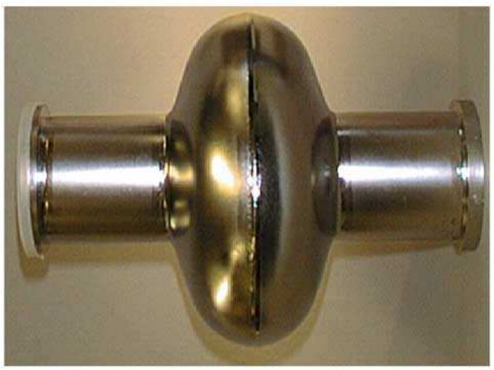
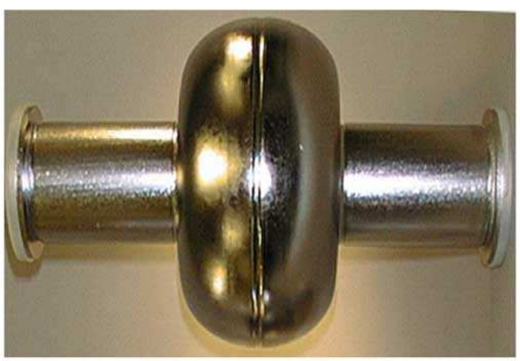
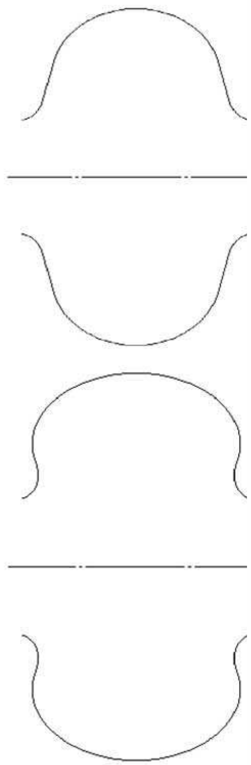
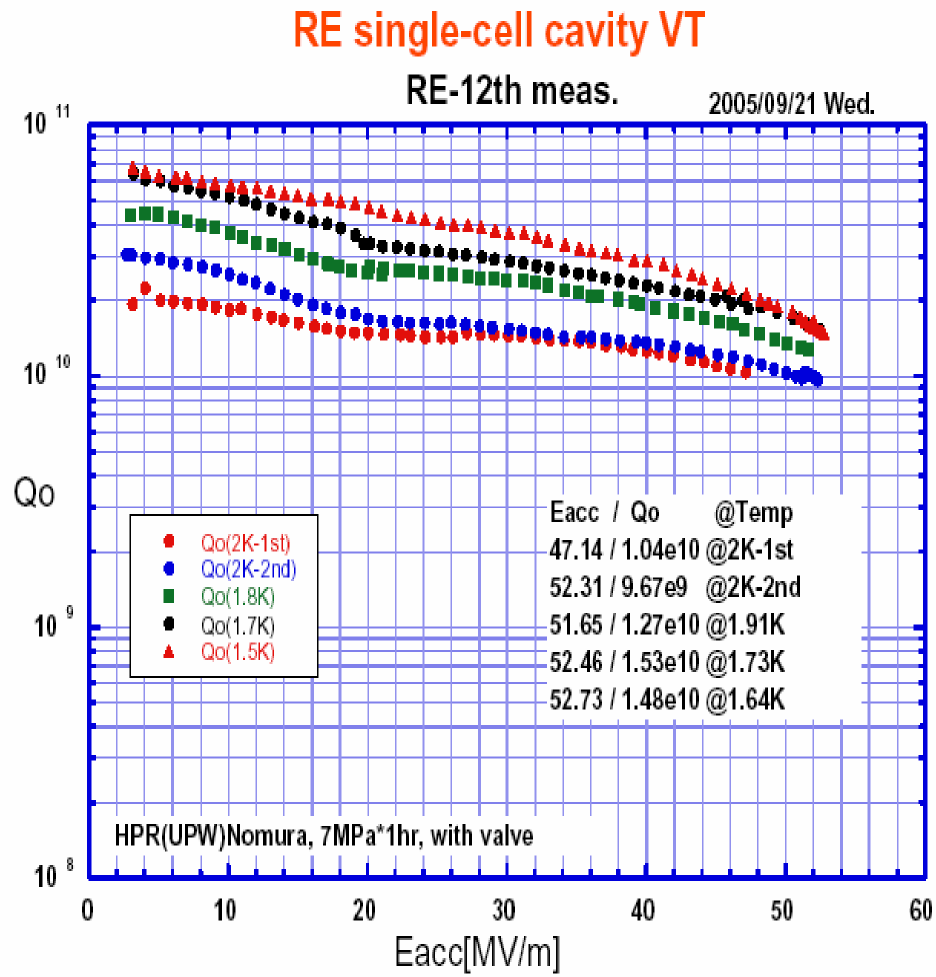
High field cavity studies for future linacs

- Re-entrant Shape Single Cell Cavity Reached 47 MV/m in May 05
- 2nd Re-entrant Cavity (built at Cornell) Treated and Tested at KEK Reached 50+ MV/m at KEK (Sept 05)









Nb-Cu Cavities for Neutrino Factories and Muon Colliders

200 MHz Nb/Cu Cavity built by CERN, tested at Cornell

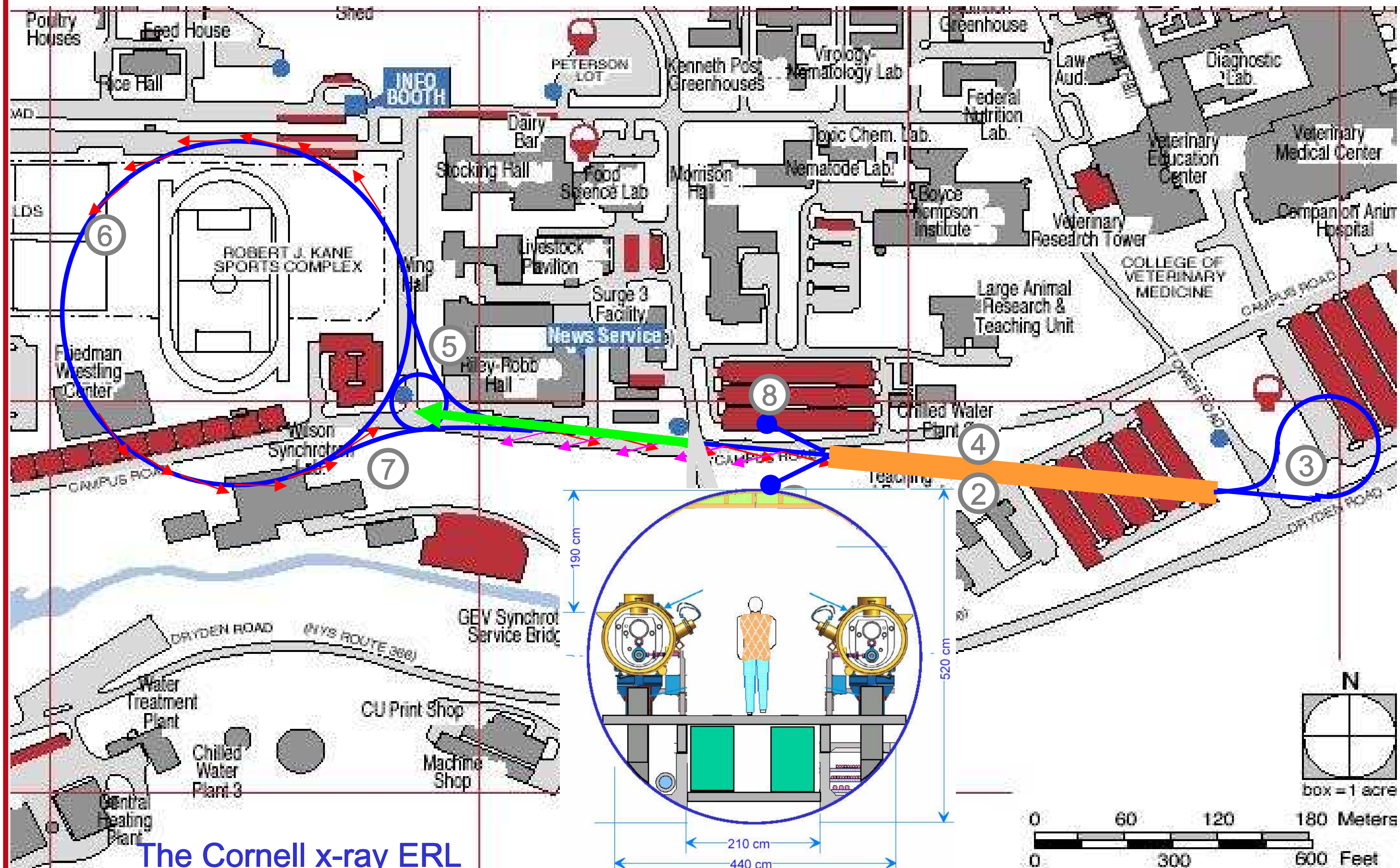
Largest SRF Cavity

Max Eacc = 11 MV/m

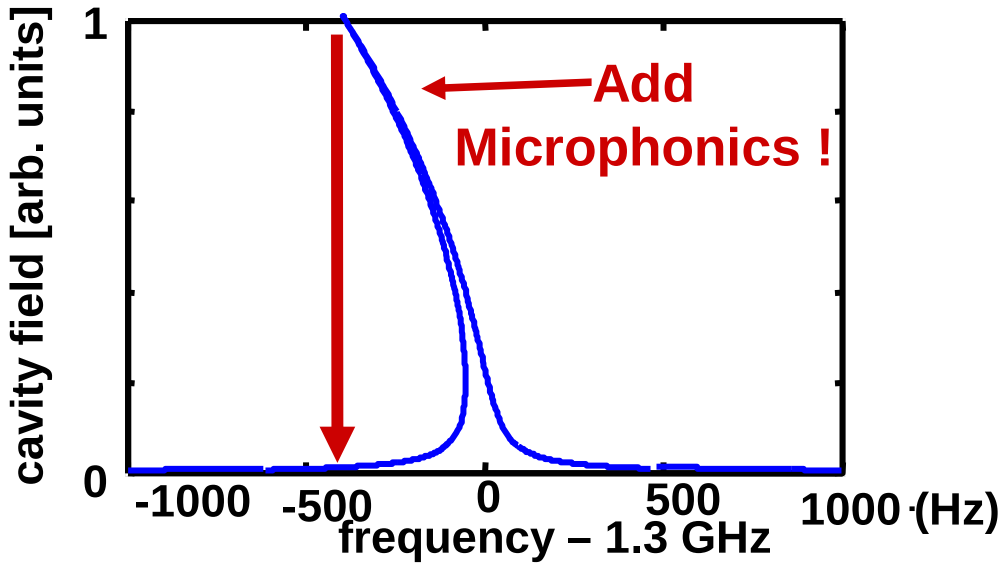
Next step: Spinning a 1mm Nb on 4mm Cu cavity by Accel, testing at Cornell.

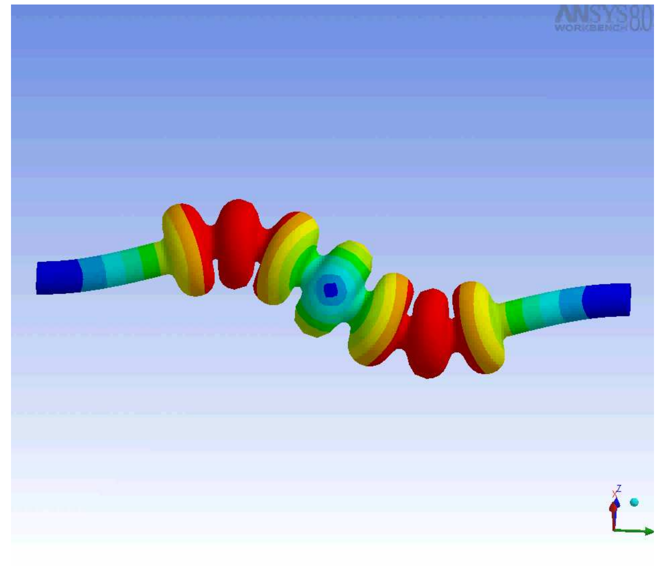
Nb/Cu cavities are relevant to ILC damping rings.

Energy Recover Linacs for colliders, light sources, and electron coolers



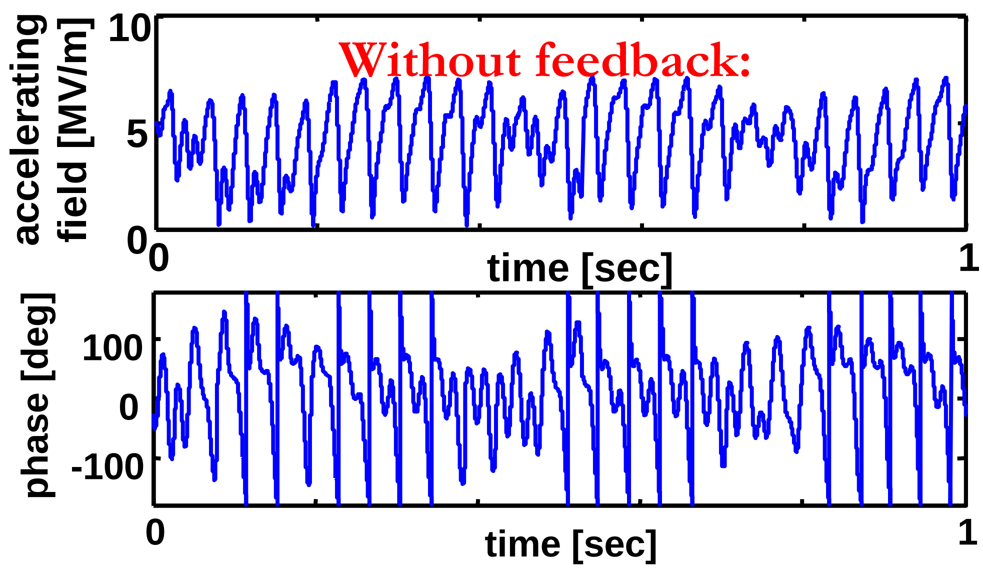
High loaded Q cavity control





- Run cavity at highest possible loaded Q for Energy recovery linac mode, i.e. without beam loading

- But: The higher the loaded Q, the maller the cavity bandwidth!



