ILC Crab Cavity

Overview and requirements

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SLAC

on behalf of ILC Beam Delivery and Crab-Cavity design teams

Joint BNL/US-LARP/CARE-HHH Mini-workshop
on Crab Cavities for the LHC

25-26 February 2008

Brookhaven National Laboratory

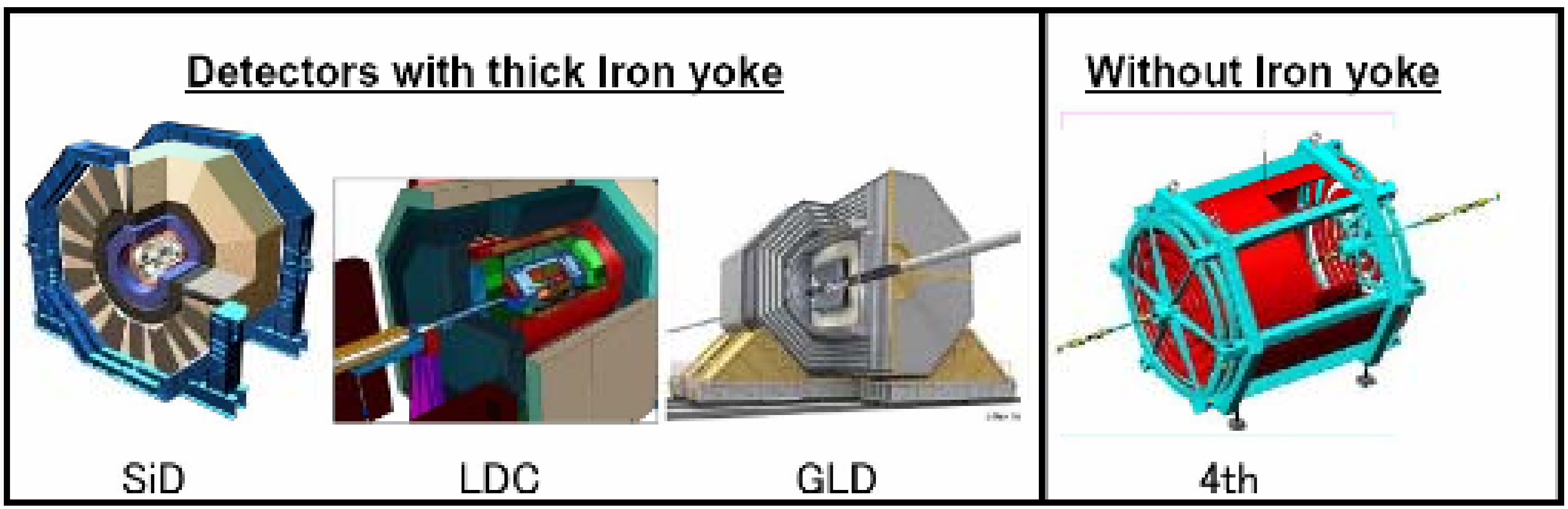
Goal of the talk

- Outline requirements for ILC crab cavity
- Briefly describe history of configuration choice
  - small crossing angle & large crossing angle
- Discuss how other systems defined CC
  - location, collimation, beam-beam, feedback, etc
- Look for analogies with LHC

- => The hope that such discussion may cross-fertilize our work on **LC and LHC**

Typical IP parameters & detector size

- IP: $\sigma_{x/y/z}$~500nm / 5nm / 300µm, 2E10/bunch
  - **σ_x/σ_z ~ 1.5mrad**
- train: ~3000 bunches, 300ns apart, every 5Hz
- Final Doublet: L* 3.5-4.5m
- Detector size: half length ~6-8m



