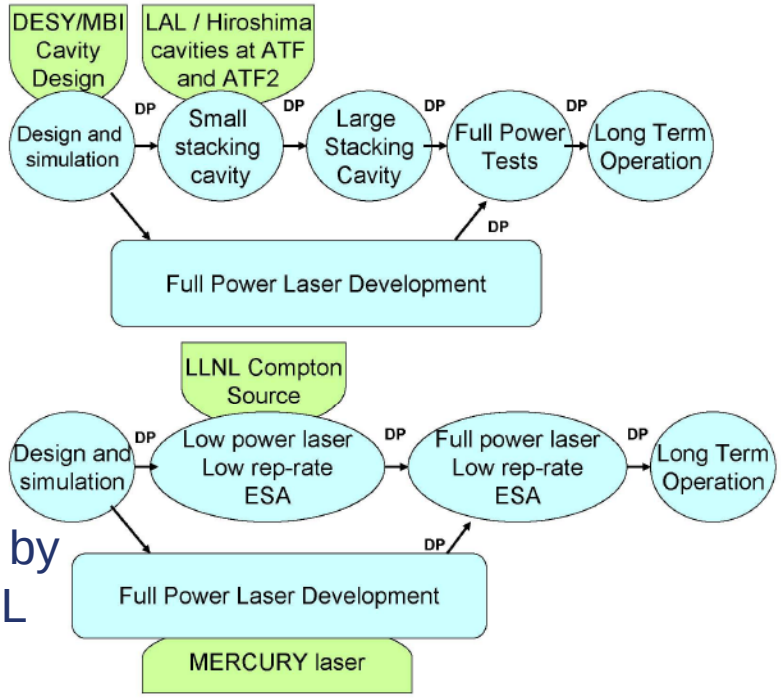
Photon Collider Technology Readiness and Near Term Plans

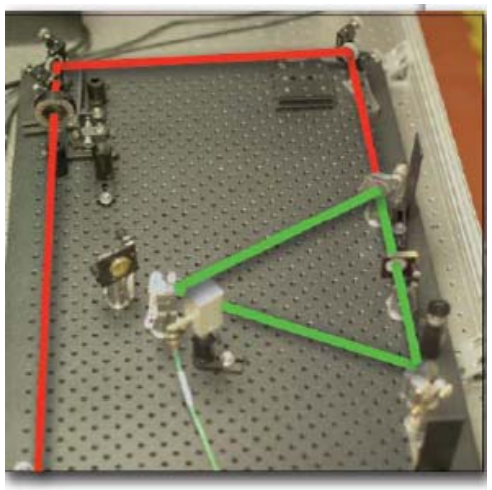
Gronberg, J. ; Omori, T. ; Seryi, A. ; Takahashi, T. ; Telnov, V. ; Urakawa, J. ; Variola, A. ; Woods, M. ; Zomer, F.



Pulse Stacking Cavity
(R&D for Positron source KEK-LAL-Hiroshima-Waseda-Kyoto-IHEP)
enhancement: 300-1000,
tight motion tolerances

- Developed R&D plan based on step-wise approach and large natural synergies with e+ laser cavities R&D





RING (Recirculation Injection by Nonlinear Gating) Cavity LLNL
recirculation of a pulse ~50 times
compensation of circulated pulse decay