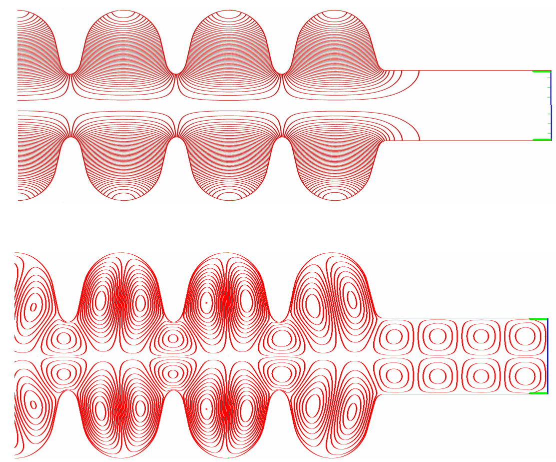
Higher Order Mode damping

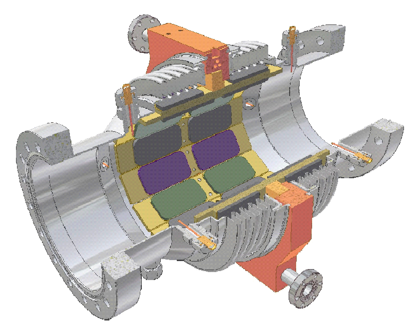
Other SRF studies

Cornell has expertise and interest in other SRF studies of long ranging relevance that could be pursued with adequate funding:

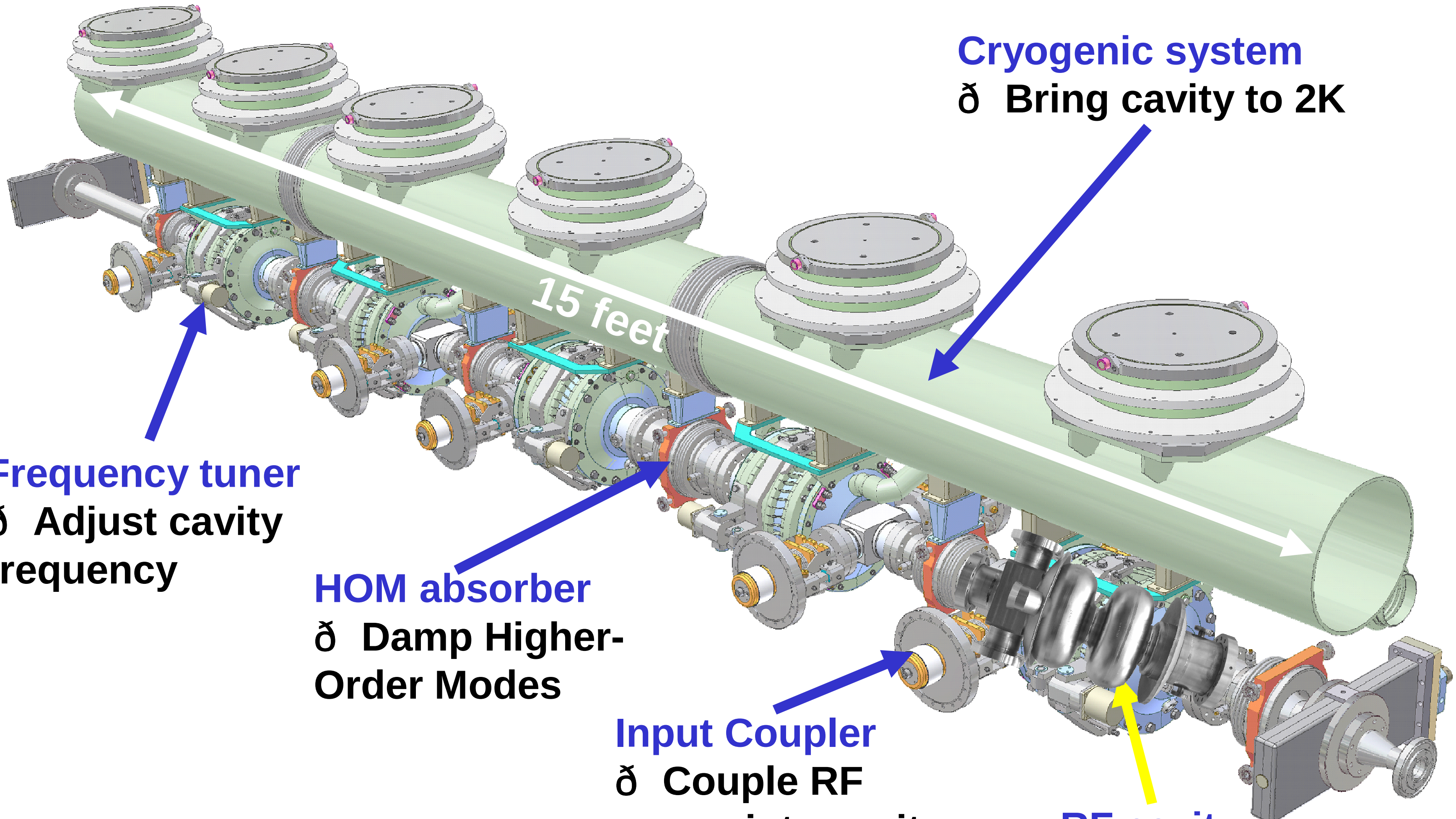
- Crab cavities: 1st design at Cornell, relevant for LHC upgrade,
- light sources, and any high luminosity future collider with crossing angle.

- New materials for SRF: Nb3Sn, NbN, Nb3Al, HiTSC
- Films on substrates, bonds on substrates
- Relates to all future uses of SRF





From Cavity to Cyromodule
e.g. The Cornell x-ray ERL injector linac



Cryogenic system
ð **Bring cavity to 2K**

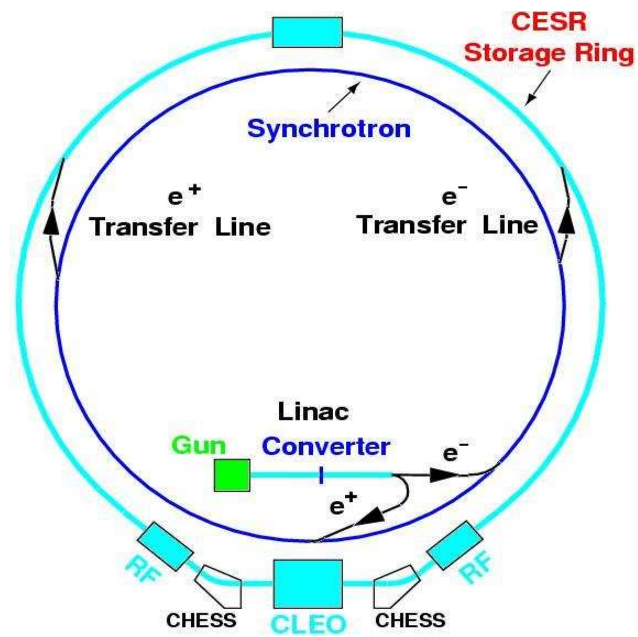
Frequency tuner
ð **Adjust cavity frequency**

HOM absorber
ð **Damp Higher-Order Modes**

Input Coupler
ð **Couple RF power into cavity**

RF cavity
Inside He vessel

Collider developments

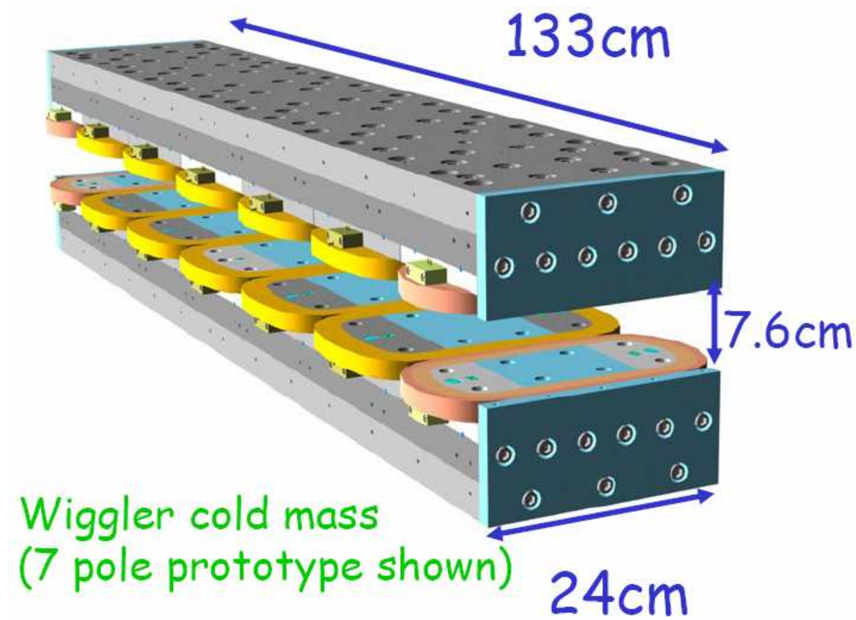


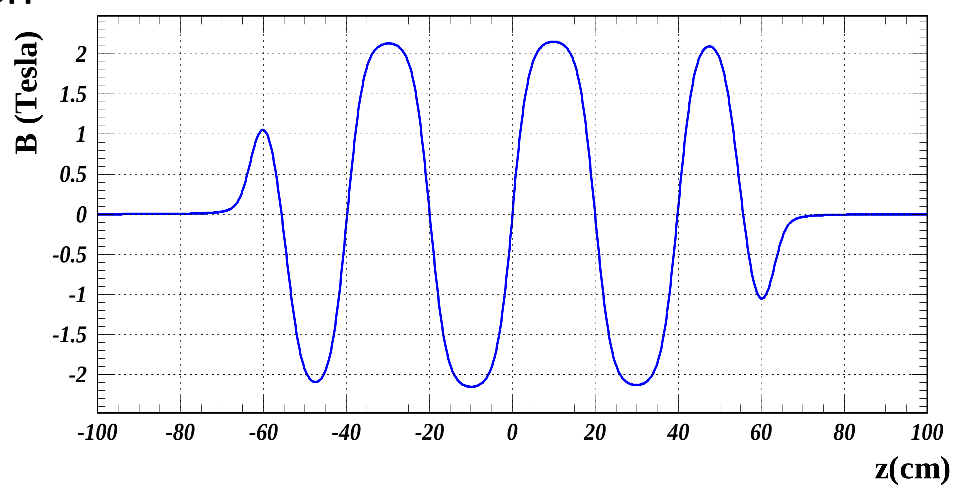
- Only wiggler dominated storage ring, 90% radiation from wigglers
  Requires advanced simulation of beam dynamics with nonlinearities, beam-beam force, ...

- Advanced interaction regions require accurate accelerator simulation benchmarked against measurements, e.g. beam-based alignment

Collider Developments

- Phase space mapping through wigglers required for simulation of dynamical effects
- Mapping is based on detailed 3D modeling using Vector Fields Opera
- Symplectic and fast representation of nonlinear motion in measured wiggler fields.

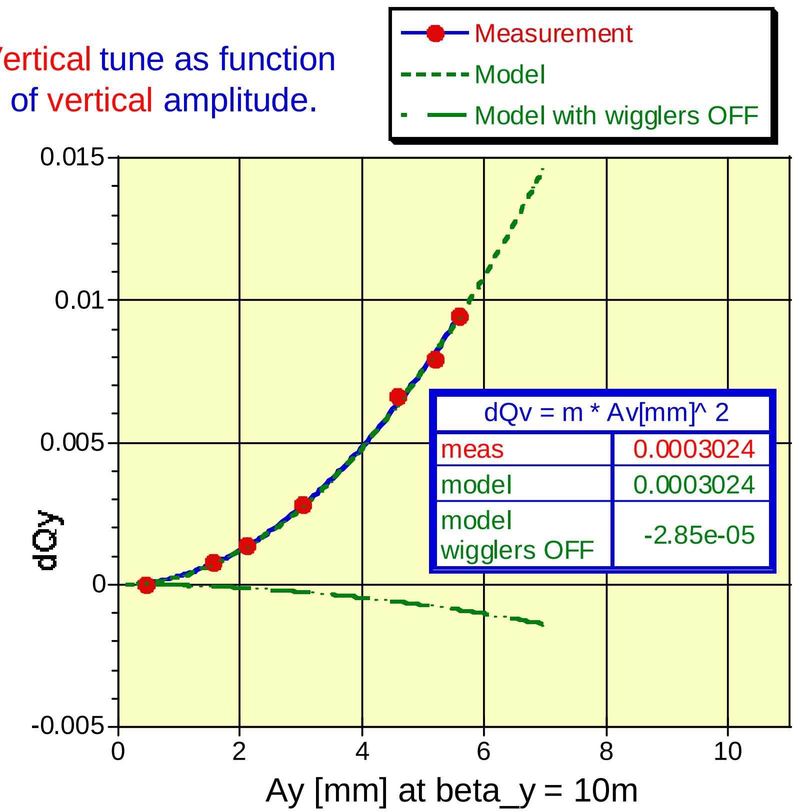




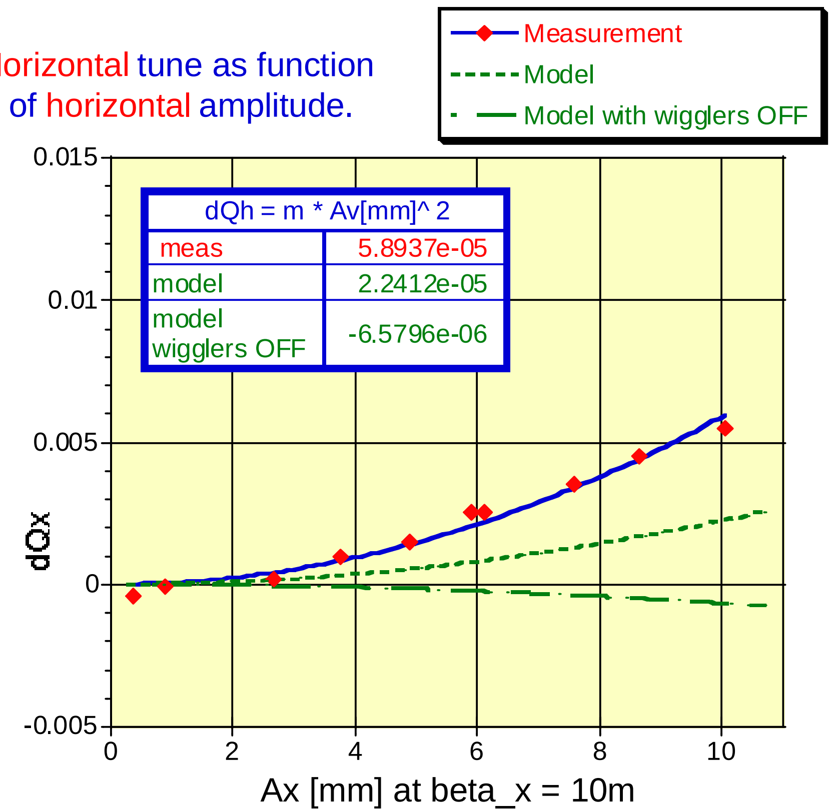
Characterization of Wiggler Octupole Components

Measured and calculated dependence of vertical/horizontal tune versus vertical/horizontal amplitude

Vertical tune as function of vertical amplitude.



Horizontal tune as function of horizontal amplitude.