Crossing angles considered for LC

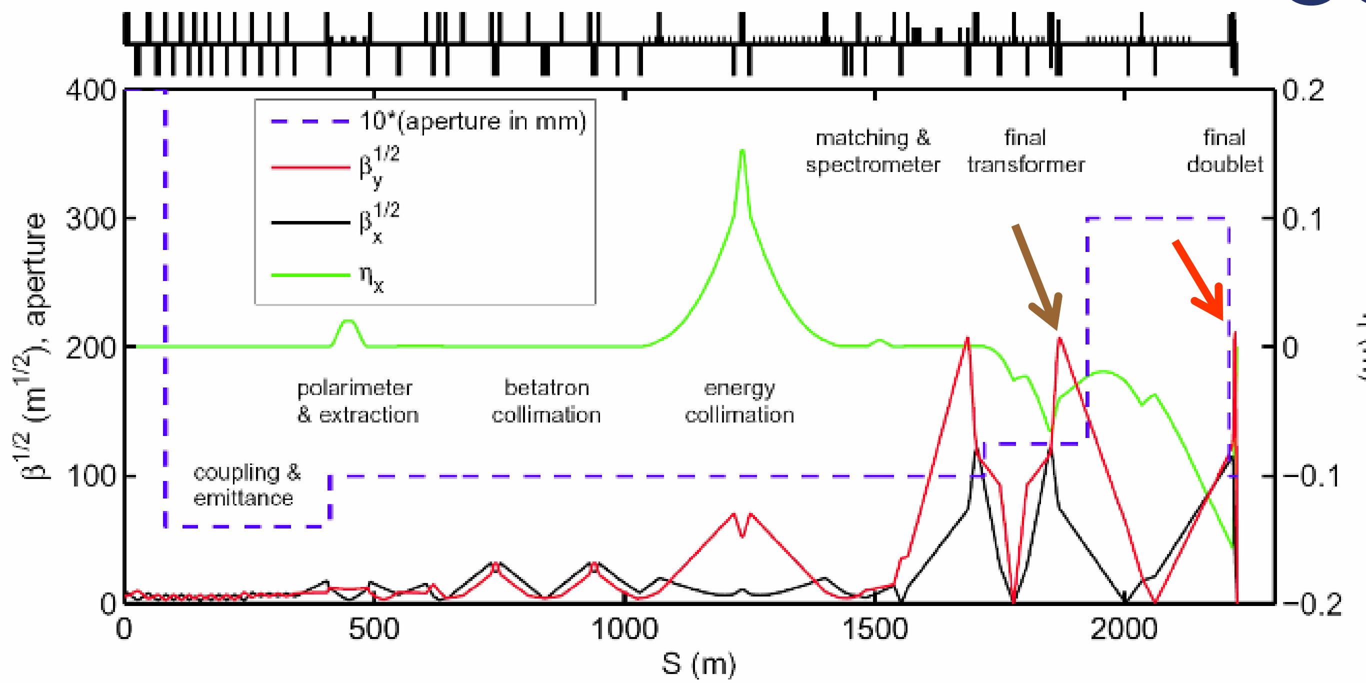
- 20mrad
  - **considered for NLC or CLIC**
- head-on
  - **considered for TESLA; difficulties with beam extraction after collision**
- 2mrad – "small crossing angle"
  - **considered as replacement of head-on scheme**
  - **Lumi loss w/o CC is 10-30%**
- 14mrad – "large crossing angle"
  - **reduced angle, provided by compact SC FD**
- 20mr & 2mr were ILC baseline in 2006
- Later baseline changed to 14/14mr and then 14mr

Technology and frequency

- With 1ms train, the SC CC was an obvious choice
- Frequencies 1.3, 2.6 & 3.9GHz were considered
- The 3.9GHz was selected for baseline, since
  - **easier phase stability, smaller voltage**
  - **more compact, ease space constraints**
  - **R&D on 3.9GHz CKM deflecting cavity at Fermilab:**
  - **clear aperture on the edge of acceptability**

3.9GHz cavity achieved 7.5 MV/m (FNAL)