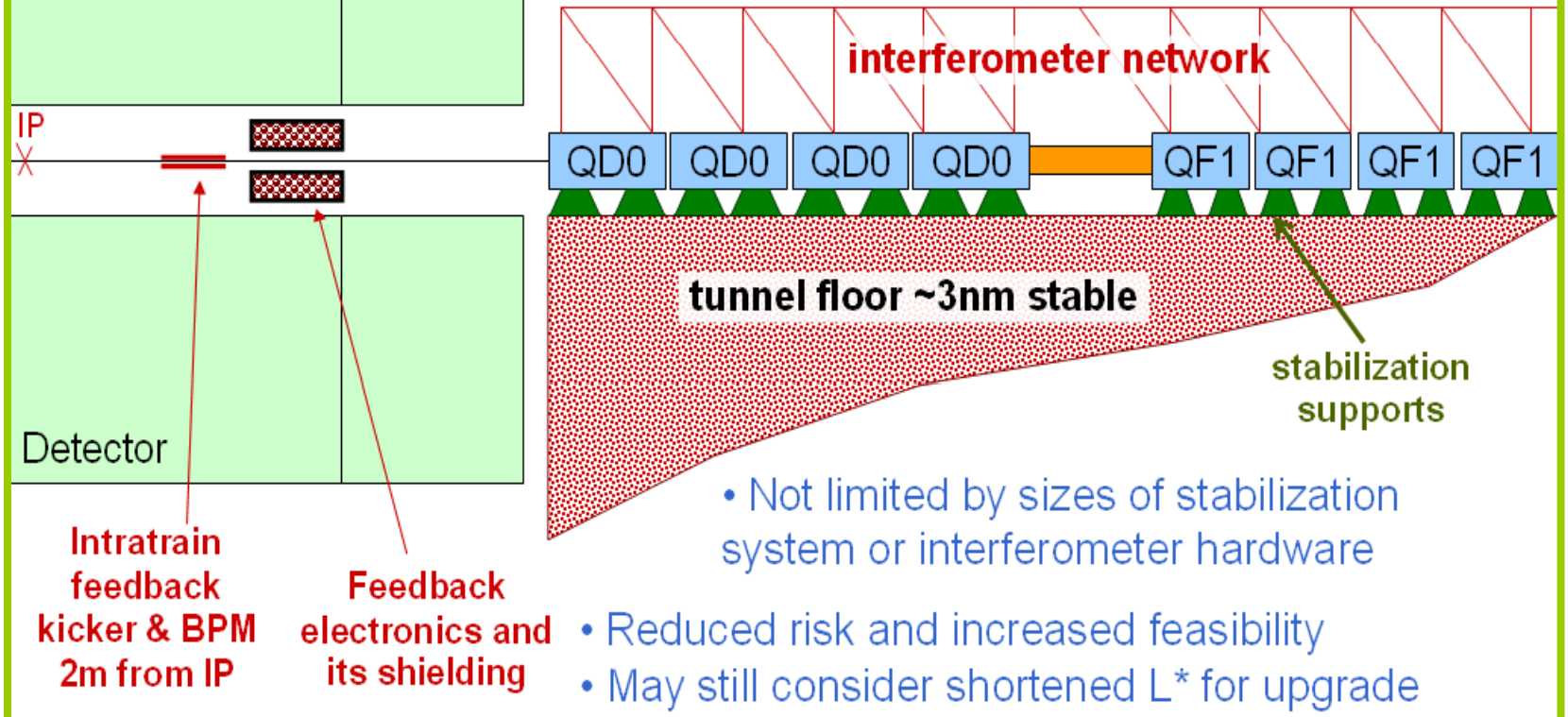
Exploration of ideas & tests for more performing machine

- Minimal machine may require tighter focusing at IP
- CERN/CLIC colleagues suggested to study squeezed y-beta* at ATF2 (0.025 mm instead of 0.1 mm nominal)
- Squeezed beta* study at ATF2 is one of example of strong synergy and mutual benefits of ILC-CLIC collaboration
- Such study may support
  - Test of high chromaticity FF, as in CLIC FF design
  - Smaller β^* for "New Low P" parameters of ILC
  - Lengthening L* for easier MDI
- Also evaluating if can test travelling focus at ATF2 (single beam)

- Exploring Volume Reflection radiation in bent crystals as a phenomena to improve the collimation system of linear collider

