GDE Main Linac and RTML Beam Dynamics

Conveners: Nikolay Solyak,
Cris Adolphsen, Kyioshi Kubo

April 20, Room 303, 14:30 – 18:00

Program

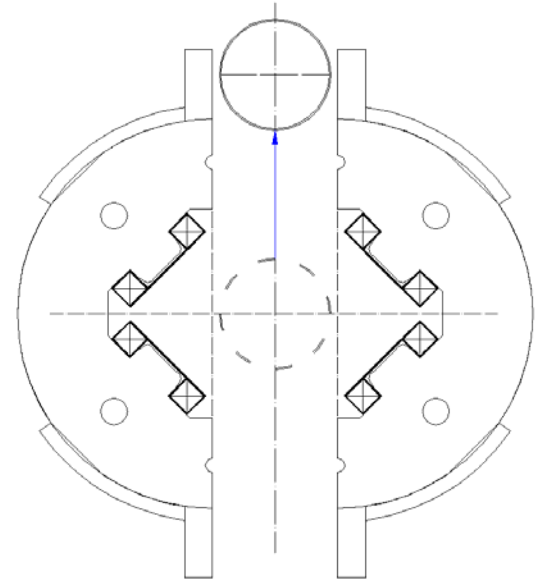
- 14:30 ILC Low energy quad --Vladimir Kashikhin (*FNAL*)
- 14:50 General quad issues -- Chris Adolphsen (*SLAC*)
- 15:10 Alignment studies -- John Dale (*University of Oxford / JAI*)
- 15:30 Overview of RTML emittance control -- Nikolay Solyak (*FNAL*)

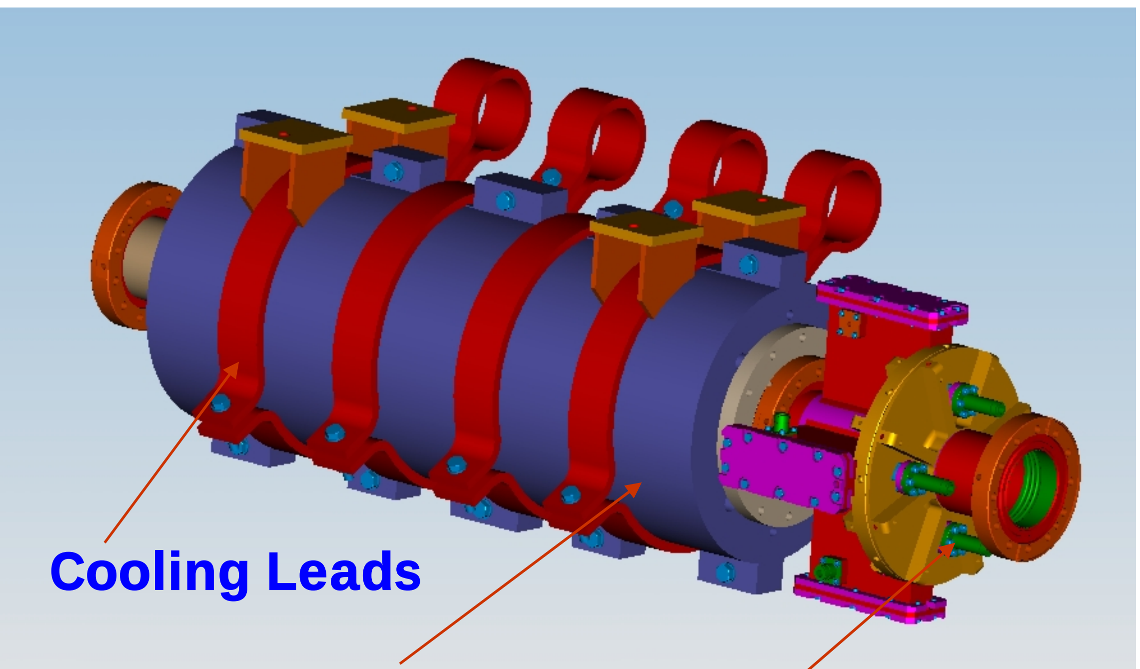
Coffee break

- 16:10 Single stage BC design – Nikolay Solyak, Andrea Latina (*FNAL*)
- 16:30 Design of extraction line for single stage BC – Sergei Seletskyi (*BNL*)
- 17:00 BC simulations, recent progress at KEK - Kiyoshi Kubo (*KEK*) , Dou WANG (*IHEP*)
- 17:20 BC alignment requirements and alignment issues – Andrea Latina (FNAL)
- 17:40 Discussion on beam dynamics studies in RTML and ML

Splittable ML Quadrupole

Task from ILC Project Management: Look at the Splittable Quadrupole conceptual design to provide the quadrupole package installation and replacement outside of a very clean room.