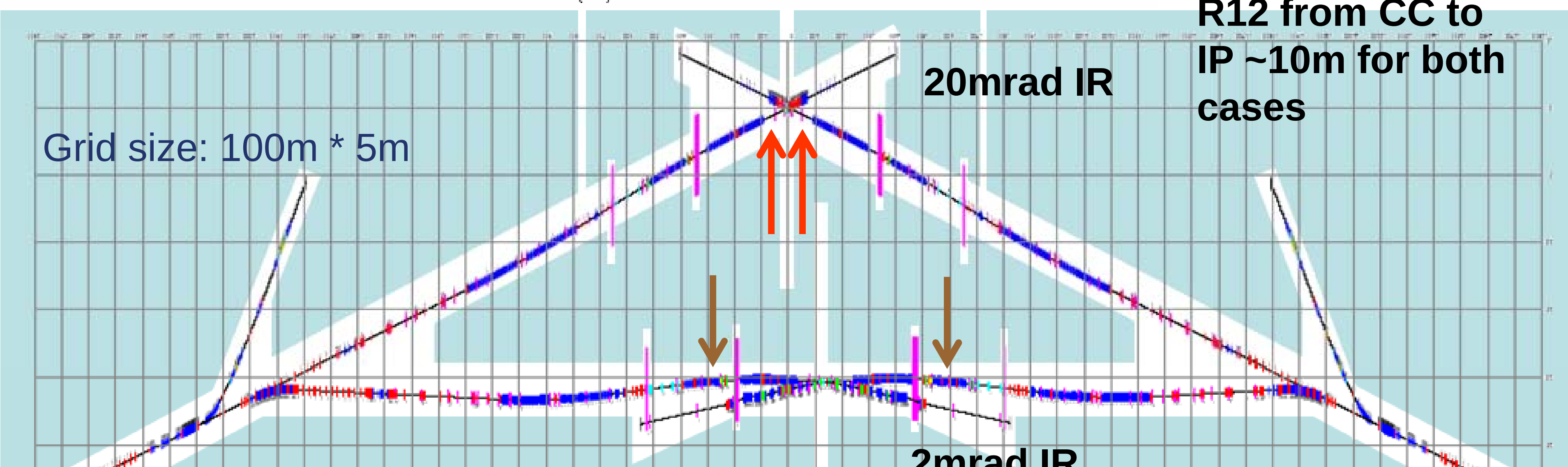
CC location



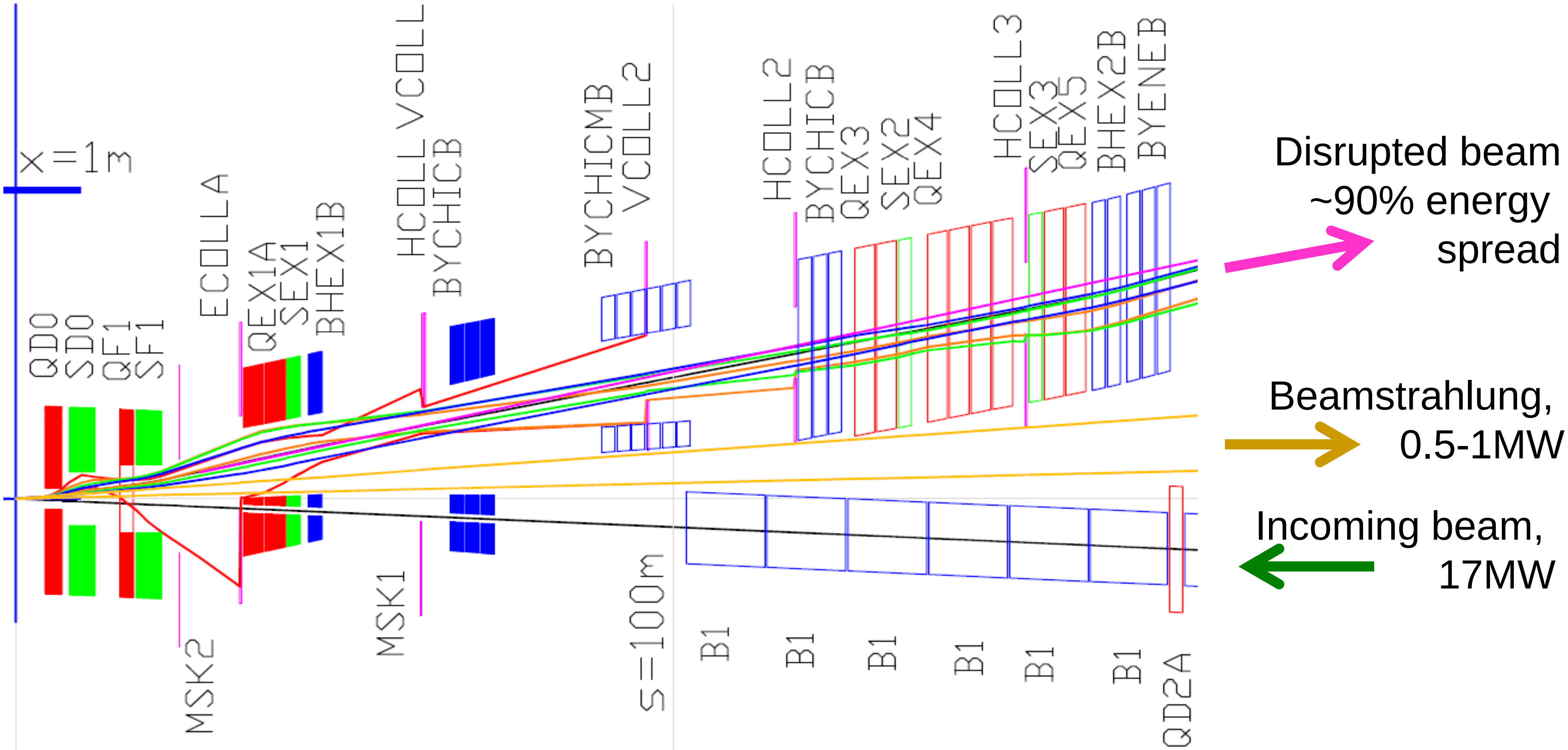
Just after Final Doublet for 20mrad

In aberr. correction section (~0.5km upstream) for 