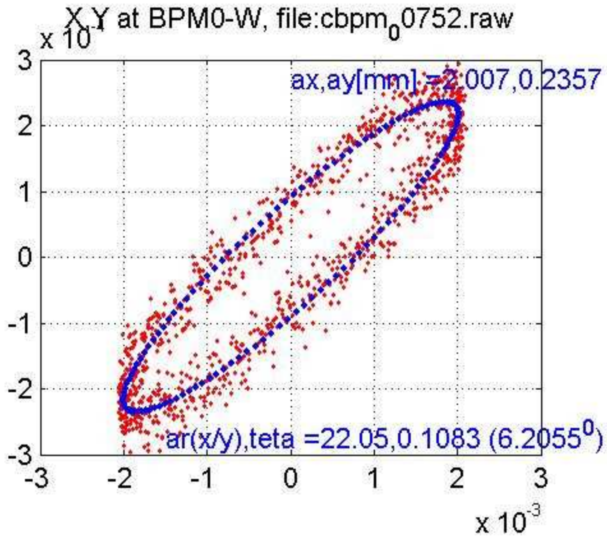


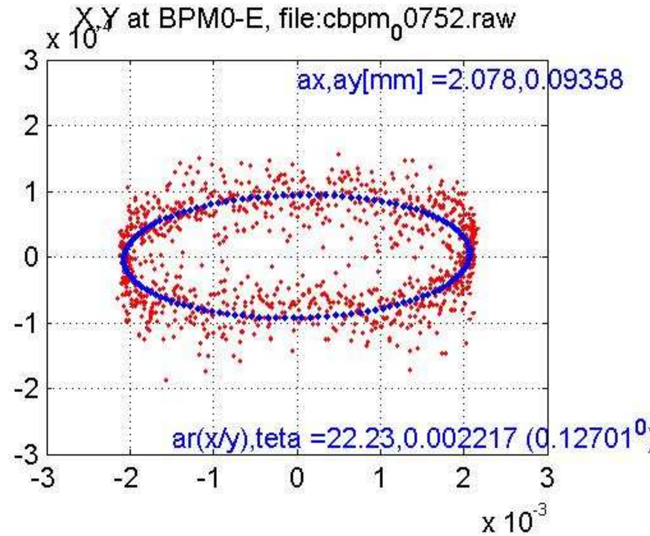
Bunch Instrumentation and DAQ Development

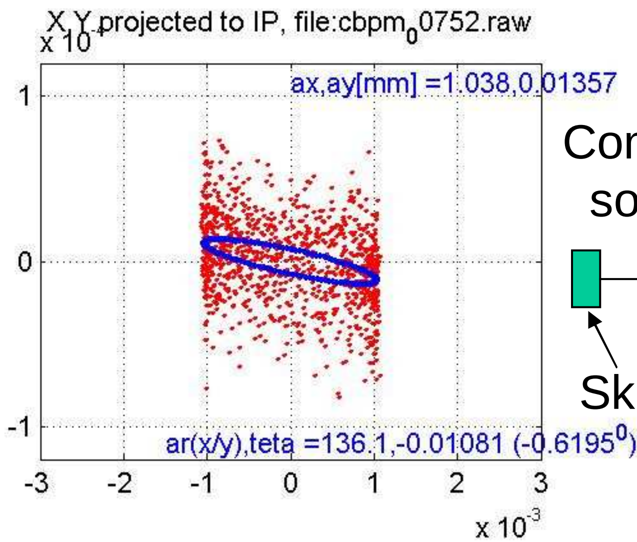
- **Instrumentation Support**
  - **General digitizer backbone for multiple instrumentation types**
    - 72 MHz digitizers
    - On-board DSP for data processing
    - CESR Field Bus and Ethernet communications
    - I/O ports for custom hardware interfaces
  - **Multiple Front-End Options**
    - Beam Position Monitors
    - Synchrotron Light Beam Profile Monitors
      - *Visible light*
      - *X-ray*
    - Fast Luminosity Monitor
  - **Core Capabilities**
    - Parallel digitization of bunches
    - Turn-by-turn operation
    - >10K turn memory buffer for each bunch
    - Tight integration to CESR timing system (eg, multi-module synchronization, triggering, shaker phase information, etc)

- **Data Acquisition System**
  - **Large data sizes require on-board processing capability**
    - High level language (C or C++) programming of DSPs
    - Memory mapping of DSP memory to control system for debugging and monitoring utilizing dual-ported memory chips
  - **Detector operation utilizes on-board processing capability**
    - Calibration
    - Gain and timing control
    - Extensive data processing implemented, eg:
      - *Local betatron phase calculation*
      - *Bunch tunes (FFT)*
      - *Timing scans*
  - **User interface**
    - Flexible multi-user interface so that many different programs can operate devices
    - Device/system-level locking to prevent collisions between multiple requests

Inter action region optimization







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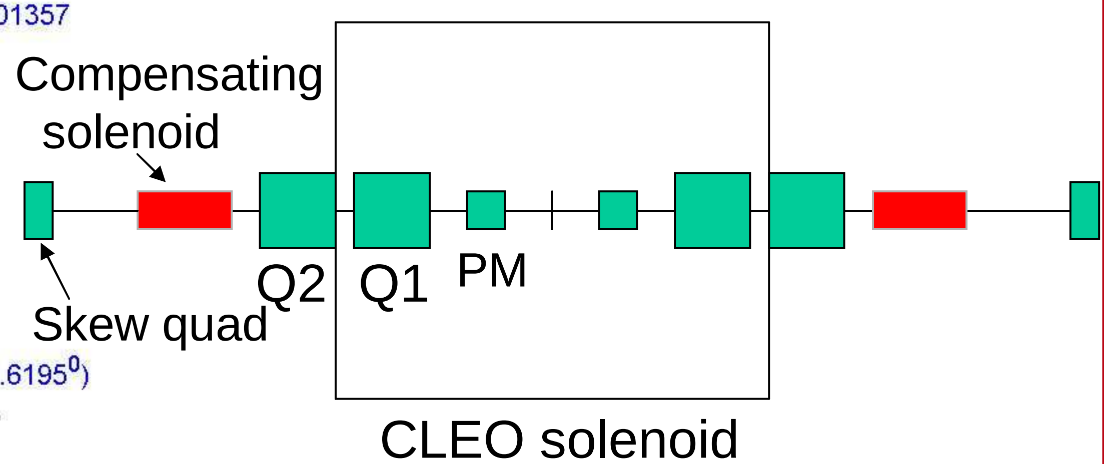
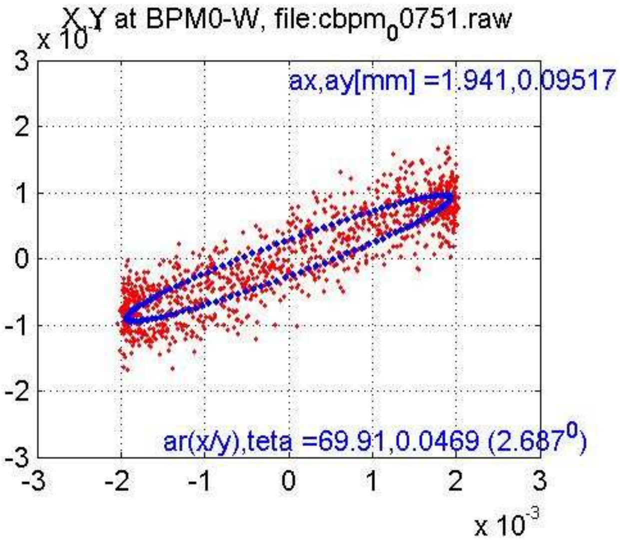
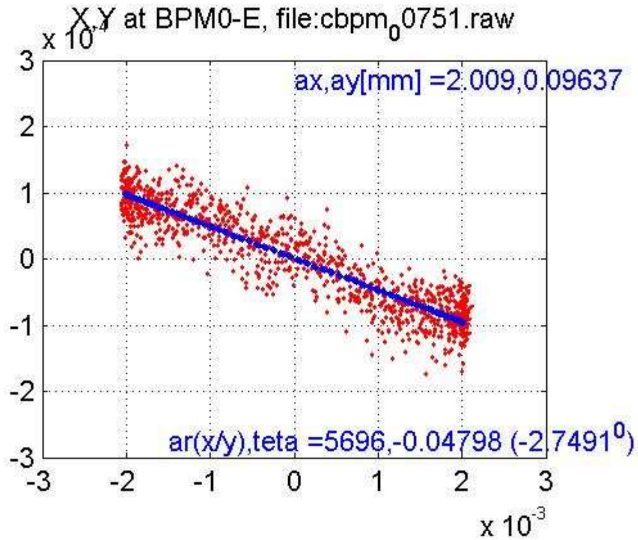
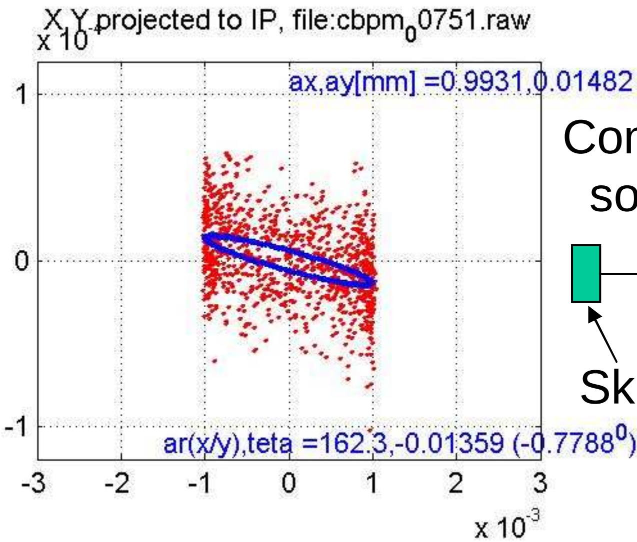


Inter action region optimization







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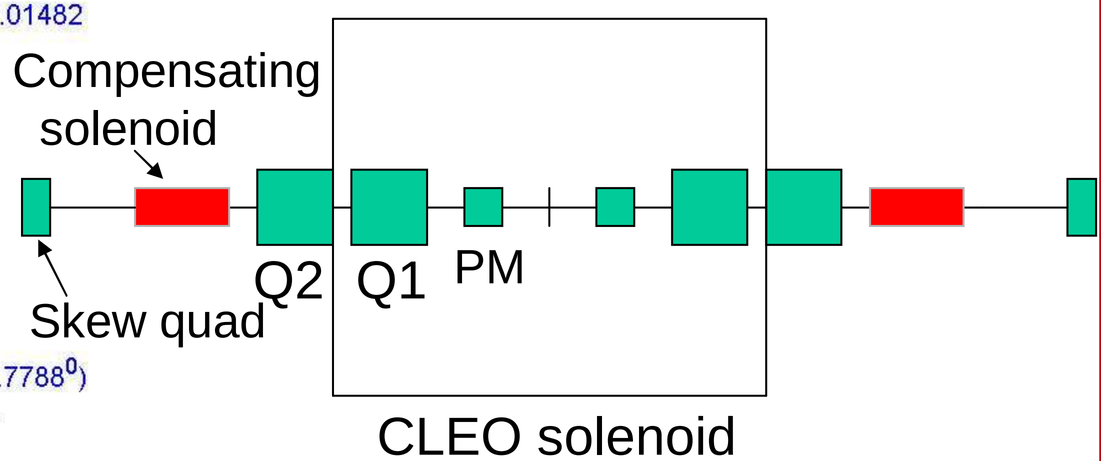
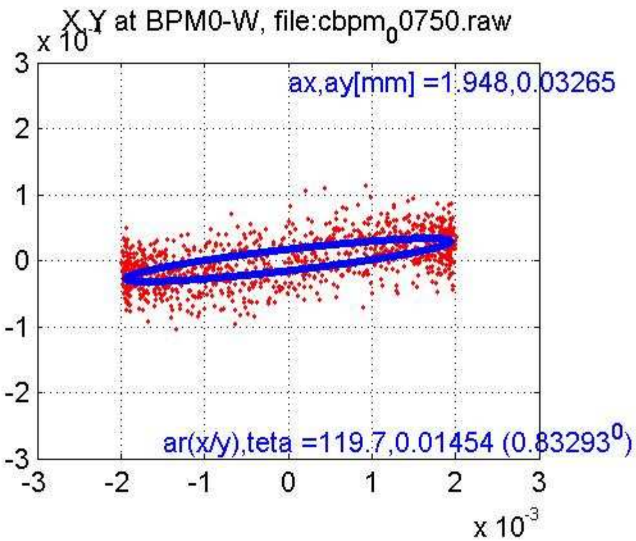
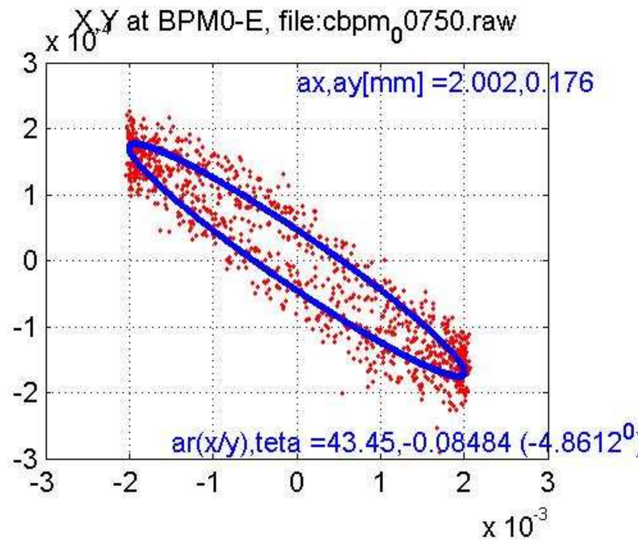
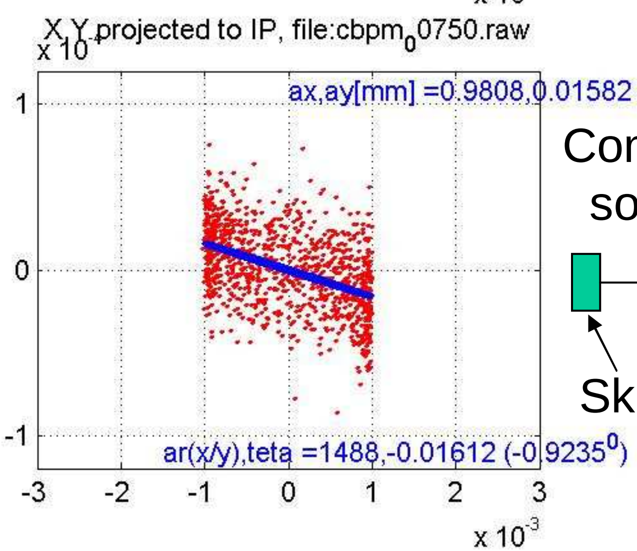
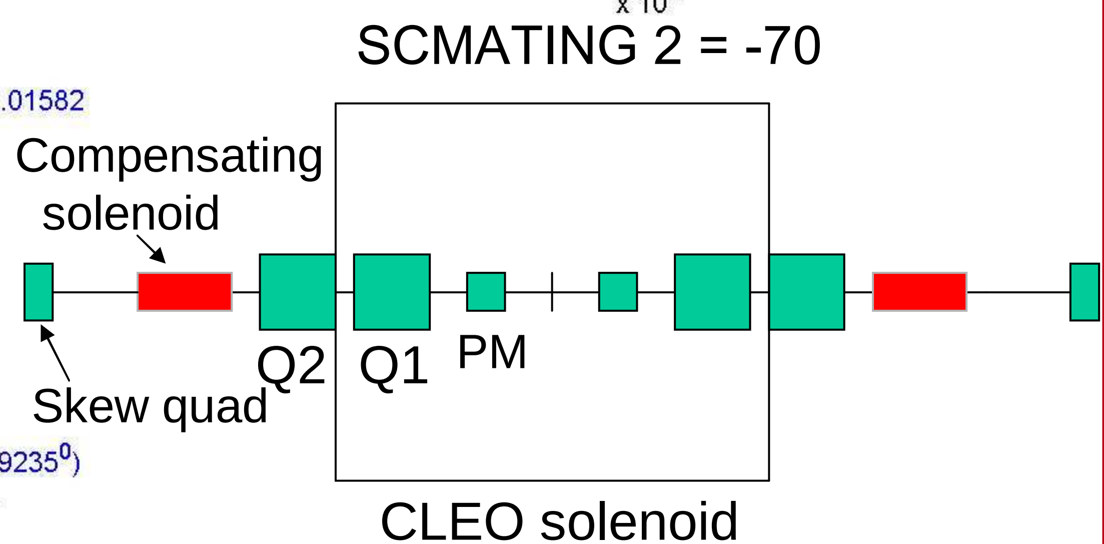