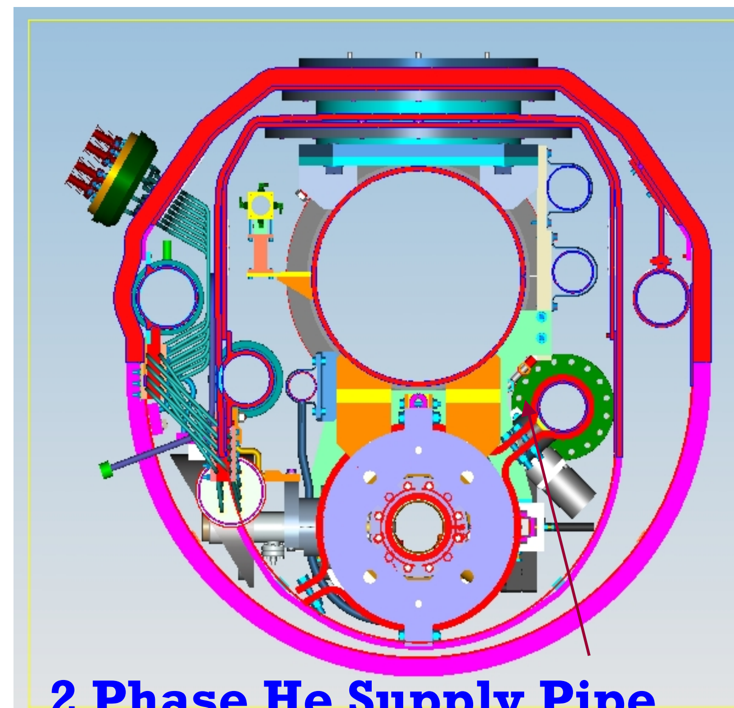




Cooling Leads

Quadrupole Package

BPM



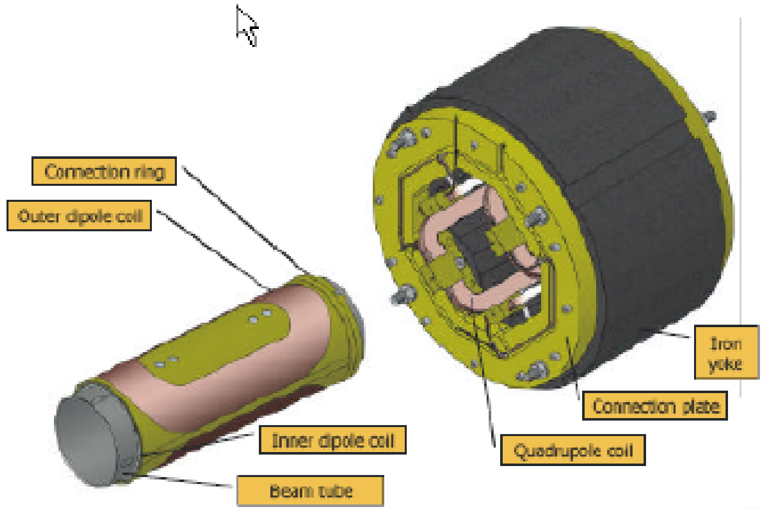
V.Kashikhin

Quadrupole Final Assembly View

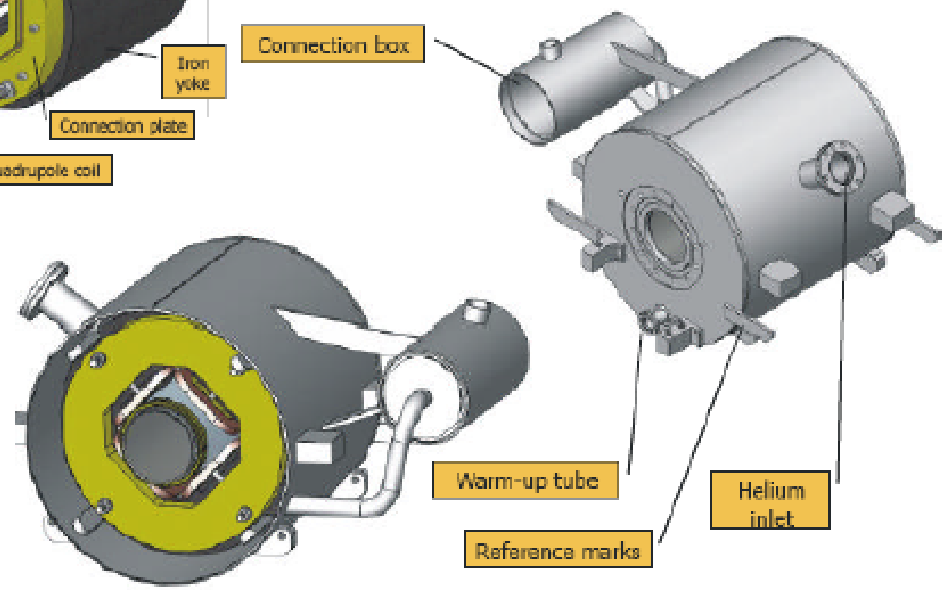
Summary

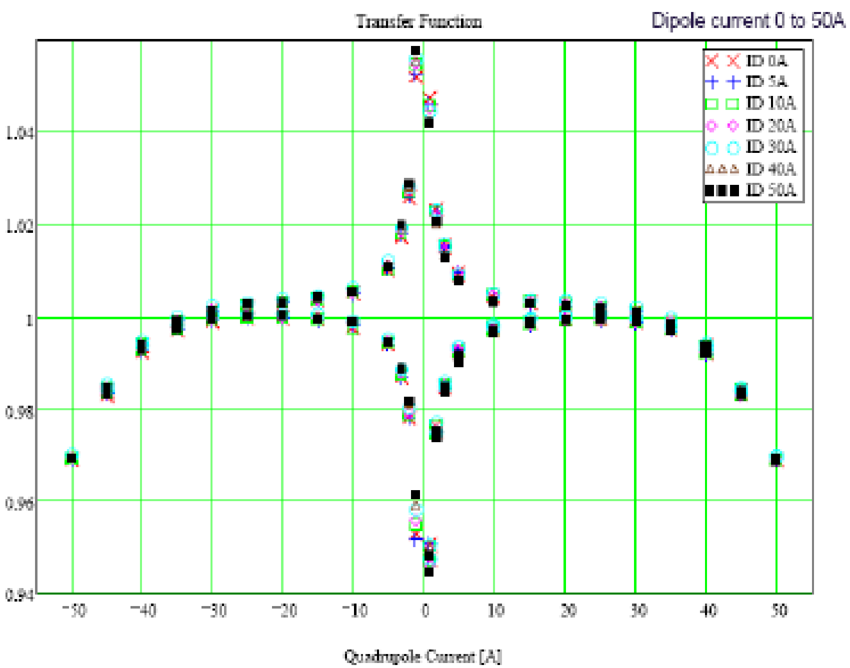
- The first look at the splittable quadrupole showed this approach visibility;
- Proposed the quadrupole concept with vertical split;
- Quadrupole has a conduction cooling from LHe supply pipe;
- Quadrupole mounted around beam pipe outside of the clean room;
- BPM has tight connection with quadrupole;
- Quadrupole bolted to the strong 300 mm diameter He gas return pipe;
- Special attention paid on the magnet assembly and mounting tolerances;
- Current leads also conductively cooled;
- Magnet cooling down time ~ 38 Hours;
- The Quadrupole model with split should be built and tested to verify the design.