2mrad due to space limitation

R12 from CC to IP ~10m for both cases

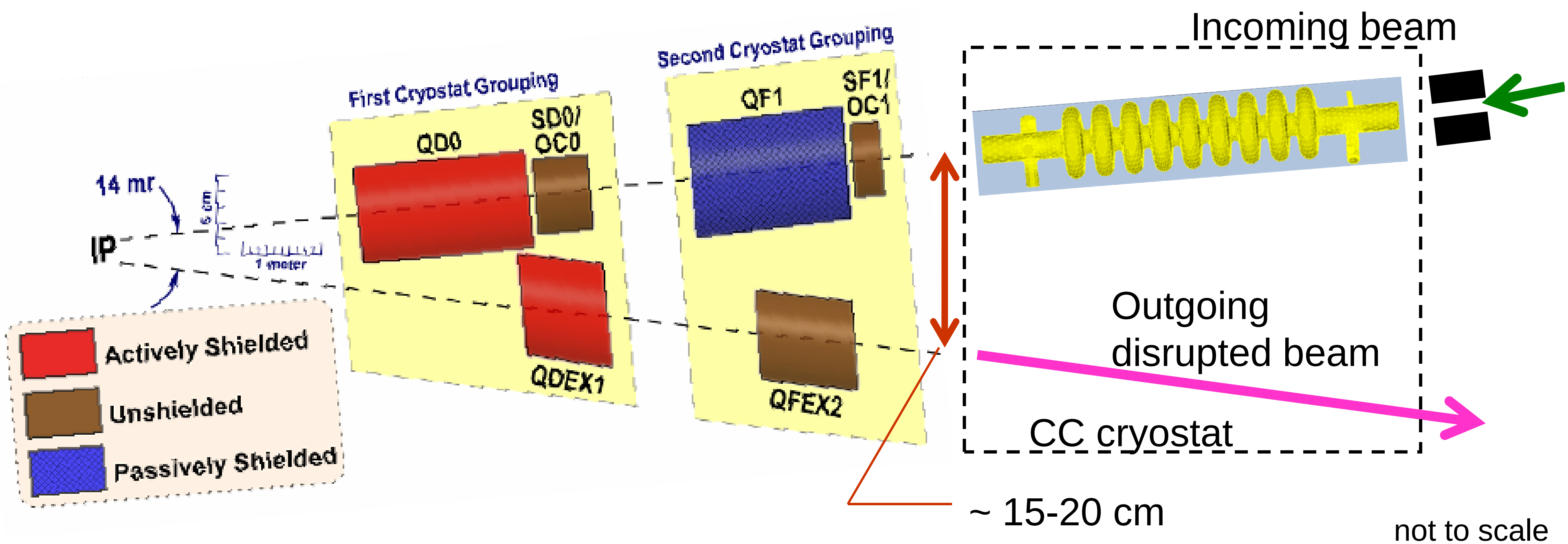


IP layout for 2mrad case & CC



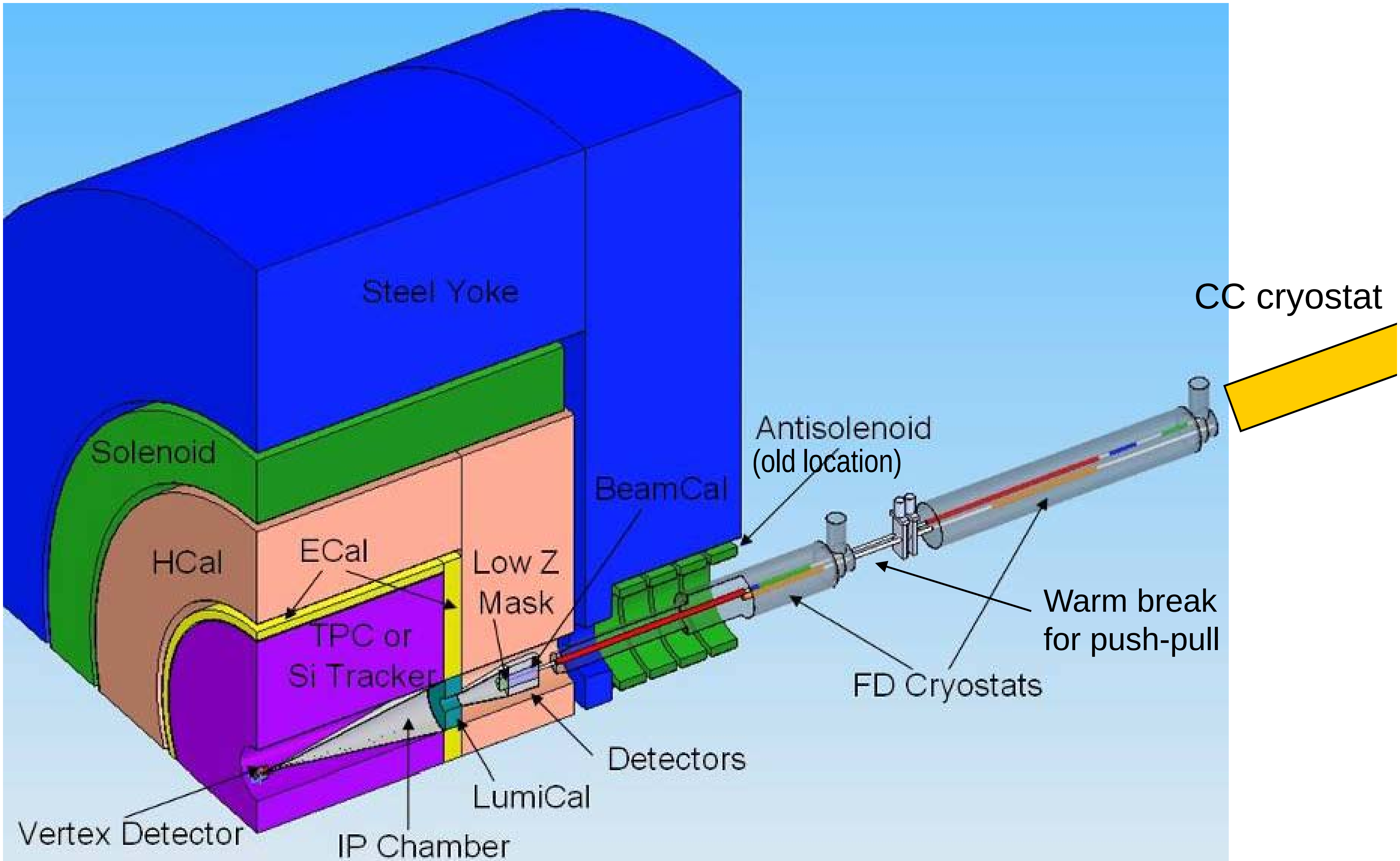
- Beams separated due to special design of warm QF1 with ~field-free pocket, septa, special magnets, etc
- No place to put crab cavity near IR, place it ~500m away