Inter action region optimization









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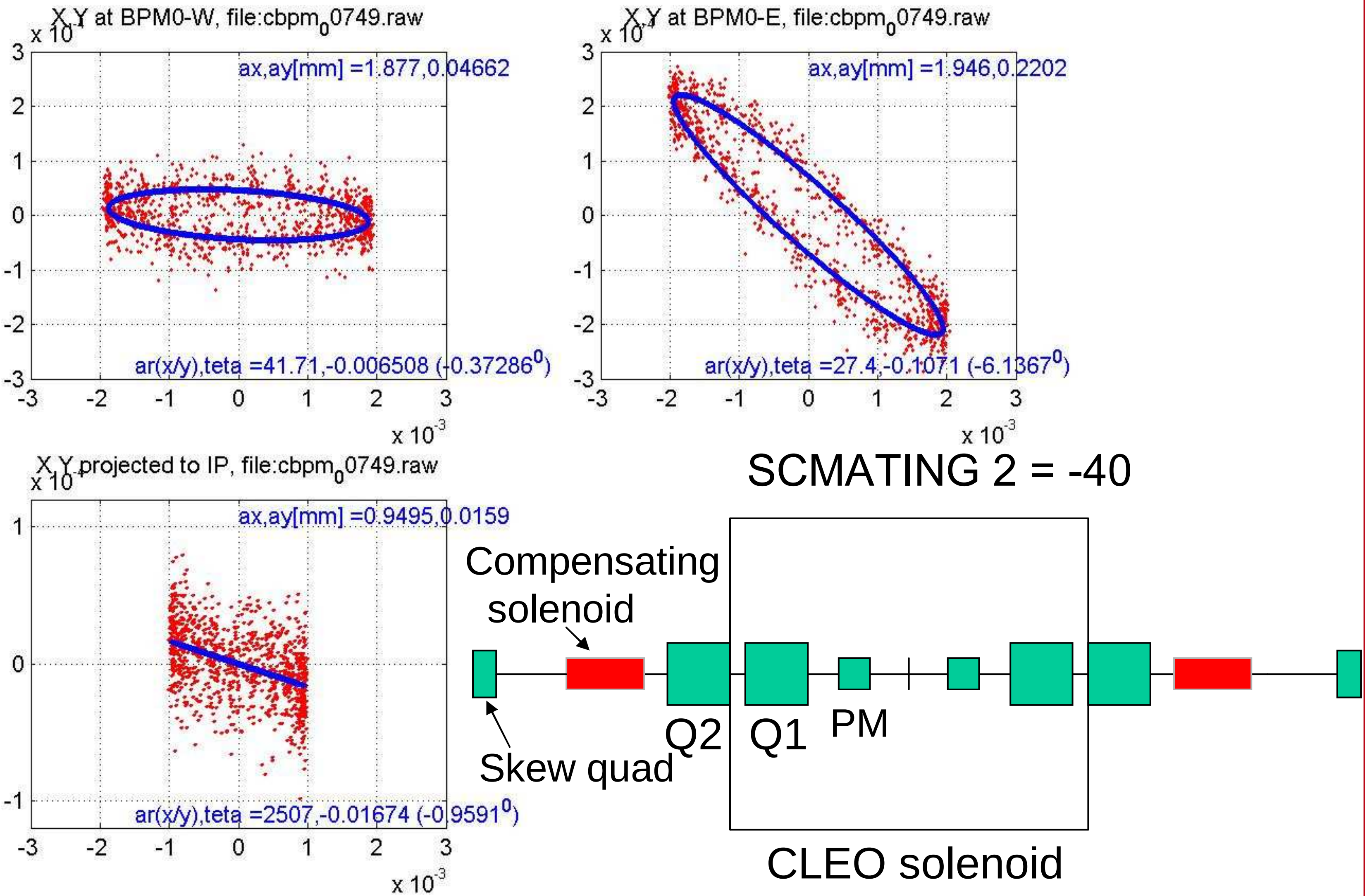
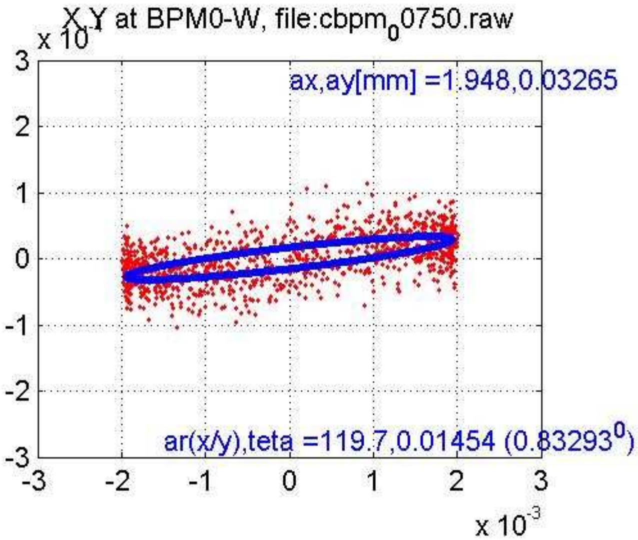
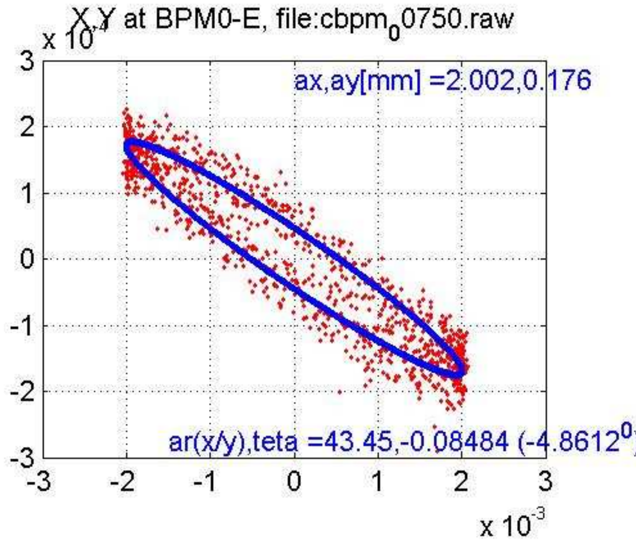


Inter action region optimization





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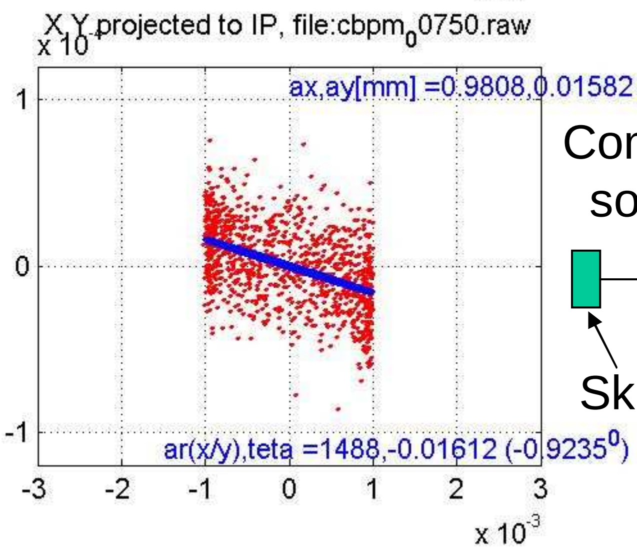

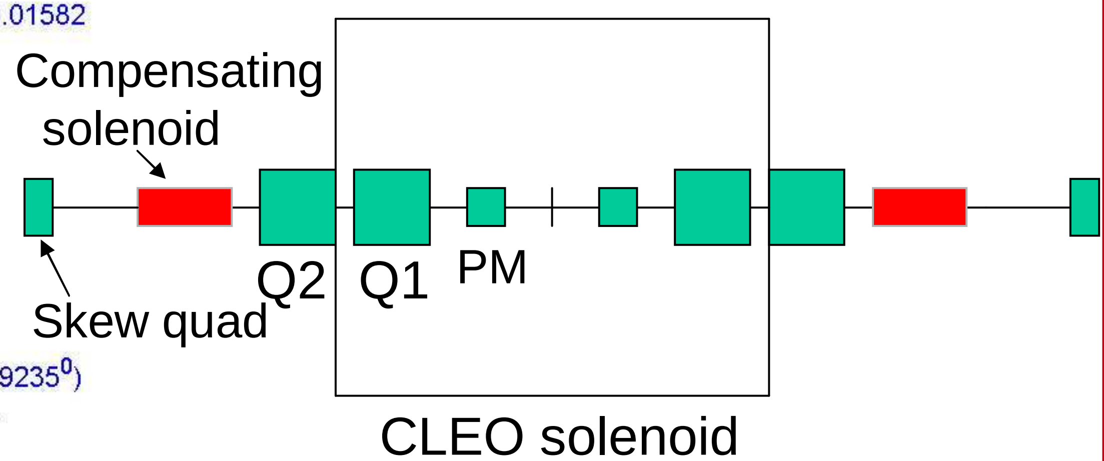

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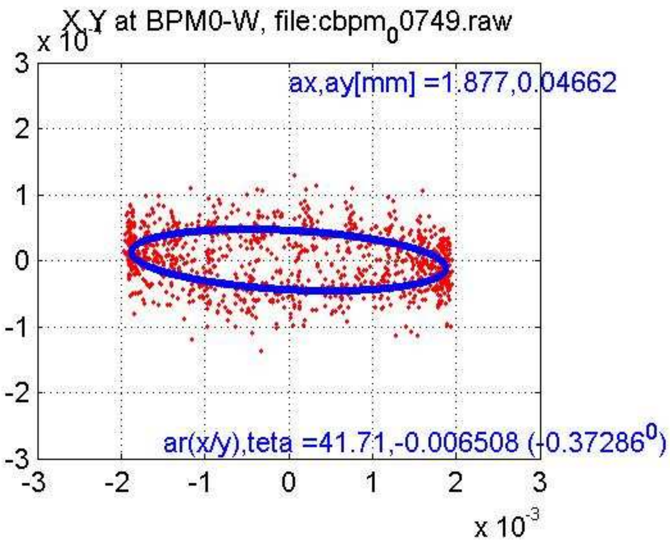