XFEL Prototype Superferric 6 T SC Quad



- Design according to TUEV pressure vessel rules
- Copperized beam tube
- Sliding supports on linear bearings
- BPM attached on endplate



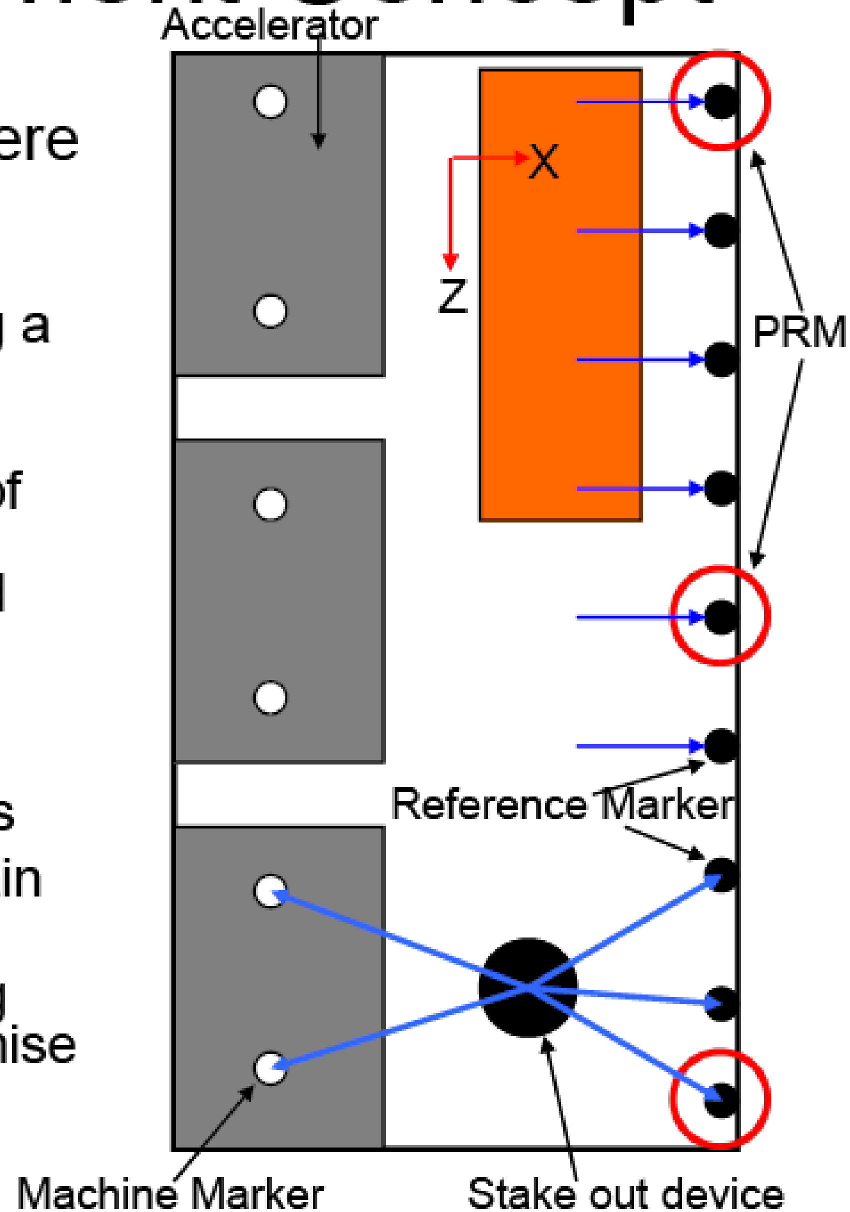


The persistent current effect of the dipole wires is very important at low currents.

Fernando Toral

Accelerator Alignment Concept

- Many possible ways to Align an Accelerator, the concept used here is:
  - Over lapping measurements of a network of reference markers using a device such as a laser tracker, stretched wires or LiCAS RTRS
  - Measurements of a small number of Primary Reference Markers (PRM) using, for example GPS transferred from the surface.
  - Combining all measurements in a linearised mathematical model to determine network marker positions
  - Using adjusted network to align Main Linac
  - Using Dispersion Matched Steering (DMS) to adjust correctors to minimise emittance



Reference Network (Survey/Alignment) Simulations
by John Dale (Oxford)

- Commercial survey adjustment software
  - Expensive, Need to be survey expert to use
  - Usually only use laser tracker/tachometers
- Full simulation of a specific device
  - Slow to generate networks
  - Restricted to one measurement technique

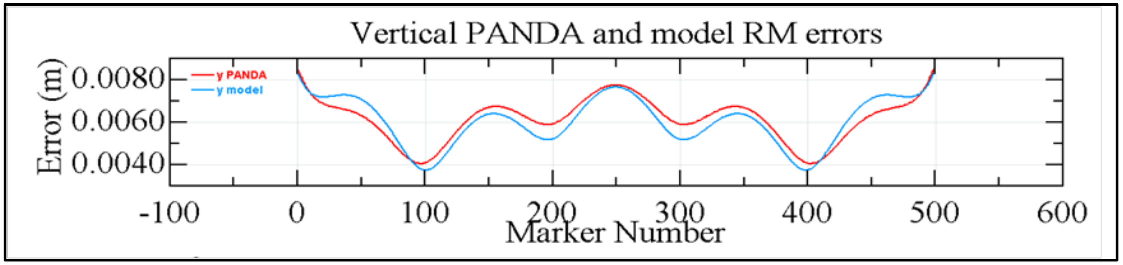
→ Simplified Model

- If designed correctly can be quick
- Can be used to model novel devices

The model is under development.

