RTML

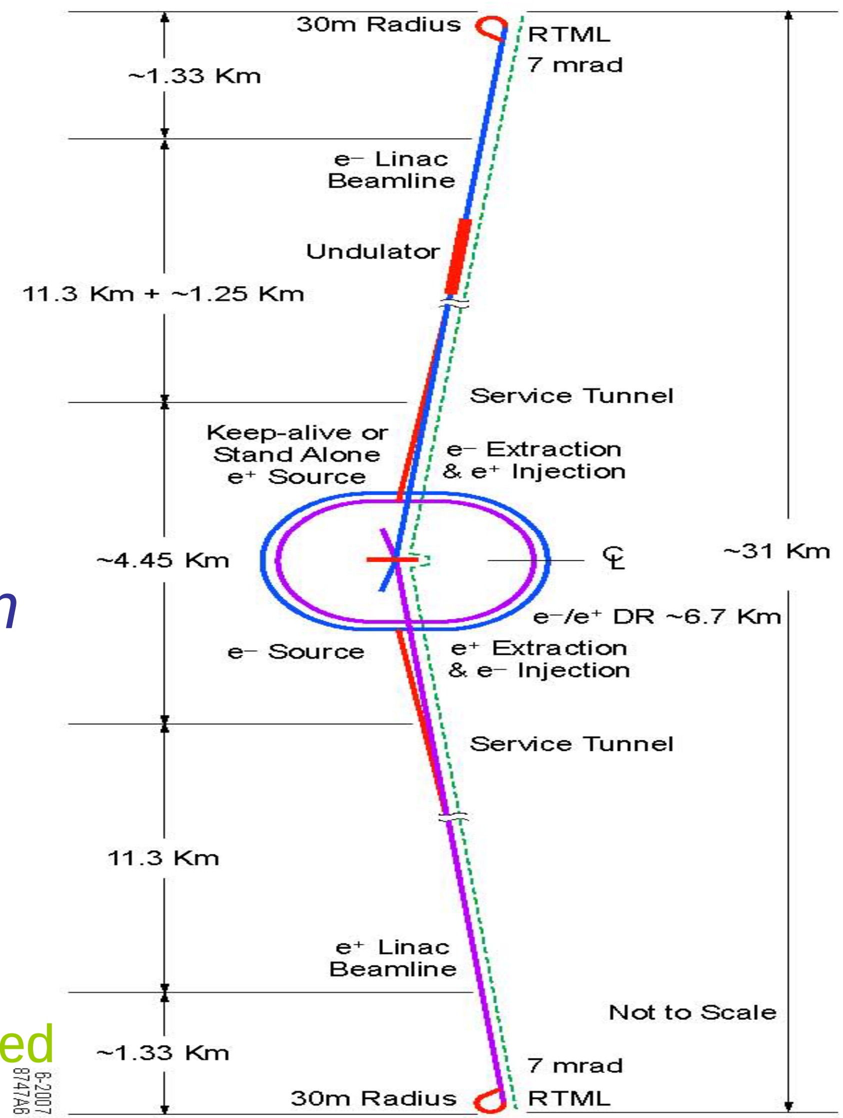
N.Solyak

Outline

- RTML RDR Design
- Technical Systems
- Cost breakdown and Risks
- Summary from RTML KOM
- Proposal for EDR Work Packages

RTML Functions

- *Transport Beam* from DR to ML
  - *Match Geometry/Optics*
- *Collimate Halo*
- *Rotate Spin*
- *Compress Bunch*
- *Preserve Emittance*
  - *vertical norm. emittance < 4nm*
- Protect Machine
  - 3 Tune-up / MPS abort dumps
- Additional constraint:
  - Share the tunnel with e-,e+injectors
  - Need to keep geometries synchronized



Geometry Matching

- Horizontal Arc out of DR ~km straight
  - **In injector tunnel**
- “Escalator” vertical dogleg down to linac tunnel
- ~11 km FODO lattice
  - **In linac tunnel**
  - **Vertically curved**
- Vertical and horizontal doglegs
- Turnaround
- 8° arc in spin rotators
- BCs are net straight