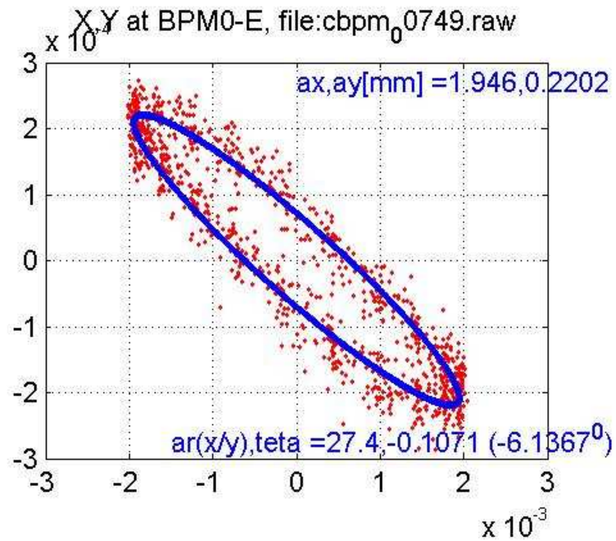

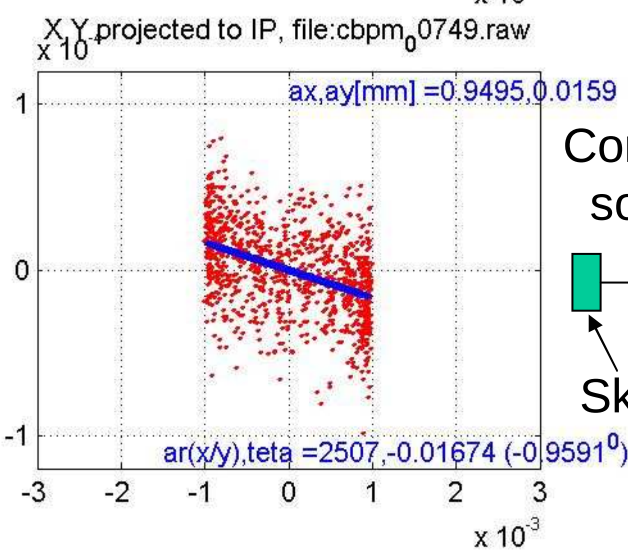

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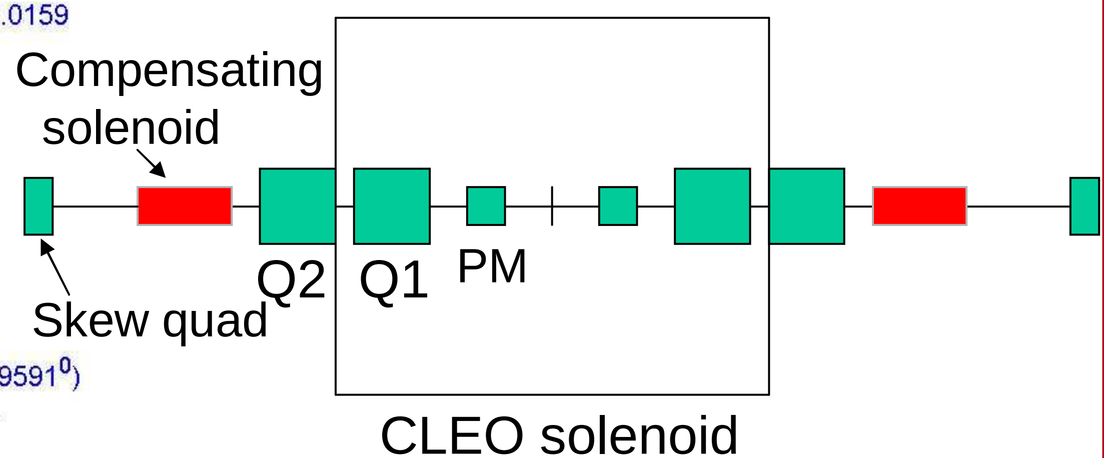
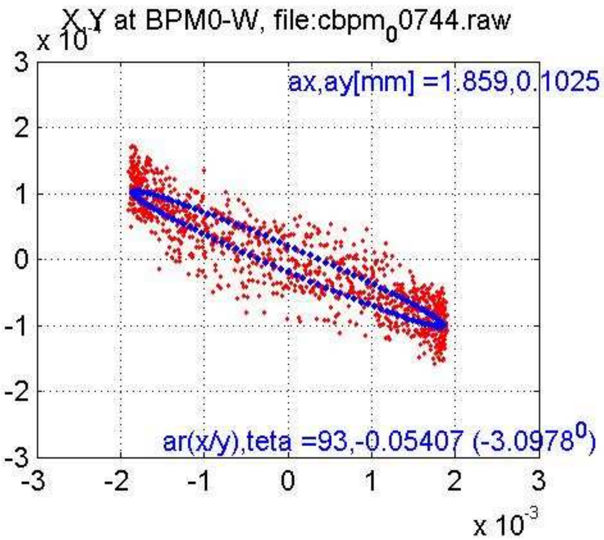
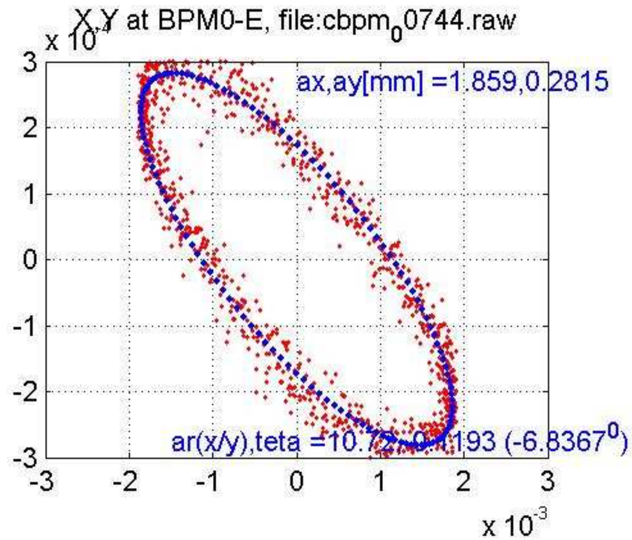
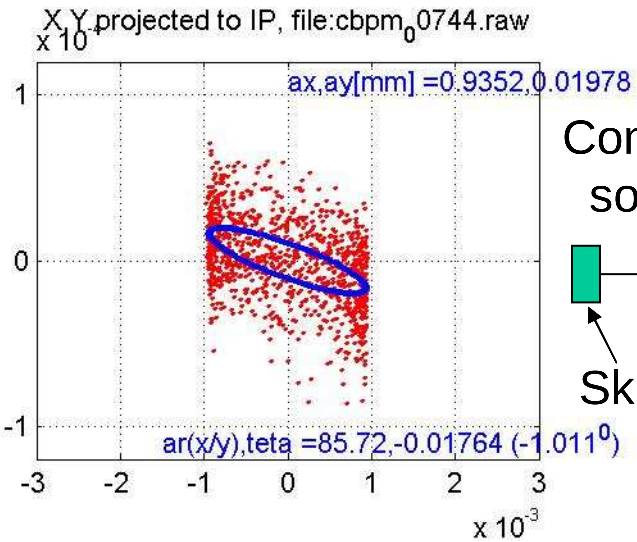


Inter action region optimization







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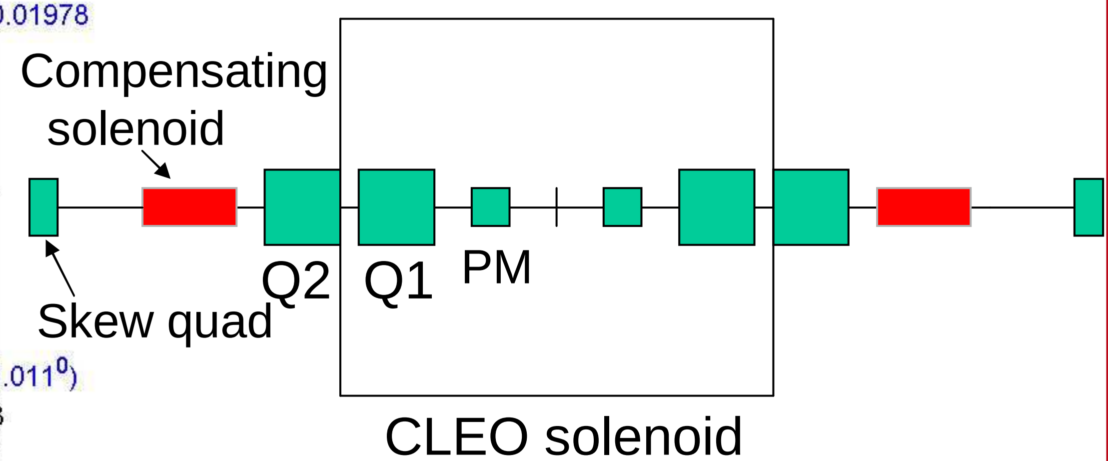

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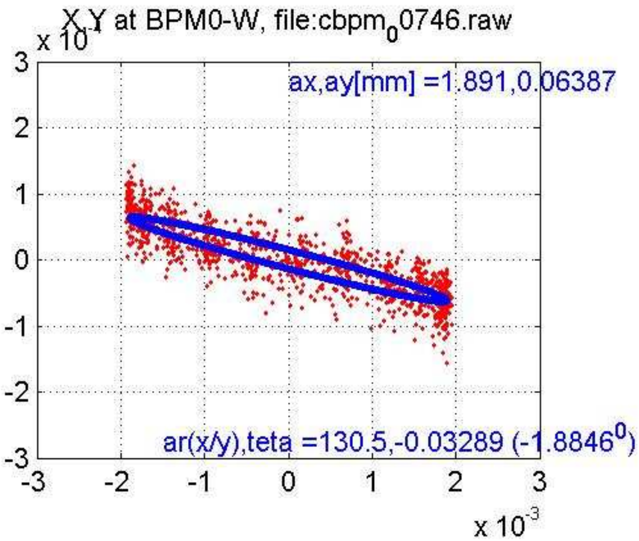

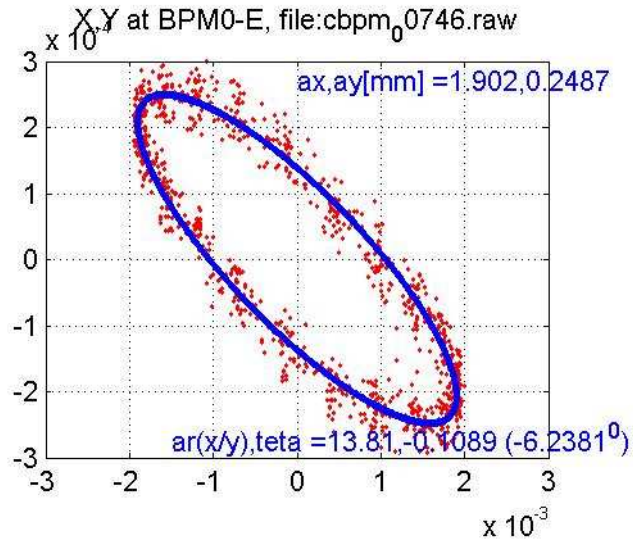

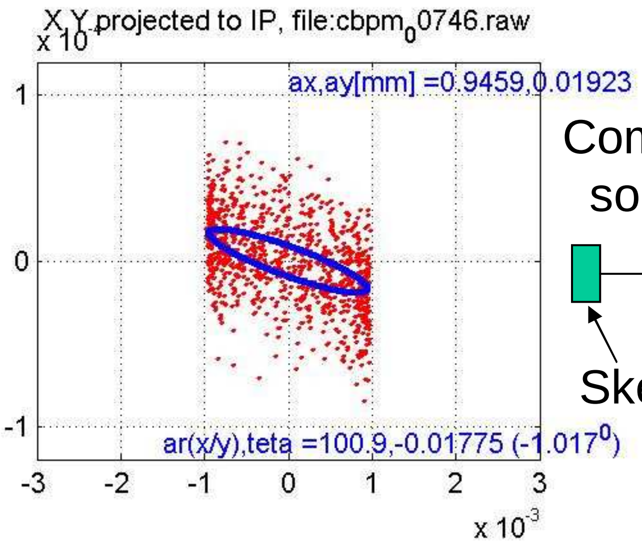

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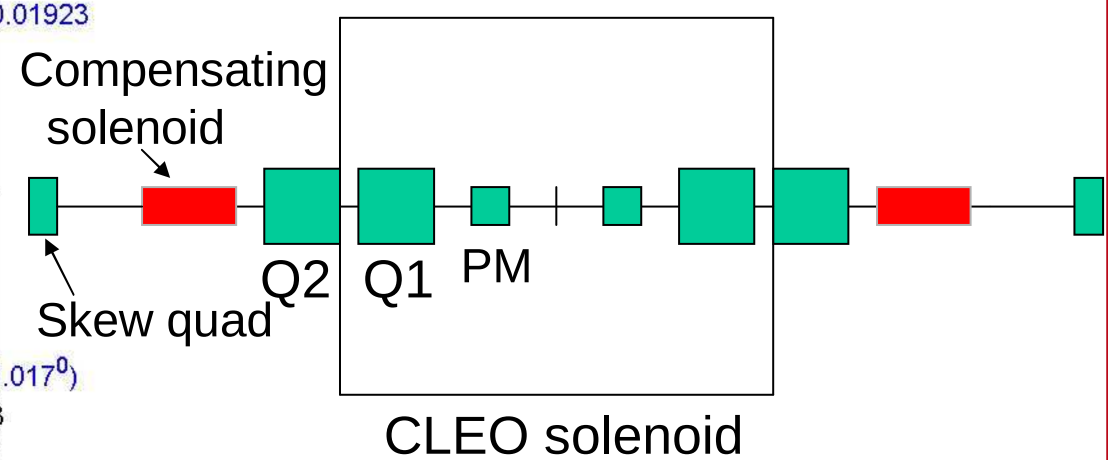
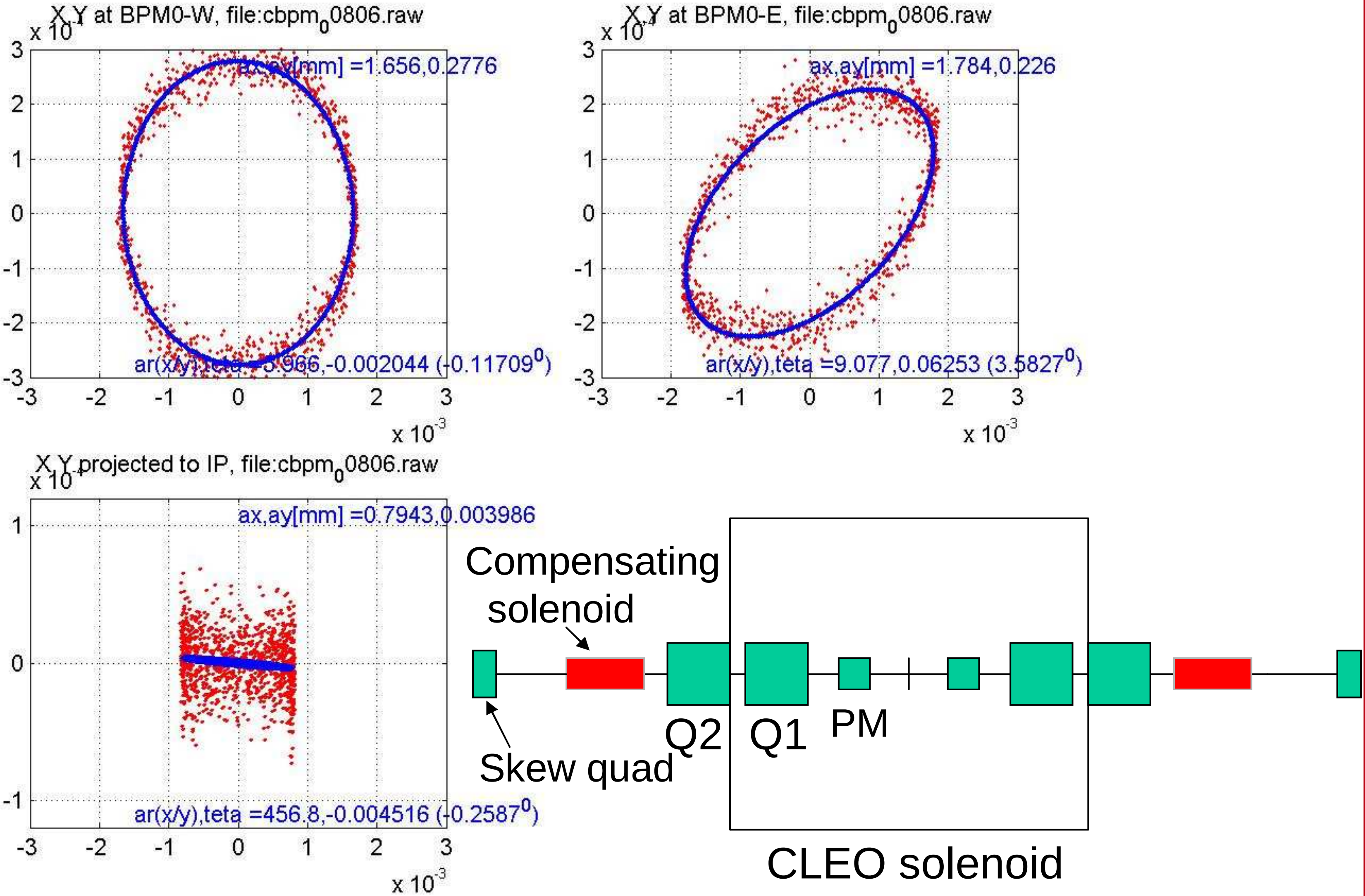