- Examples of misalignment from the model with tracking are reported
  - One example is in next slide
  - The model should be improved.
  - It seems: Laser tracker network is not suitable for the ILC

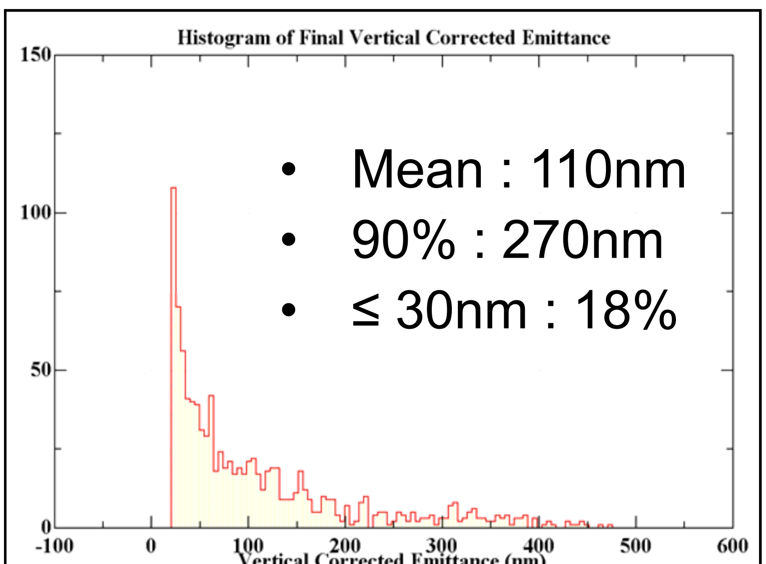
Error Curve Comparison of the simplified model with a commercial code “PANDA” for Laser Tracker Network



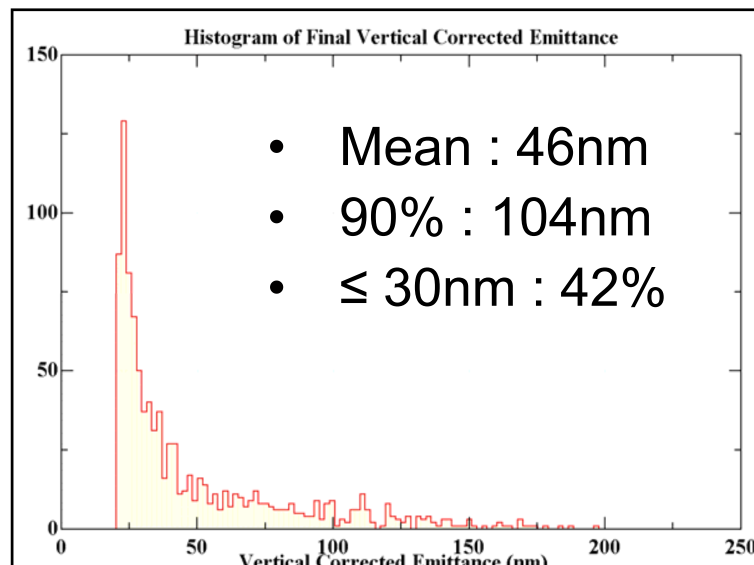
DMS Simulations for Laser trackers

- 100 networks generated with PRMs using PANDA and the model
- 10 DMS simulations performed on each network using Merlin