14mrad IR & CC

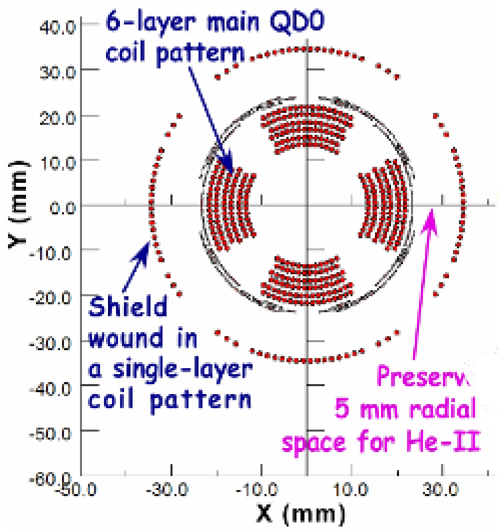


- CC just behind the Final Doublet
- FD aperture r~1cm => constraint on CC aperture and coupler penetration (to not limit collimation depth)
- Limit for couplers outputs oriented toward outgoing beampipe
- Outgoing beam (~17MW, highly disrupted) goes through CC cryostat

IR & CC

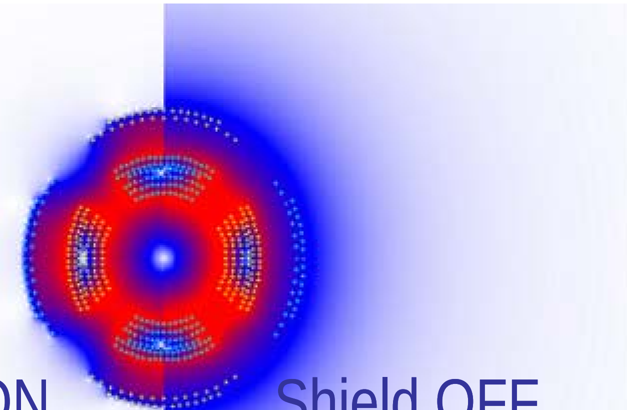


Steel Yoke
CC cryostat
Solenoid
Antisolenoid
(old location)
BeamCal
HCal
ECal
Low Z
Mask
TPC or
Si Tracker
Warm break
for push-pull
FD Cryostats
Detectors
LumiCal
Vertex Detector
IP Chamber