Inter action region optimization

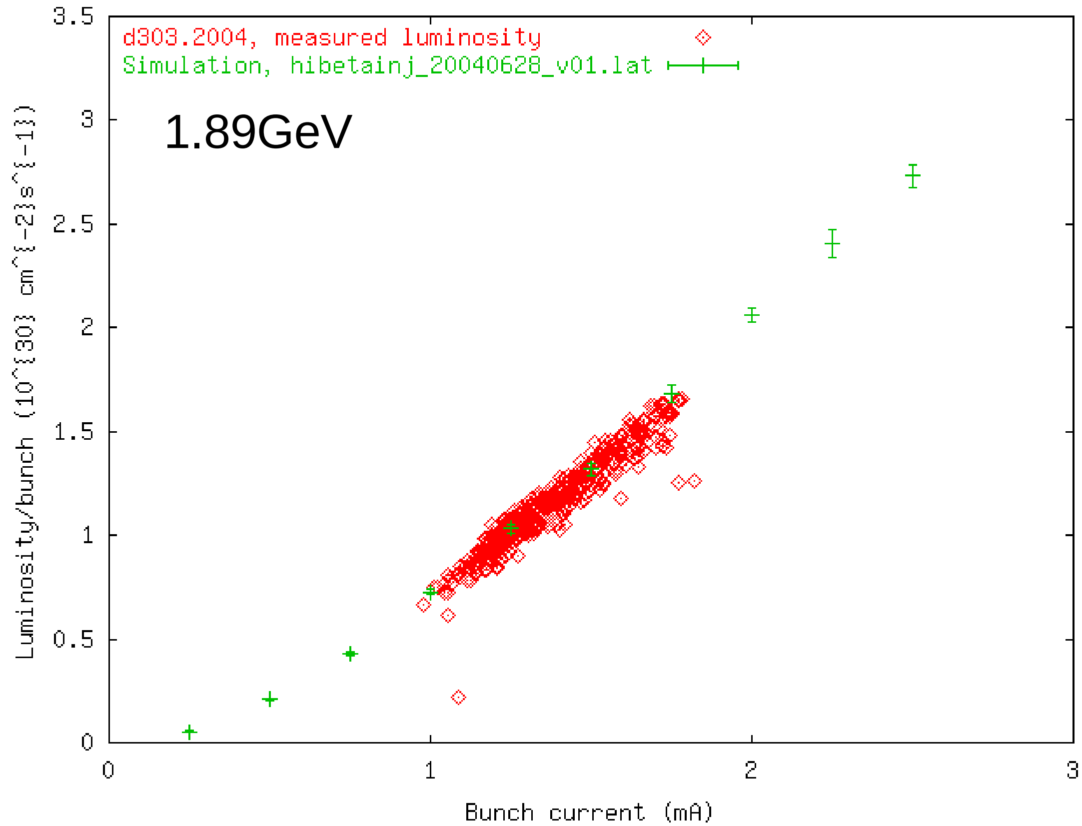


Complete modeling of collision mode

LEPP

Model includes:

- solenoids overlapping tilted quads,
- separator tilts
- differential coupling with skew sextupoles
- wigglers
- beam-beam force incl. parasitic interactions
- RF
- linear and nonlinear fileds
- radiation
- crossing angle
- pretzel

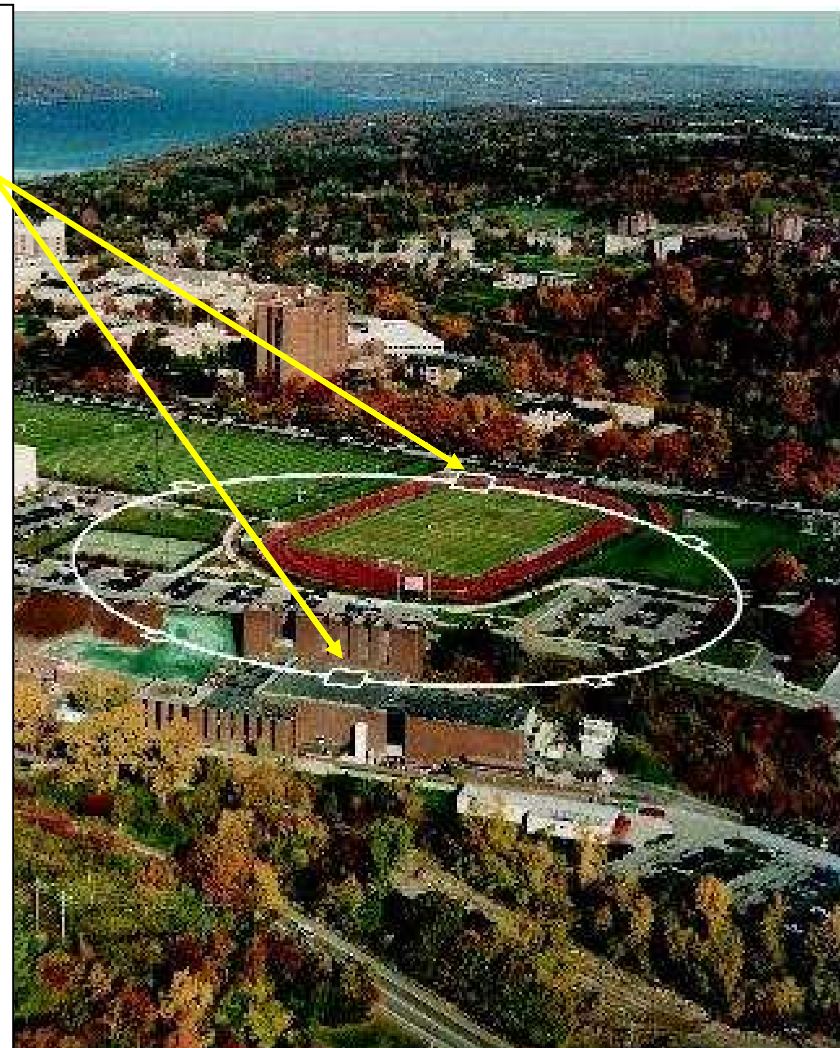


Cornell LEPP ILC accelerator physics activities

- Damping ring to main linac design
- Low emittance transport & preservation studies
- Damping ring optimization:
    - studies of wigglers: electromagnetic design, impact on ring dynamic aperture
    - studies of fast kickers
- Positron source
    - undulator design
    - E166 participation
- Study of the use of CESR as an ILC positron damping ring test facility (after 2007)

ILC damping ring studies at CESR

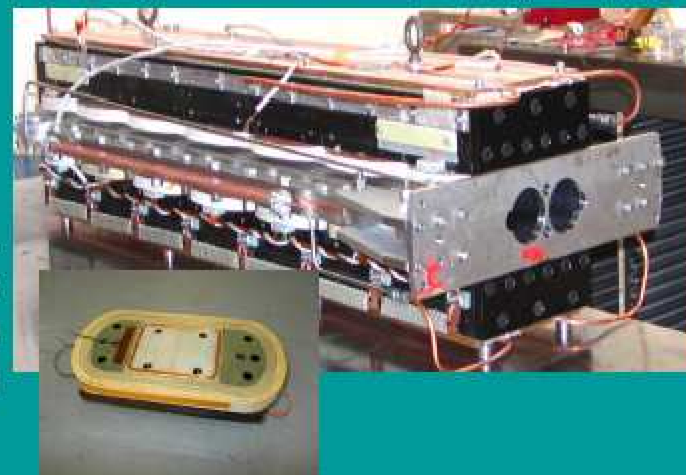
- **Rearrangement of CESR wigglers**
- **North and South Interaction Regions**
  - **South IR provides dispersion-free insertion region in standard optics**
    - Remove CLEO ⇨ South IR provides ~18 m of "free" space
    - Cryogenic support locally available
  - **North IR can be configured similarly**
    - Also ~18 m insert region
    - No cryogenic support so far
- ε_x=2.5nm, ε_y=5pm
- Disp and coupling correction
- Analysis of adequate wigglers.



Wigger studies

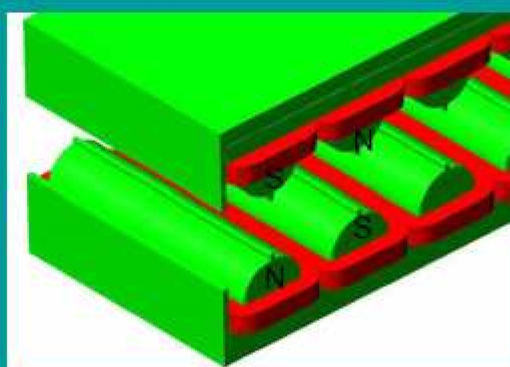
e.g. for Damping Rings

Wiggler for the damping ring was described in 2000, also at LC02 Feb.4-8 SLAC. The Cornell wiggler served as a prototype. Lot of ideas introduced for the first time



7-pole, **Wide** poles, Large aperture 90X50mm^2, Optimized coils shape, Recessed poles, Active field correction (end poles and central) for field adjustments, Tapering, Easy assembled cold mass...

Recently an **Ideal wiggler** was introduced. This wiggler has no nonlinearities. Field profile is ***piecewise-linear*** in this Wiggler. So the wiggler is not a problem anymore.



Beam Dynamics Studies for various accelerators

Advanced simulation tools have been developed:

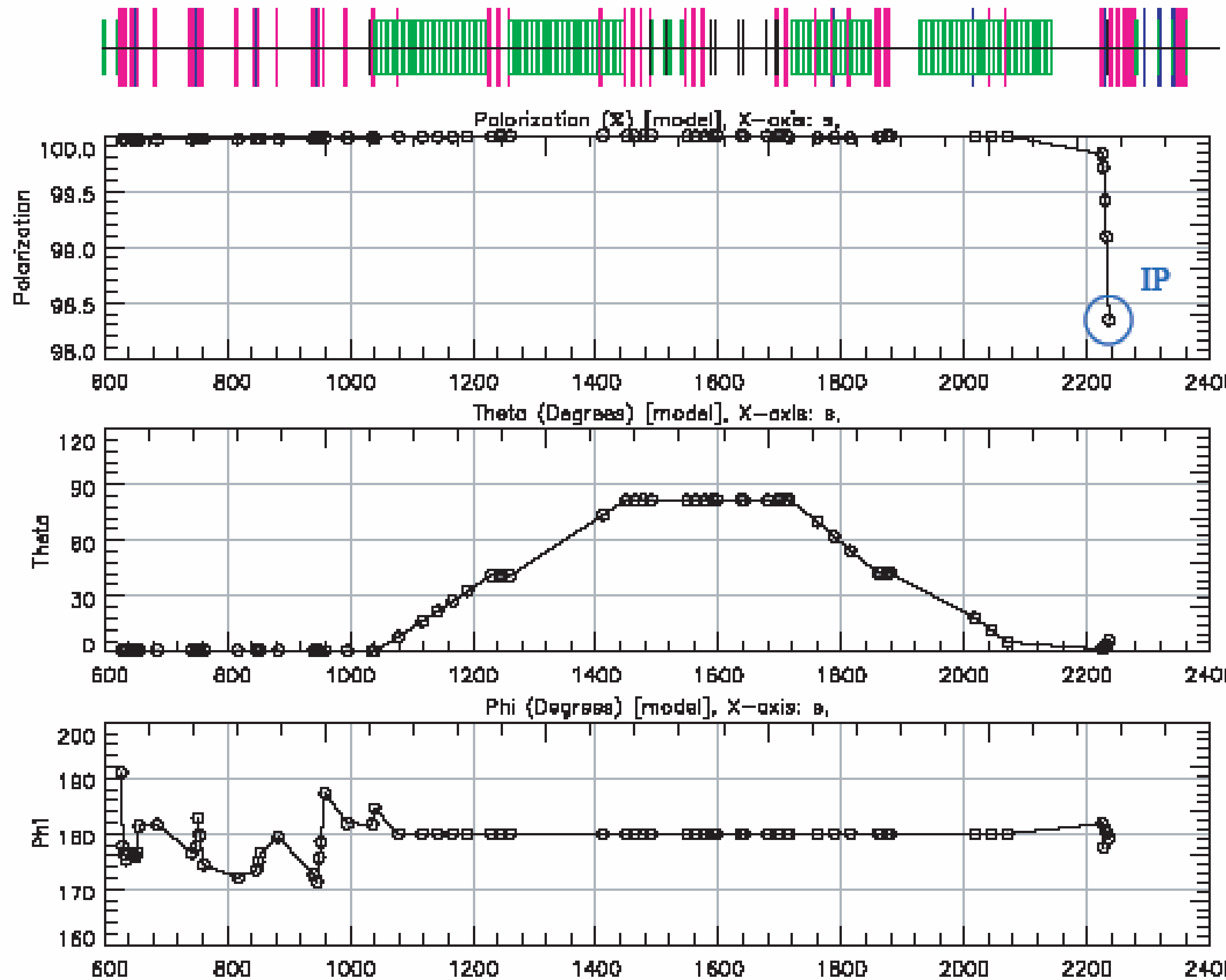
BMAD: Beam dynamics library
CESR-v: Virtual CESR representation, experimentally benchmarked.
Tao: Virtual representation of general accelerators, used for ILC and ERL

They include:
- Linear and nonlinear fields
- symplectic propagation through measured Wigglers
- Polarization propagation
- Beam-breakup instabilities
- CSR
- Space charge, and more

They relates to:
- ILC damping rings
- ILC linac
- light sources
- electron ion collider
- and any future accelerator

Polarization / phase space dynamics in the ILC

- Virtually all the depolarization is in the Final focus
- Haven't looked at effects of misalignments