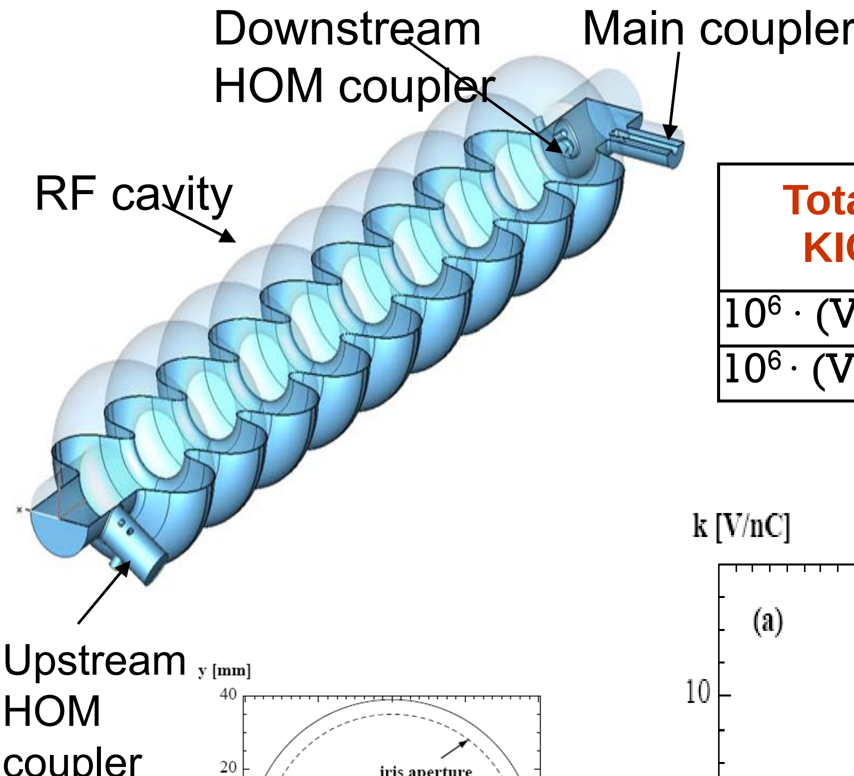
Model



PANDA

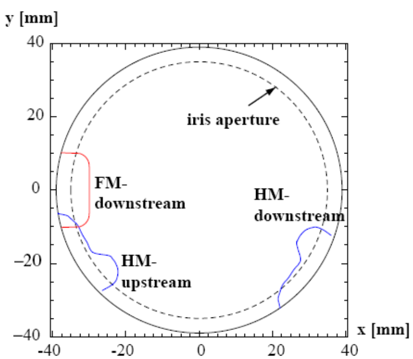


Simulations of Coupler Kick and Wakes



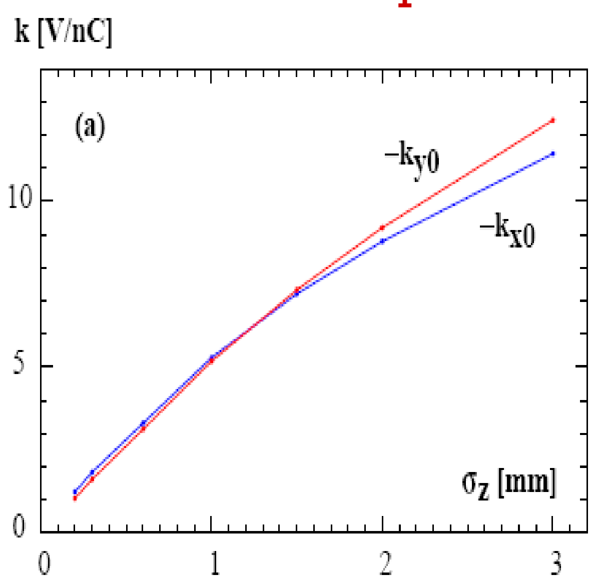
The couplers break the RF field symmetry and cause transverse RF kick and Wakes DESY,2007. Simulations: DESY/FNAL/SLAC

Total RF KICK	FNAL $Q=3.5\times10^6$ HFSS	DESY $Q=2.5\times10^6$ MAFIA	SLAC $Q=3.5\times10^6$ OMEGA3P
$10^6 \cdot (V_x/V_z)$	-105.3+69.8i	-82.1+58.1i	-88.3-60.2i*
$10^6 \cdot (V_y/V_z)$	-7.3+11.1i	-9.2+1.8i	-4.6+5.6i

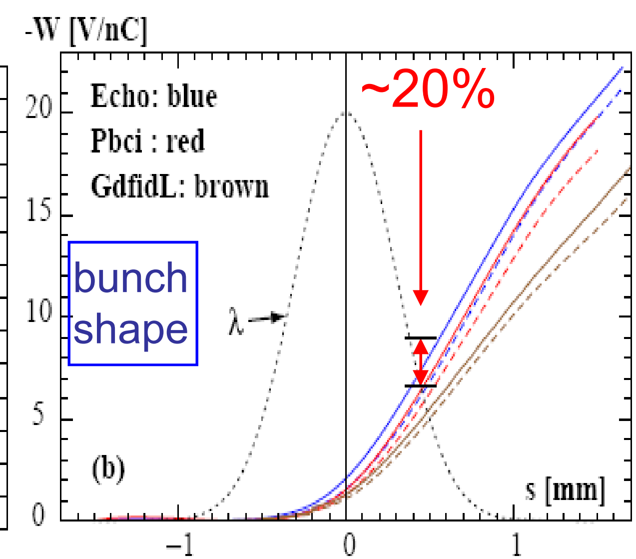


The profiles of the 3 couplers, as seen from the downstream end.