Actively shielded QD0

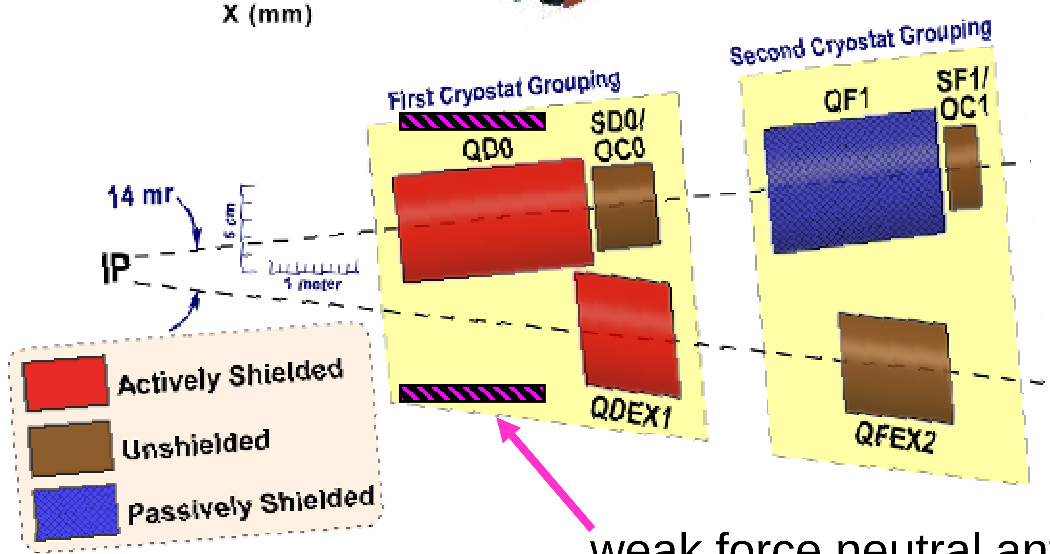
BNL



Shield ON

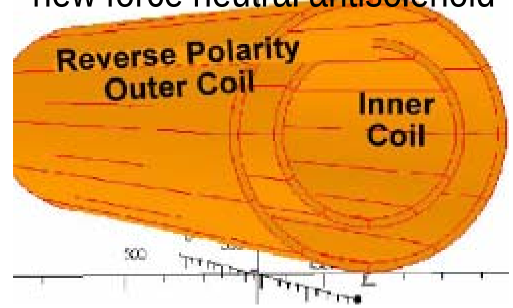
Shield OFF

Intensity of color represents value of magnetic field.



Two Coils; Different Radii

new force neutral antisolenoid



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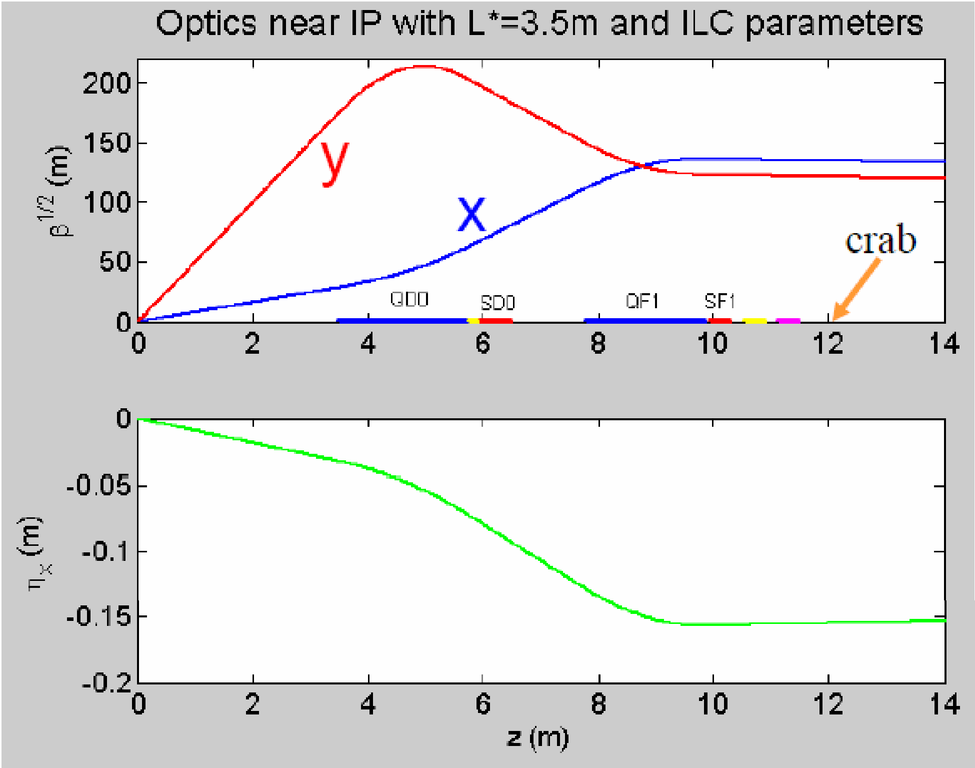
weak force neutral antisolenoid