Longer L*

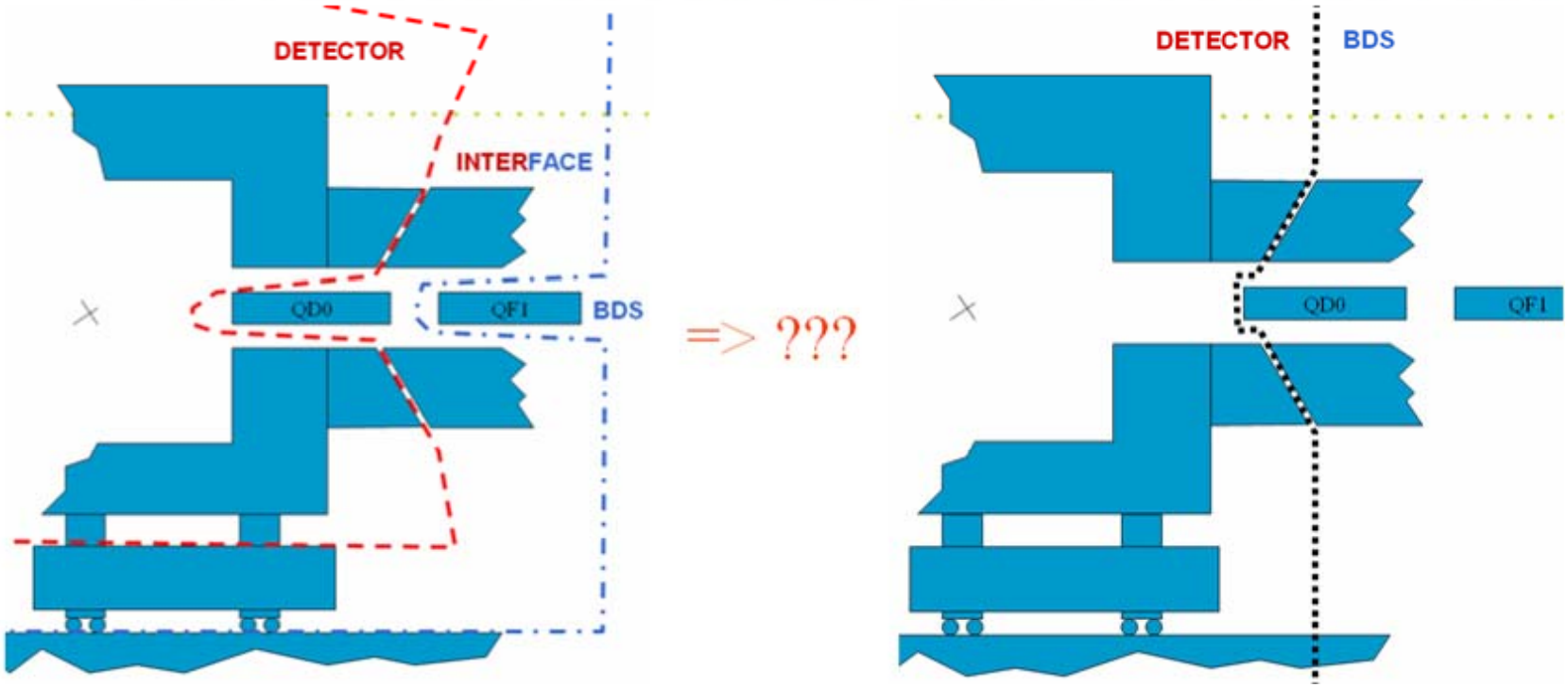
- Slower than 1/L* dependence of Lum => ↑L*
- Reduced feedback latency – several iteration of intratrain feedback over 150ns train
- FD placed on tunnel floor, which is ~ten times more stable than detector – easier for stabilization



- Not limited by sizes of stabilization system or interferometer hardware
- Reduced risk and increased feasibility
- May still consider shortened L* for upgrade

- Study prompted by the CLIC FD stability challenge (< 0.2nm)
- Double the L* and place FD on a stable floor
- Initial study show that L*=8m optics is possible (CLIC08 workshop)
  - » Some (maybe tolerable) impact on luminosity is still unavoidable

Longer L* → Simplified MDI?



- If doubled L* is feasible and acceptable then the MDI may be simplified tremendously
  - » and cost is reduced – do not need two extra sets of QD0
- An option of later upgrade for shorter L* may always be considered
- Has to be studied further