Coupler Transverse Wakefield



On-axis kick factor vs. σ_z



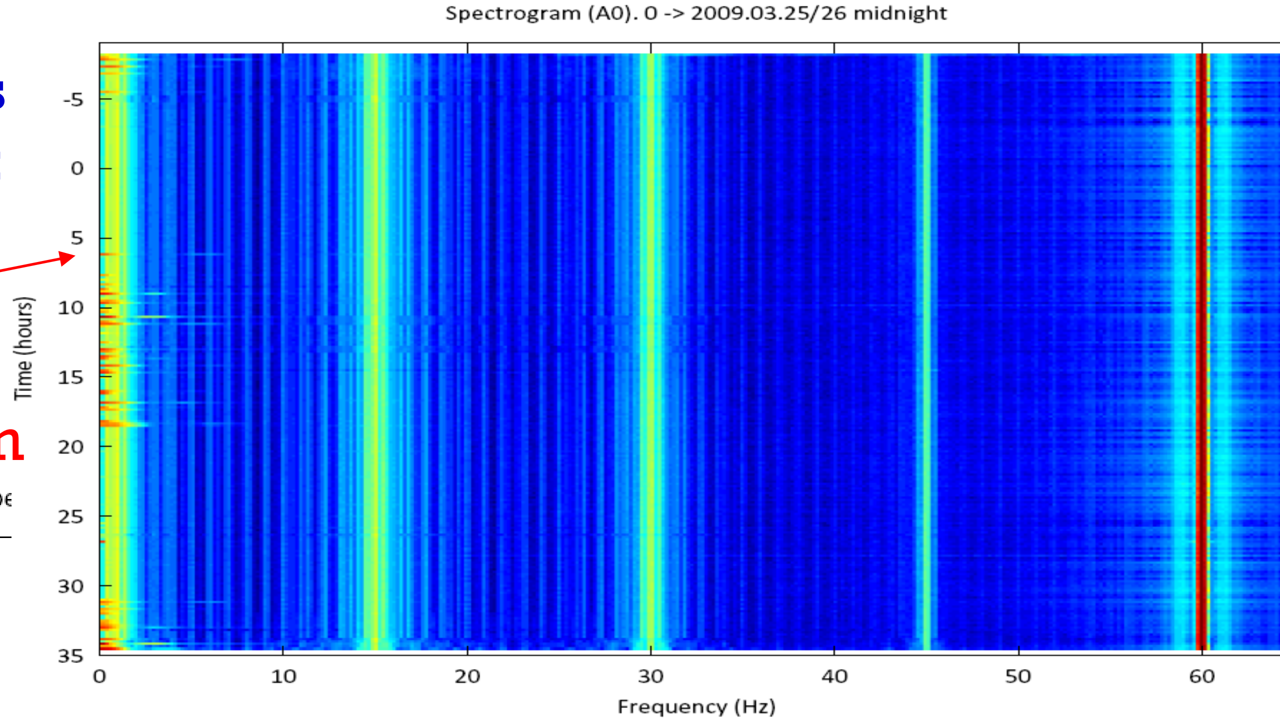
$W_x(s)$-solid,,$W_y(s)$-dashed for $\sigma_z = 300$ μm.

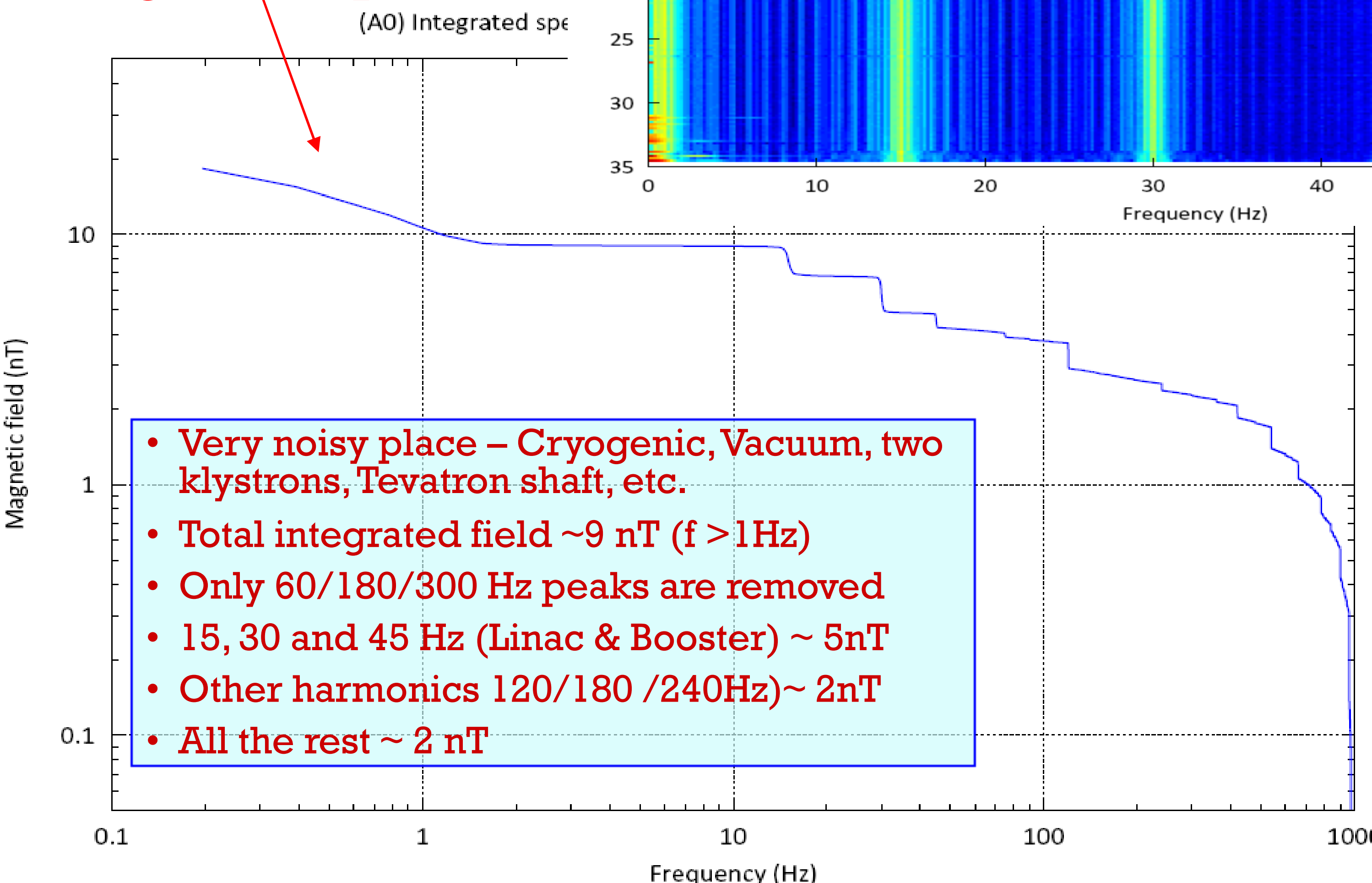
Stray magnetic fields measurements at A0:

Spectrogram

and

Integrated spectrum



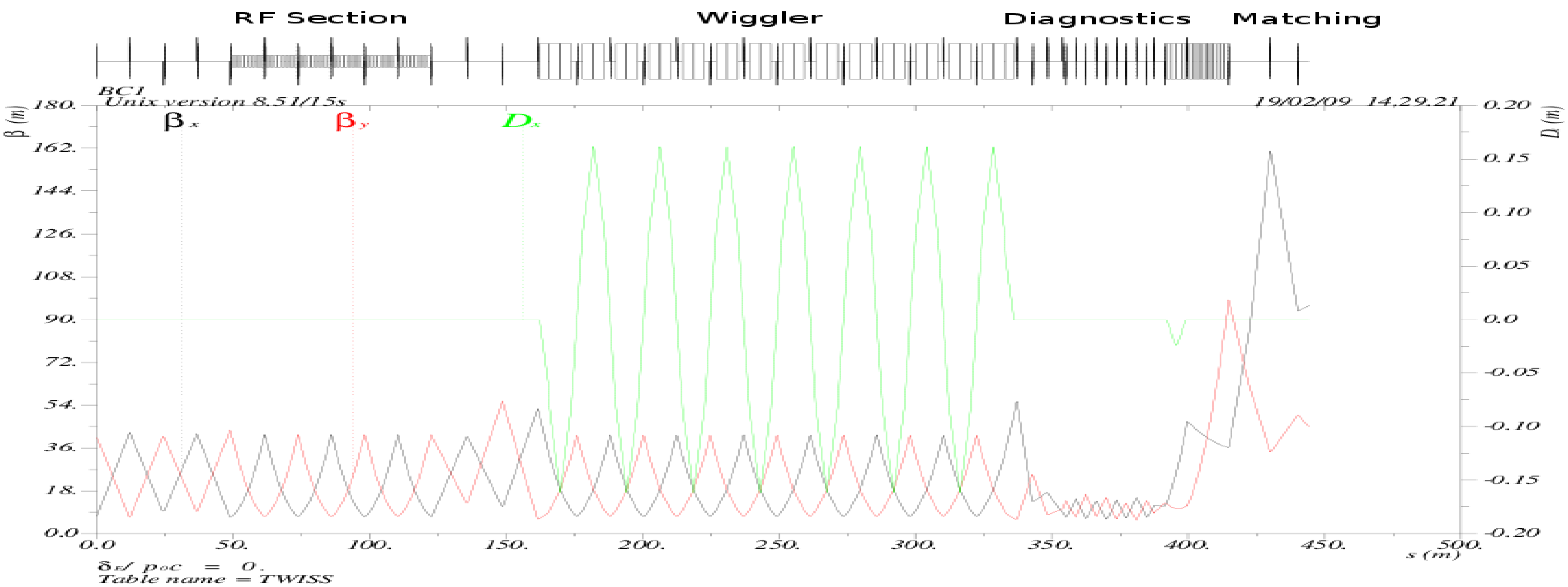


- Very noisy place – Cryogenic, Vacuum, two klystrons, Tevatron shaft, etc.
- Total integrated field ~9 nT (f > 1Hz)
- Only 60/180/300 Hz peaks are removed
- 15, 30 and 45 Hz (Linac & Booster) ~ 5nT
- Other harmonics 120/180 /240Hz)~ 2nT
- All the rest ~ 2 nT

- 5MW Klystron
- Modulator
- Transformer
- Cryogenic
- Pumps
- Power Supplies
- Etc…

Single-Stage Bunch Compressor

Based on the original design, proposed by PT et al. in April 2005:
http://www-project.slac.stanford.edu/ilc/acceldev/LET/BC/OneStageBC.html



- six cryomodules for RF acceleration (Eacc=26MV/m, phase=-119)
- 6-cells wiggler: a single bend magnet between quads in a 6-cells FODO lattice

+ NEW sections added:

(1) beam diagnostics adapted from BC2, re-design extraction after BC→shorter
(2) Post-acceleration linac from 5 to 15 GeV – part of ML (Eacc=31.5 MV/m)

A.Latina

Single-stage Bunch Compressor

Design Characteristics

- The beam properties at injection are:

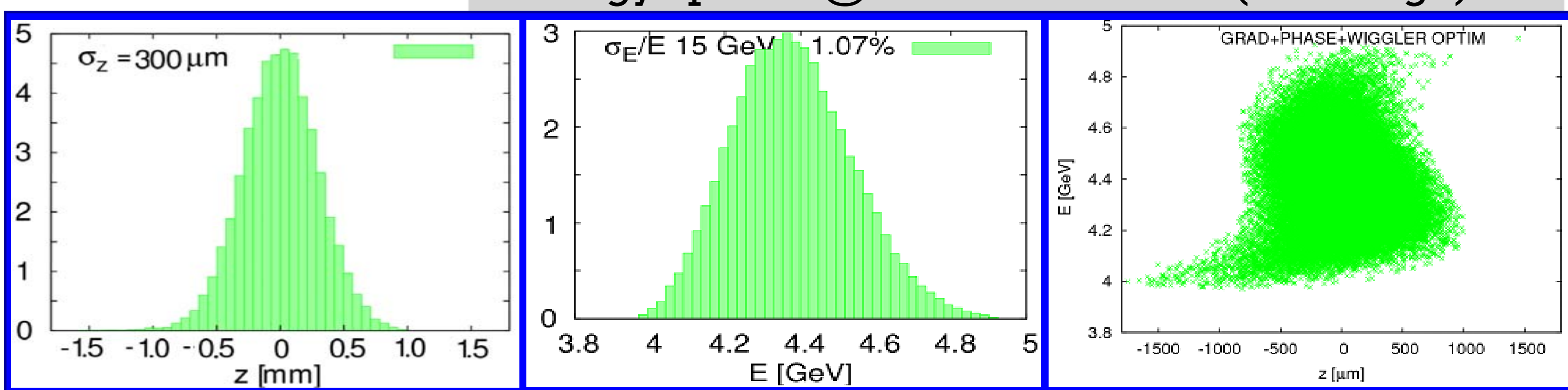
Charge	2e10 (3.2 nC)
Energy	5 GeV
Energy spread	0.15% (0.13% from DR)
Bunch Length	6 mm