- **Final doublet includes self shielding quads, sextupoles for chromatic corrections, octupoles for higher order aberrations, weak antisolenoid to correct coupling, dipole and skew corrections for orbit tuning, etc.**

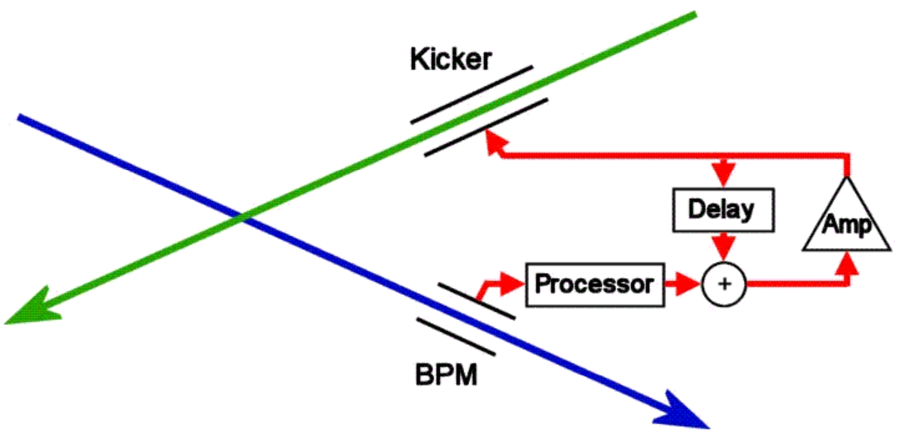
CC & FD nonlinearities

- Crab cavity produces the x’ kick, which creates x orbit through the FD sextupoles
- This will cause yy’ and other beam distortions at the IP, correlated with z
- For nominal parameters these distortions give <1% effect
- Longer bunch length, smaller β^*_y, etc., may increase this effect



CC and IP offset

- CC phase error=> IP offset: ~0.2σ => ~2% luminosity reduction => phase stability requirement
- IP intra-train feedback, acting within the train (~3000 bunches, 300ns apart) can capture trains, measuring first ~50 bunches, and the capture range ~1σ_x
- => Feedback can relax phase stab. requirements although we do not rely heavily on that



Conclusion

- During design of ILC IR, had studied crab cavity as one of subsystem among others (FD, collimation, feedbacks, etc)
- Although details differ, there are similarities between ILC and LHC
- Would like to continue looking into LHC-CC design, but also to look into LHC IR upgrade as a whole system, for mutual scientific interest

ILC Crab Cavity collaboration

- Cockcroft Institute :
  - Graeme Burt (Lancaster University)
  - Richard Carter (Lancaster University)
  - Amos Dexter (Lancaster University)
  - Philippe Goudket (ASTeC)
  - Roger Jones (Manchester University)
  - Alex Kalinin (ASTeC)
  - Lili Ma (ASTeC)
  - Peter McIntosh (ASTeC)
  - Imran Tahir (Lancaster University)
- FNAL
  - Leo Bellantoni
  - Mike Church
  - Tim Koeth
  - Timergali Khabiboulline
  - Sergei Nagaitsev
  - Nikolay Solyak
- SLAC
  - Chris Adolphson
  - Kwok Ko
  - Zenghai Li
  - Cho Ng
  - Andrei Seryi
  - Liling Xiao