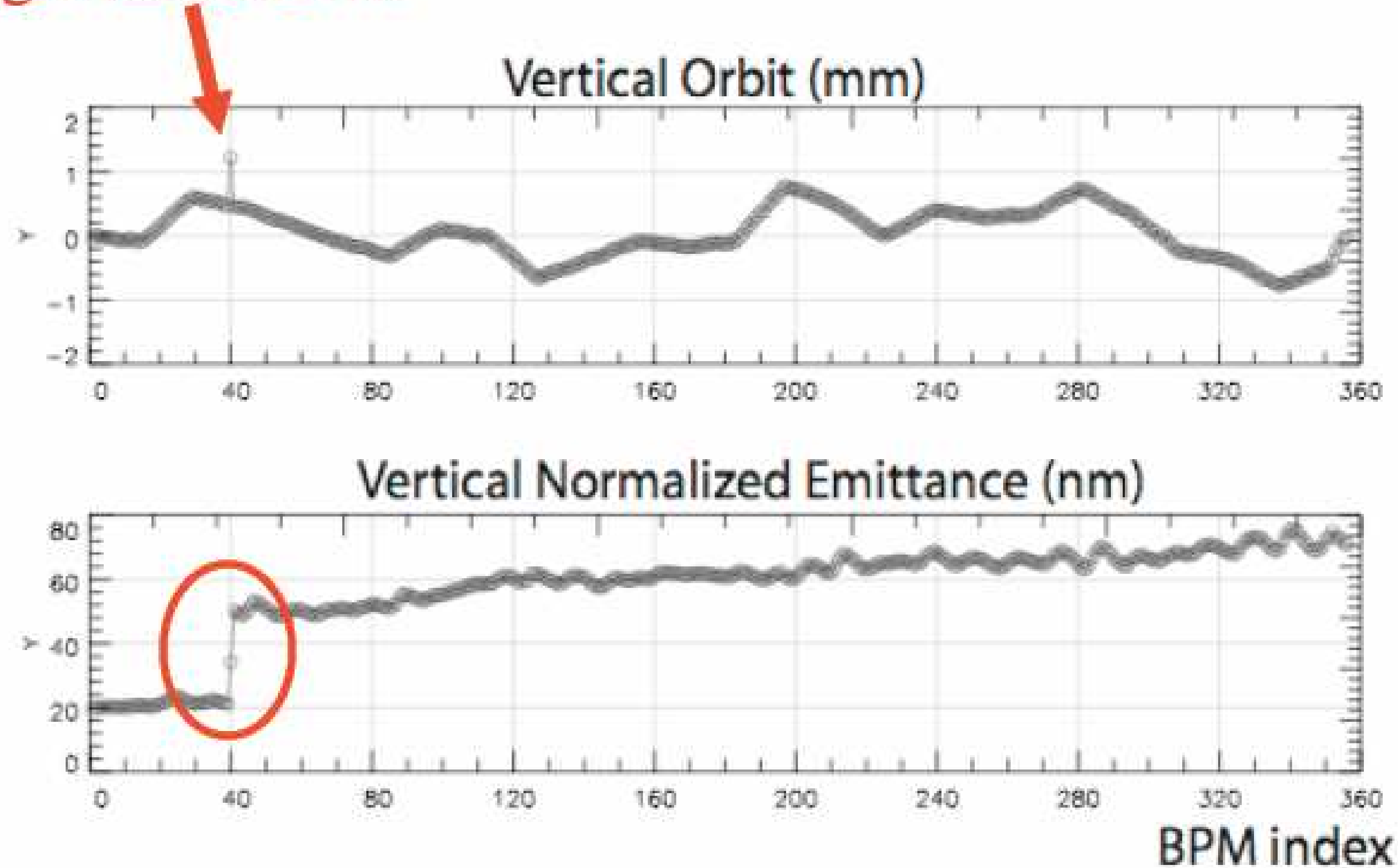


Low emittance transport for the ILC and ERL

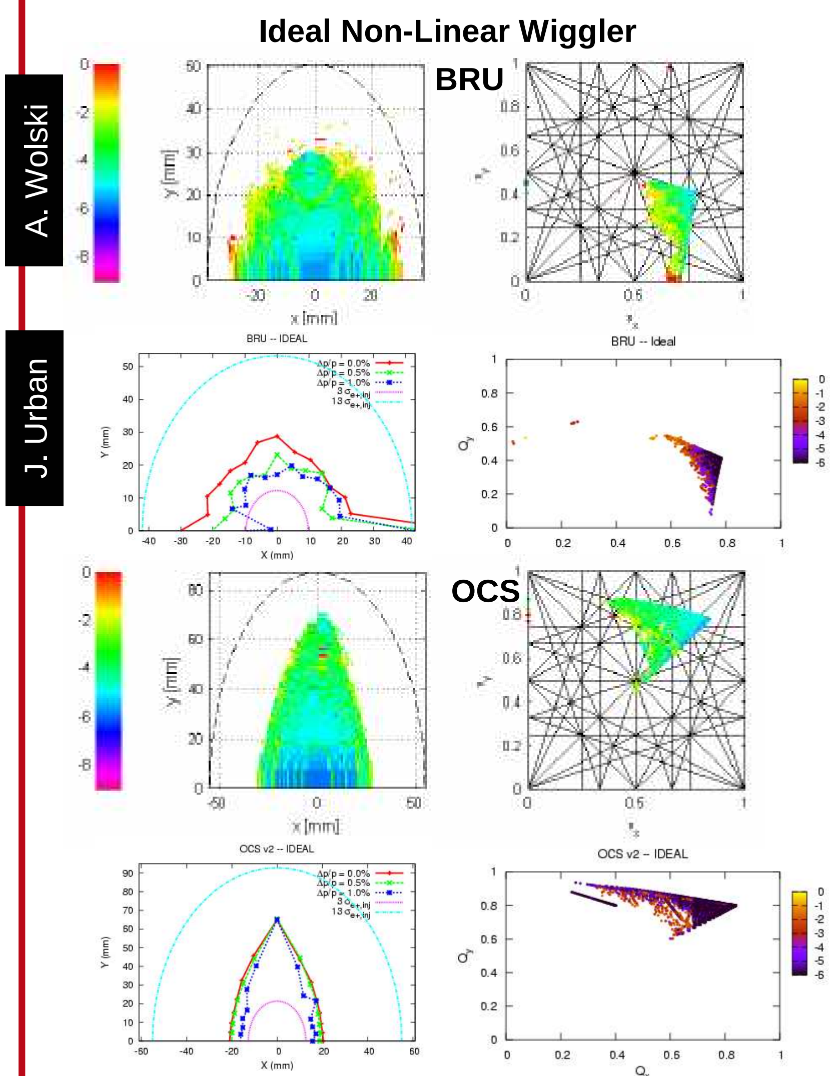
LEPP

Single failed BPM

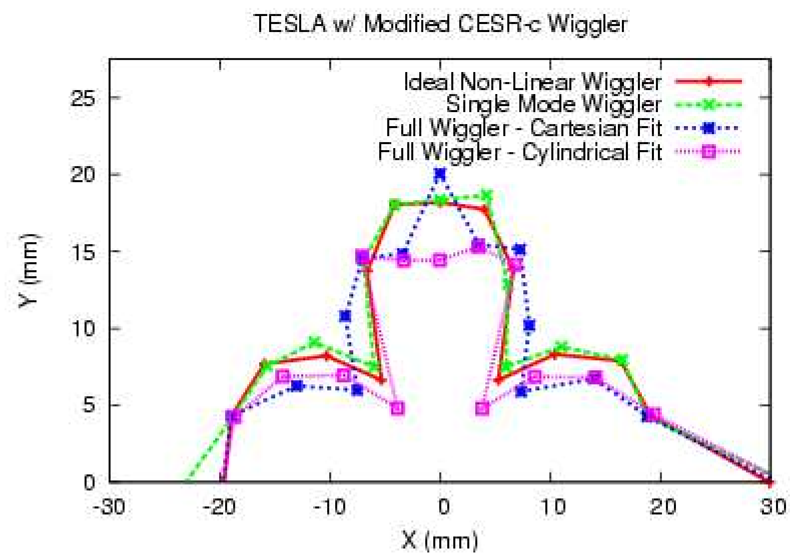
This failed BPM is ignored in the BA algorithm.



Damping ring studies, e.g. dynamic aperture



Results from PAC2005 showed the TESLA TDR wiggler was unsatisfactory. All wiggler studies performed with the CESR-c wiggler.

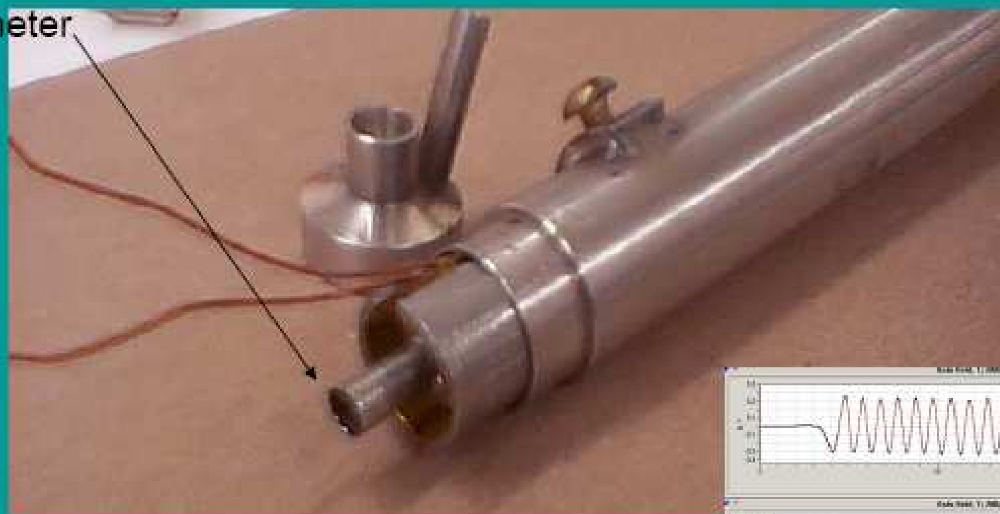


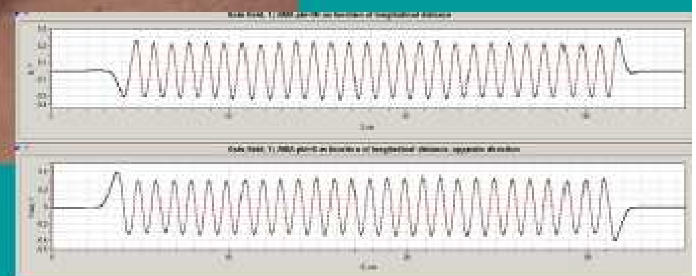
The CESR-c wiggler has a large aperture which produces fields well approximated by the Ideal Non-Linear Wiggler Model = Single Mode Wiggler Model.

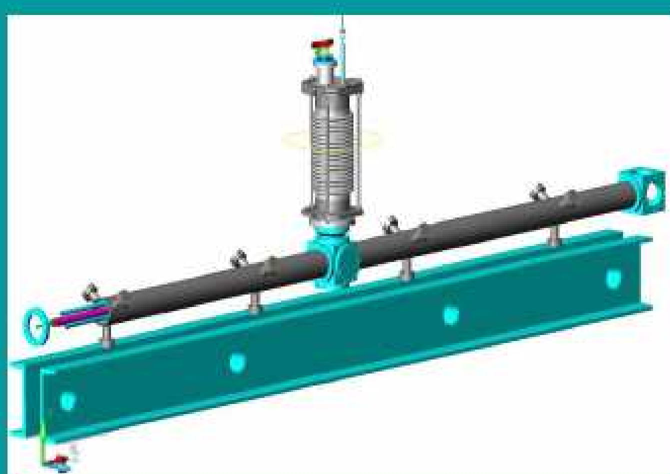
Undulators for polarized-positron production

MEASURED LONGITUDINAL FIELD DISTRIBUTION IN LHE

6 mm in diameter





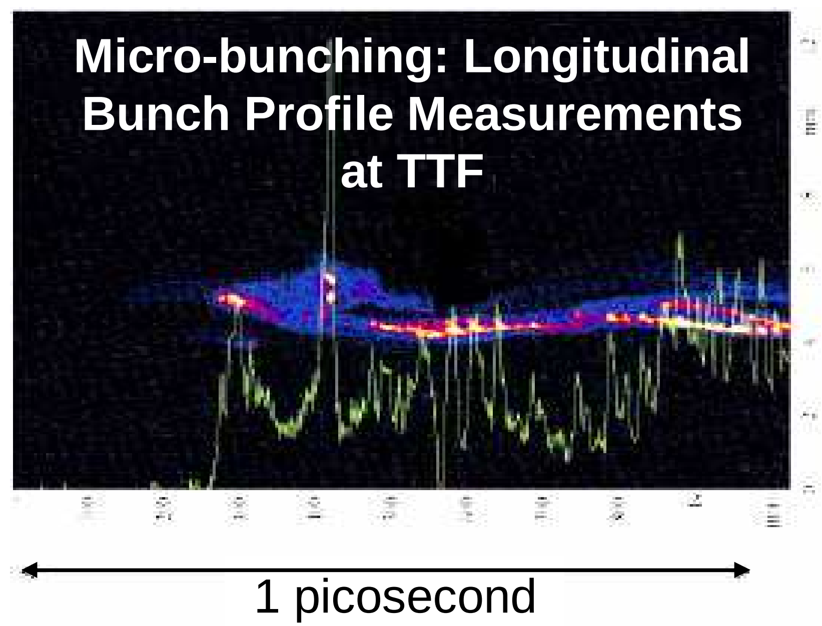


Goal: Assemble and test working 4-m long prototype module for ILC

Bright Electron Source and ERL

Aspects of x-ray ERL that are of general relevance for future accelerators

- Bright electron beams, gun developments for ILC and beyond.
- Component and technology development
- Space charge dominated beams
- Coherent Synchrotron Radiation
- Bunch compression

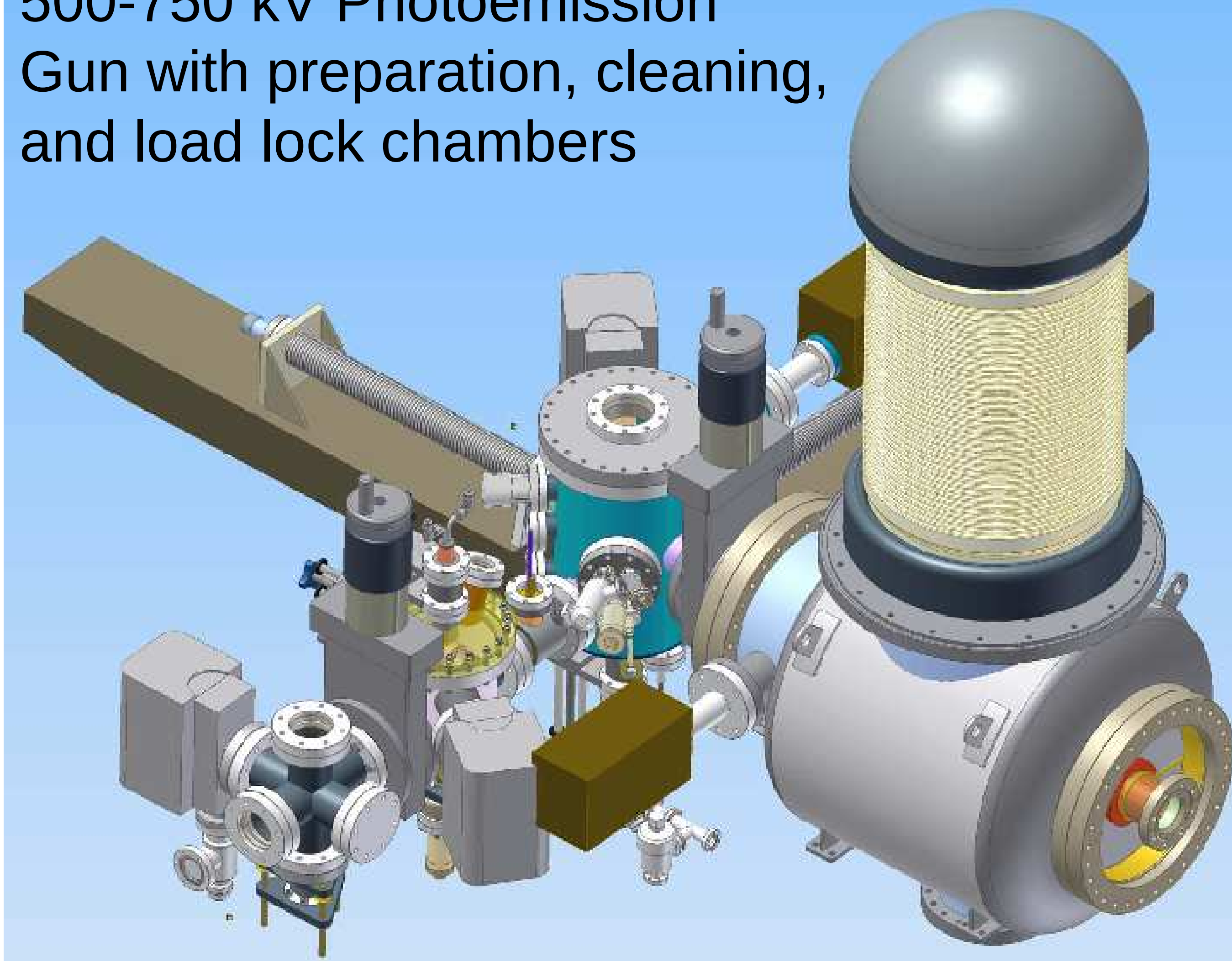


First quantitative CSR/bunch length measurements (A.Sievers et al. at Cornell)

- Ongoing measurement developments

Bright Electron Source and ERL

500-750 kV Photoemission Gun with preparation, cleaning, and load lock chambers



Emittances: down to 0.1mm mrad

Current: up to 100mA

DC, 1.3GHz

Workforce enhancement

Graduate Students (currently 10, as many as for HEP)
Undergraduate Students (4 per year)
High School Interns through the learning web (2 per year)

Undergraduate Summer Students (2 per year)
Summer Students for the NSF's REU program (15 per year)
Largely from underrepresented groups

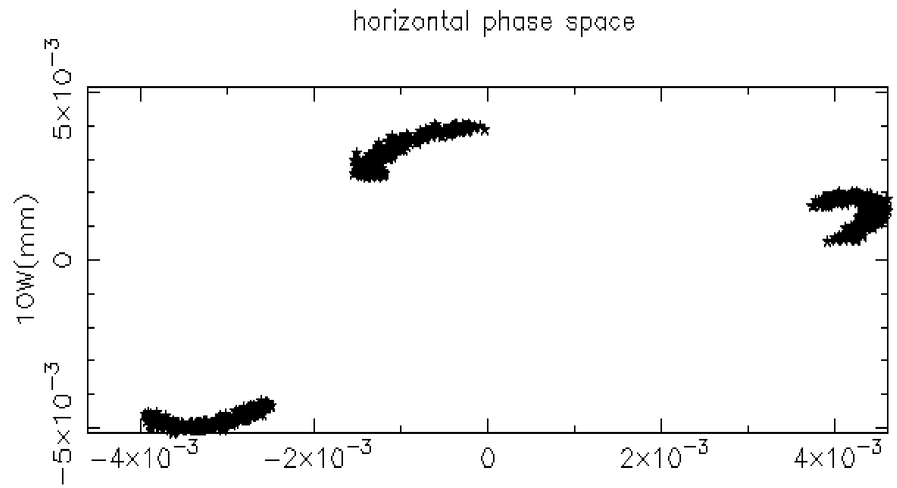
US Particle Accelerator School 2005:
unique storage ring based experimental program.