- Properties of the bunch compressor:

Integrated voltage	1275 MV @ 1.3 GHz
Cavity gradient	$\approx$25.6 MV/m
Accelerating Str	48 (6 CM ; old-type)
Phase	-119.5 degrees
Energy Loss	627.9 MeV
R_{56}	-147.5 mm
Total length	$\sim$433 m

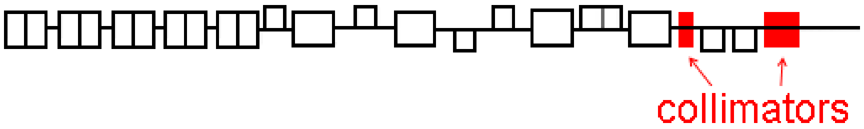
After optimization:

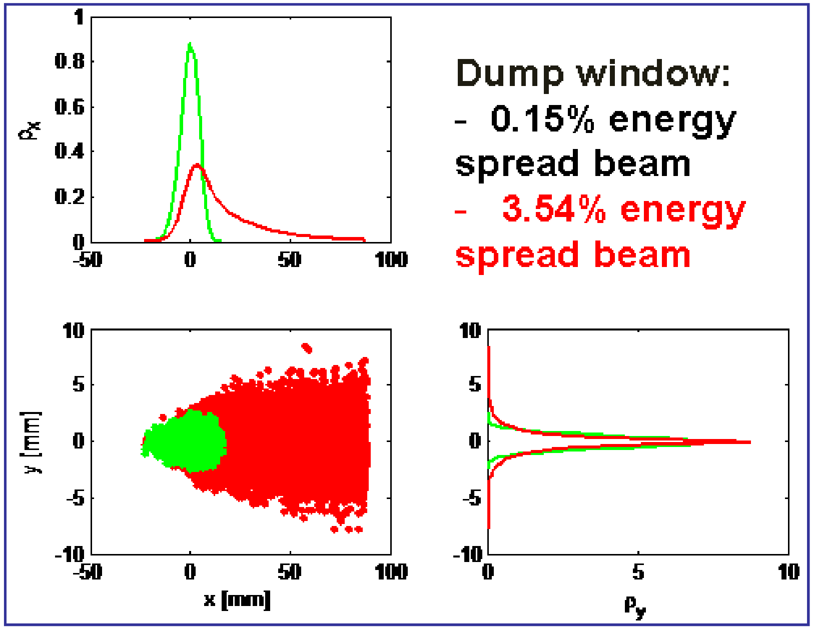
- Bunch length = 300 um
- energy spread = 3.54 %
- energy spread @ 15 GeV = 1.07 % (as 2-stage)



Need modifications: CM type4, modified wiggler design, shorter EL on beamline (shorter system with better performances)

Extraction Line after BC1S: Collimation summary





- Designs for 3 Extraction Lines done.
- Re-design EL after BC1S → first look
- <u>Example: Option with Strong collimation</u>
    - Two collimators to protect the doublet and use dump with small window *(details: S.Seletskyi talk)*

	No collimation	No collimation SC magnets	1 collimator (weak collimation)	2 collimators (strong collimation)
Collimators			1.9kW/train; 7.4mm horiz. aperture	2.2kW &11.7 kW per train 7.2mm & 50mm H-aperture
Sextupoles	1T pole tip field; exotic shape	Two sextupoles 12cm aperture and pole tip filed <6T	1T pole tip field	
Dump	12.5cm diameter	60cm diameter	60cm diameter	20cm diameter

Simulation Studies on ILC Bunch Compressor with SLEPT

Dou WANG and Kiyoshi KUBO

Summary

1. Coupler wake has been newly introduced to SLEPT. Final vertical emittance growth in RDR BC RF section including coupler RF kick and wakes is :

    BC1: 0.21 nm

    BC2: 4.41 nm

2. DFS changing RF phase was introduced in SLEPT.
3. This DFS is not very effective to cavity tilt. (Should be checked.)
4. With all other errors except for cavity tilt, the final emittance growth can be controlled to 0.5 nm. But the final emittance growth will be 6 nm including 200 urad cavity tilt.
5. SLEPT is being improved to include Z-position change for BC.

Summary Table of Vertical Emittance Growths in BC

	Technique	Misalignments	Couplers[1]	Misalign+Couplers
BC1S	DFS	14.8 nm	4.8 nm	27.0 nm
	BUMPS	1.47 nm	3.4 nm	4.6 nm
	GIRDER	0.8 (*) nm	2.2 nm	2.6(*) nm

	Technique	Misalignments	Couplers[1]	Misalign+Couplers
BC1+BC2	DFS	91.2 nm	7.7 nm	371.0 nm
	BUMPS	2.1 nm	4.3 nm	6.9 nm
	GIRDER	-	0.8 nm	2.0 nm

(1) 1 machine

(*) 40 machines

A.Latina

- Emittance growth due to misalignments and couples seems to compensated both for BC1S and BC1+BC2
- Girder Pitch optimization is very effective to counteract coupler kicks, both for BC1S and BC1+BC2
- In BC1S, Crab Cavity Option seems to be similarly effective, but it would require a slight redesign of the RF stage