DRX-Connection,

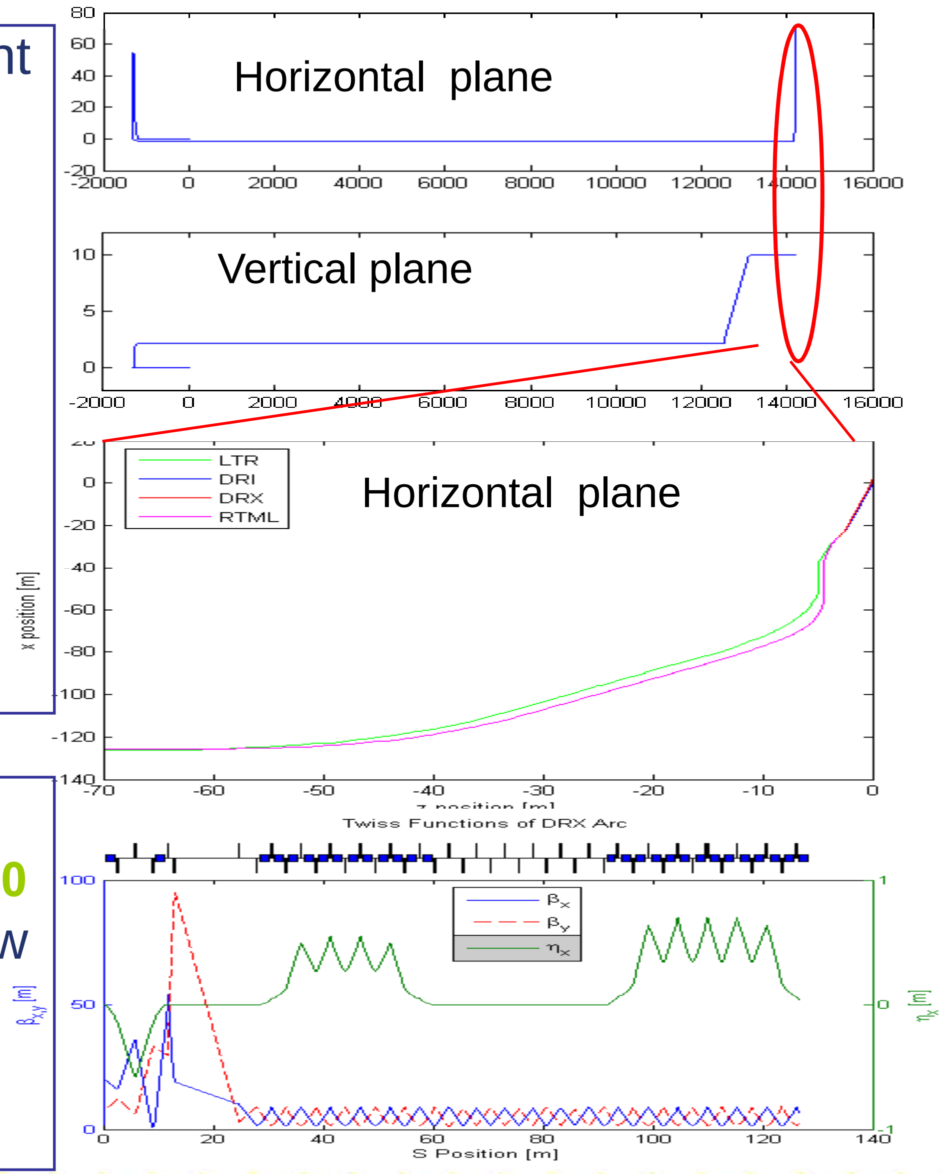
DR-RTML hand-off point defined

- extraction point where η,η’ → 0

RTML mostly defined by need to follow LTR geometry

- Stay in same tunnel