Conclusion

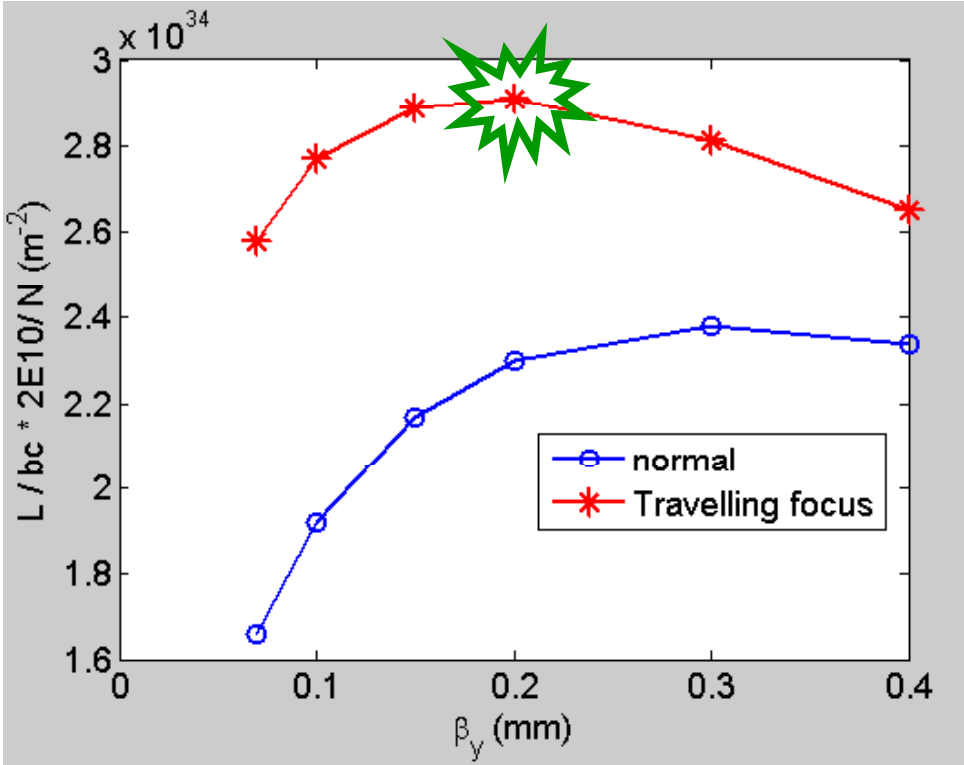
- The BDS group, in TDP phase, will focus on several key areas
- MDI work is one of the main focus points
- Planned work expected to make significant contribution to TDP efforts on reduction of cost, risk and increase of machine performance