Many Cornell alumni have gone on to dominant positions in accelerator physics.

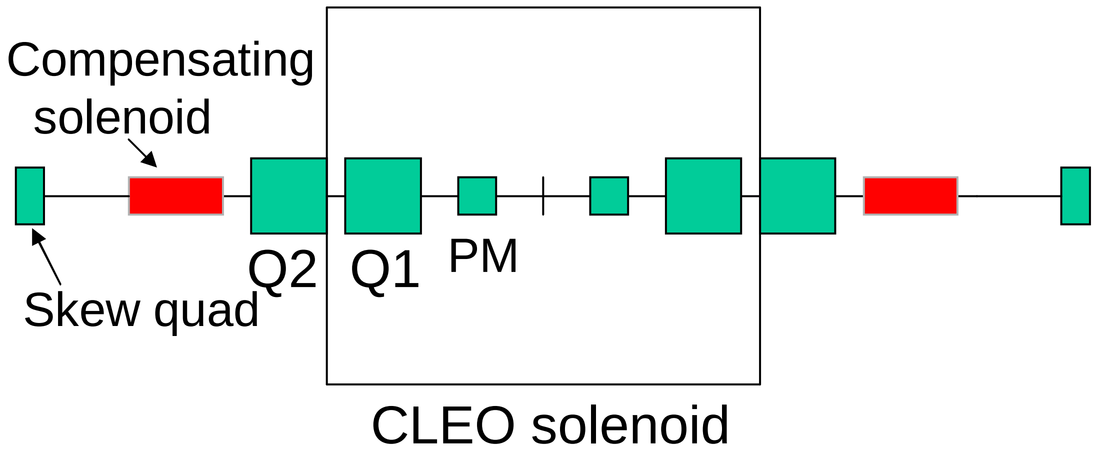
Homework of the USPAS 2006 at Cornell

Unique course of USPAS 2006 at Cornell University:
Experimental Accelerator Physics With Control Room Experiences

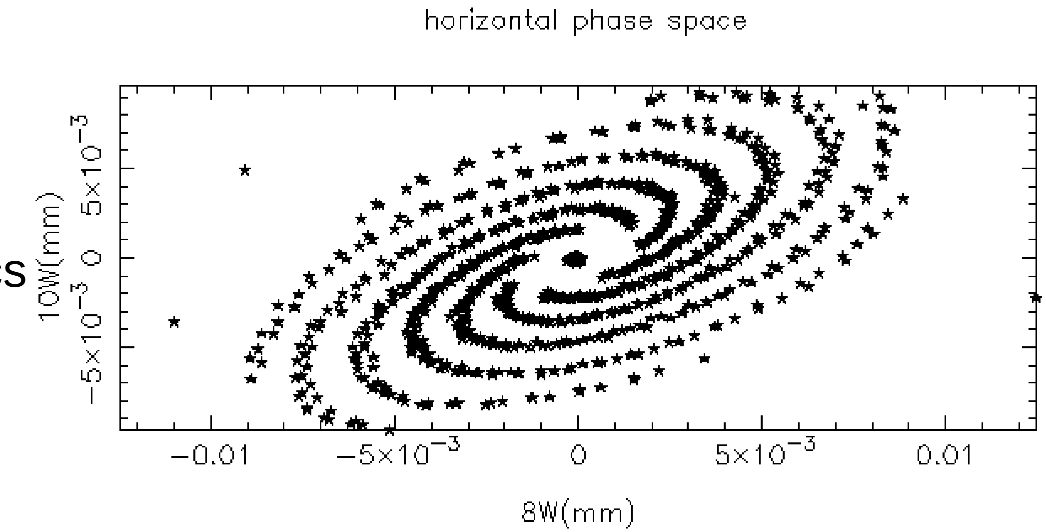
Homework:
e.g. Phase space measurements in CESR



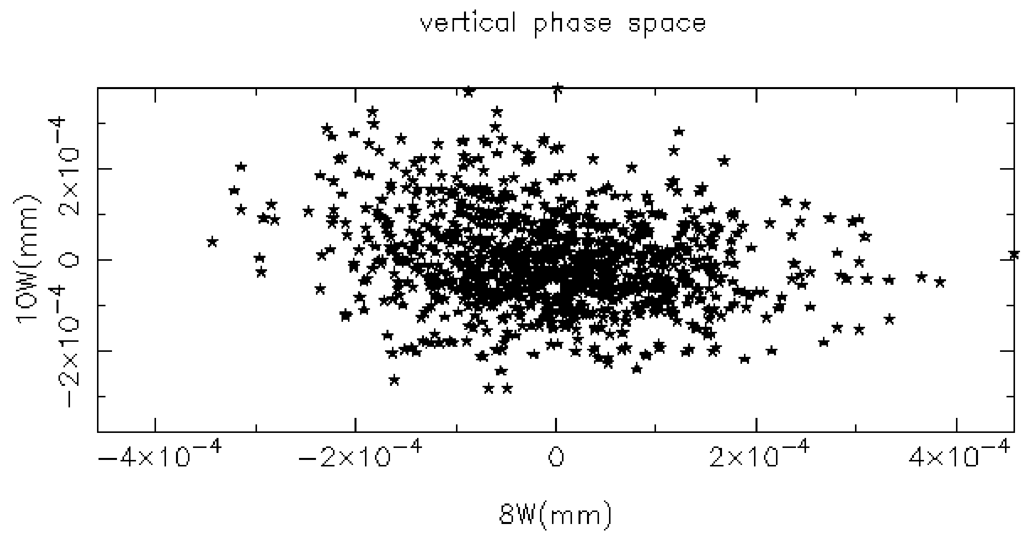
Horizontal pseudo phase space at $\nu = 2/3$.
Position at 10W vs position at 8W



Nonlinear Phase space dynamics for Students



Homework:
Horizontal and vertical pseudo phase space dynamics with
- damping
- tune shifts
- nonlinearities



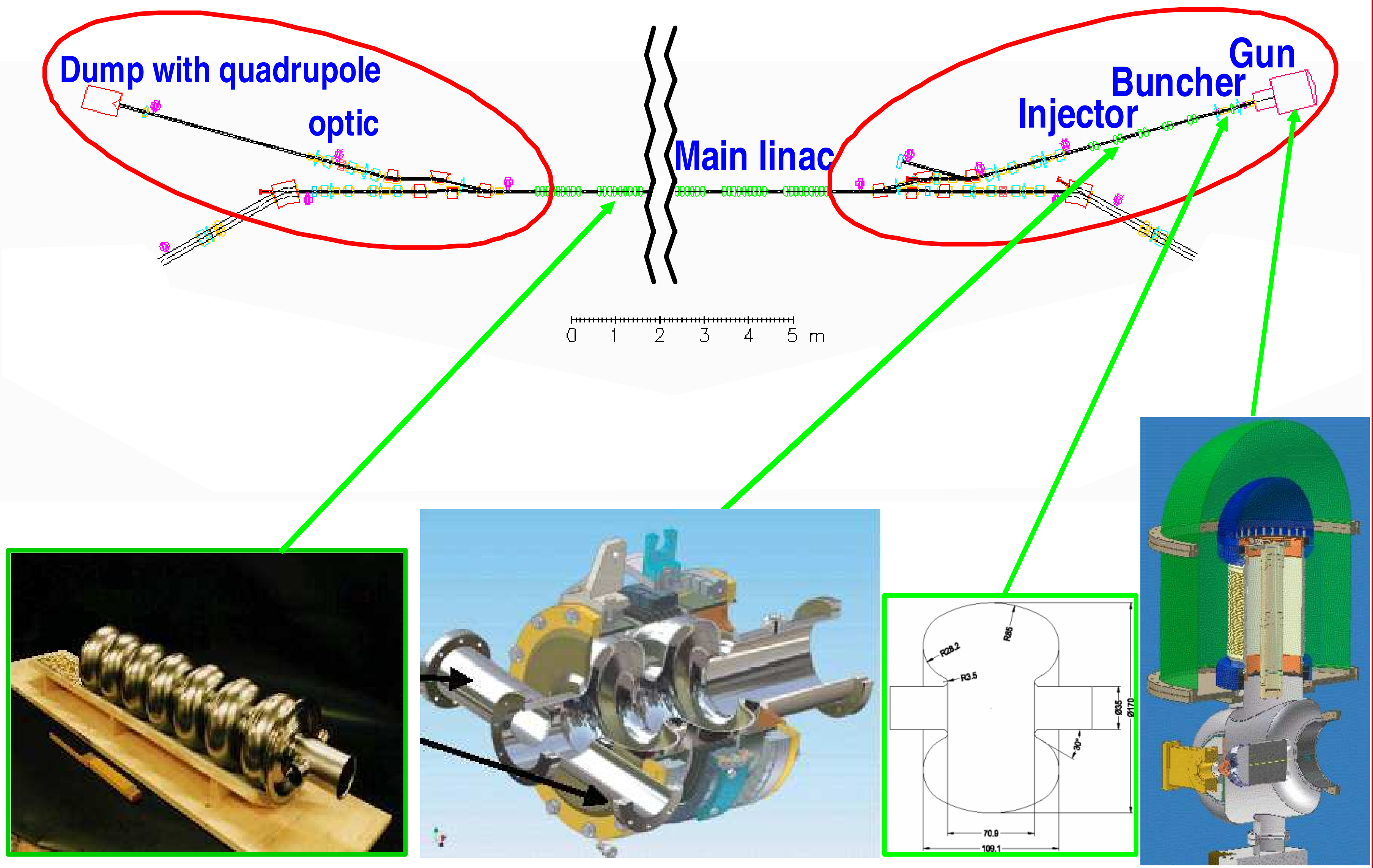
Position at BPM 10 West vs position at BPM 8 West

Conclusion

- Cornell has a long an successful history of accelerator physics
- Cornell has facilities and scientific groups that allow participation in a wide range of accelerator physics and component developments
- Cornell is involved in several mayor ongoing accelerator R&D projects
- Cornell contributes to R&D that is relevant for particle accelerators in the near and far future by pushing system parameters at many fronts.

Thanks to the Accelerator Physics Group at Cornell University

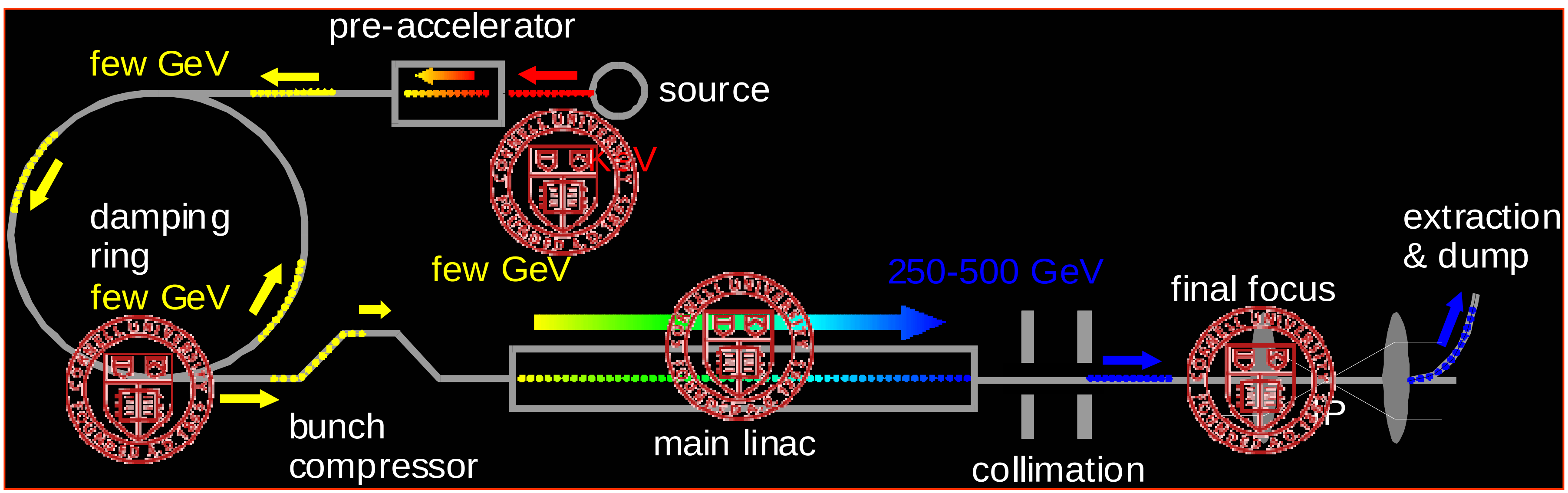
Examples of Component Developments



Linear Collider @ Cornell

Subjects esp. suitable for Cornell:

- Low emittance electron sources (as ERL)
- Undulator based positron sources (from CESR undulator expert)
- Damping rings (have wigglers like CESR)
- Beam dynamics simulation and accelerator modeling (based on codes for CESR and ERL)
- Bunch compressors (similar to ERL)
- Many superconducting RF subjects (as ERL)
- Crab cavities for the collision region (as in LHC)



Notes

- Mention which items are long term AARD, and which are mid and short term R&D: Most of our research is mid and short term R&D while keeping in mind that these mid term advances are the basis for a long term AARD impact.

- Other areas where we could contribute if the need comes up and we are supported are: LHC upgrade: crab cavities, accelerating cavities, interaction regions, optical acceleration.