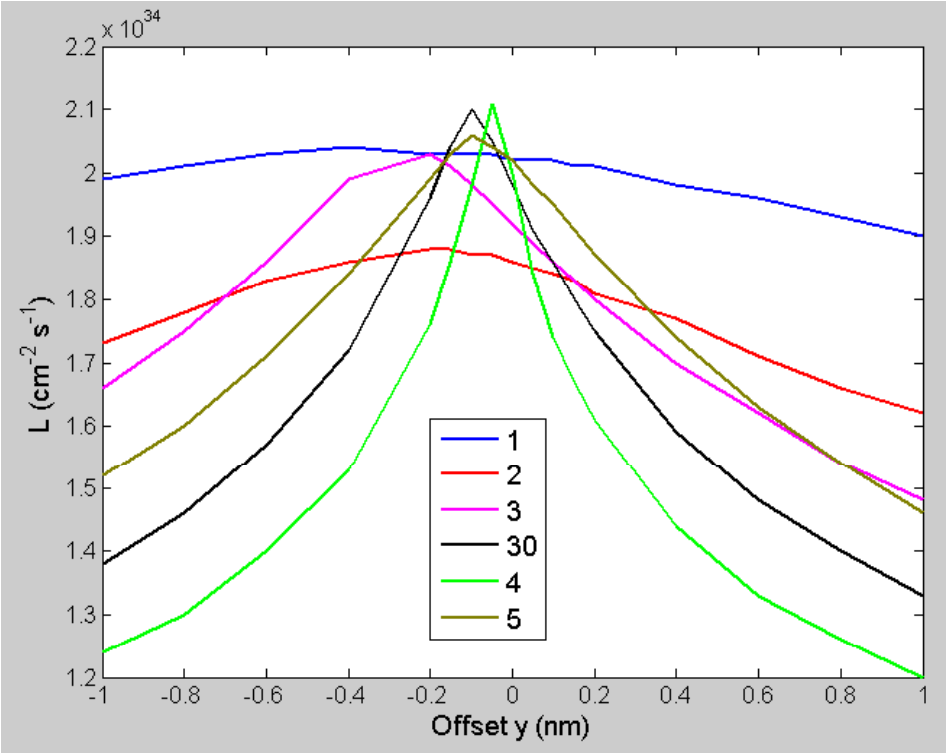
Acknowledgement

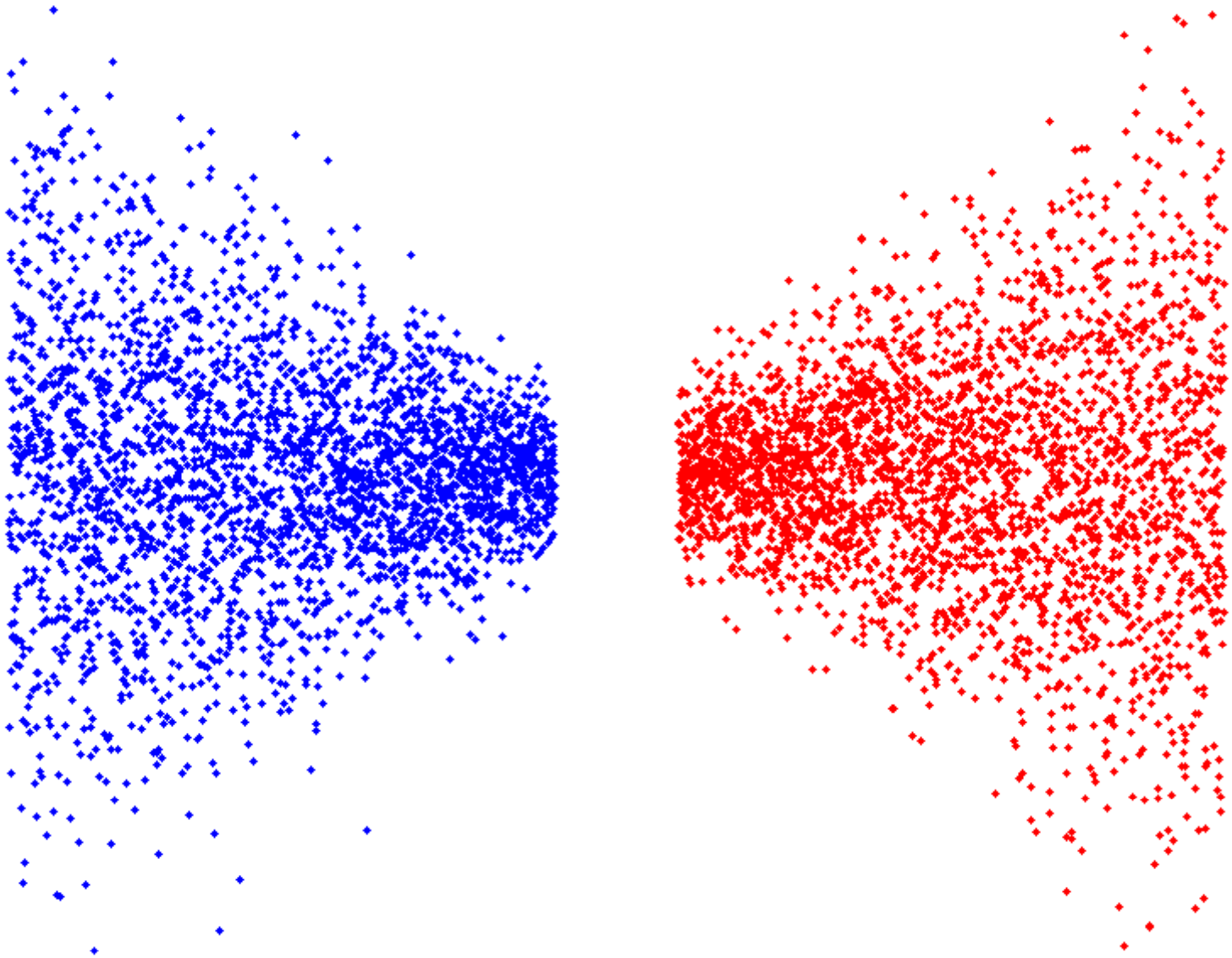
- To many colleagues in BDS design group and Detector groups

Extra slides

Case 3: better Low P, with TRAV_FOCUS





- In travelling focus [V.Balakin, 2000], higher disruption is needed for the bunches to keep focusing each other
- It then produces higher sensitivity to offset of the beams
- Operation of intratrain luminosity optimization is more challenging

Case 4: even Low P, TRAV_FOCUS, FLAT_Z