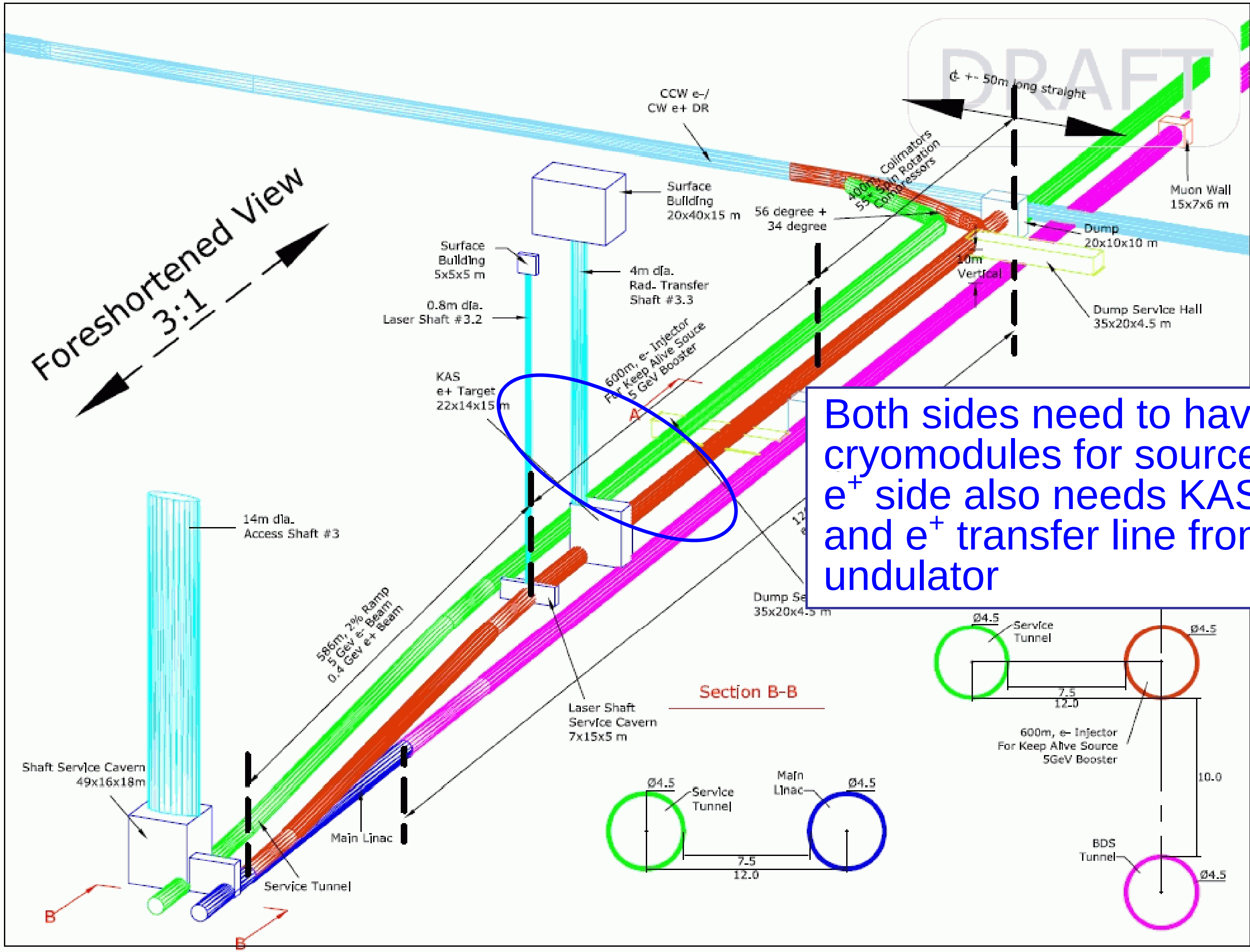
Design is OK at *conceptual* level



DR connection

Discussed possible Modifications

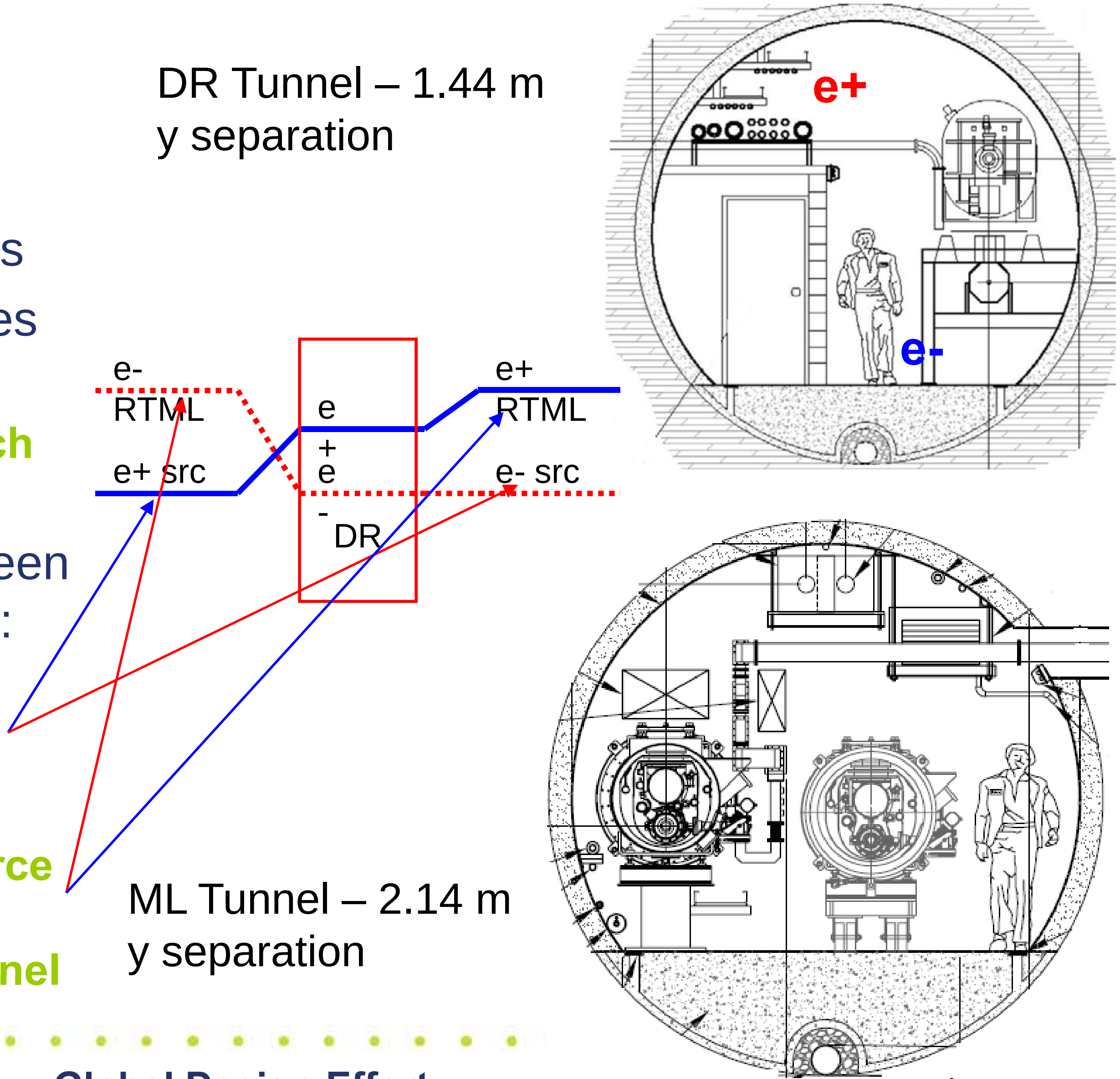
- No elevation for the service tunnel
- ML and LTR/RTML tunnels merge in horizontal plane
- Shorter ?



Both sides need to have cryomodules for sources; e^+ side also needs KAS and e^+ transfer line from undulator

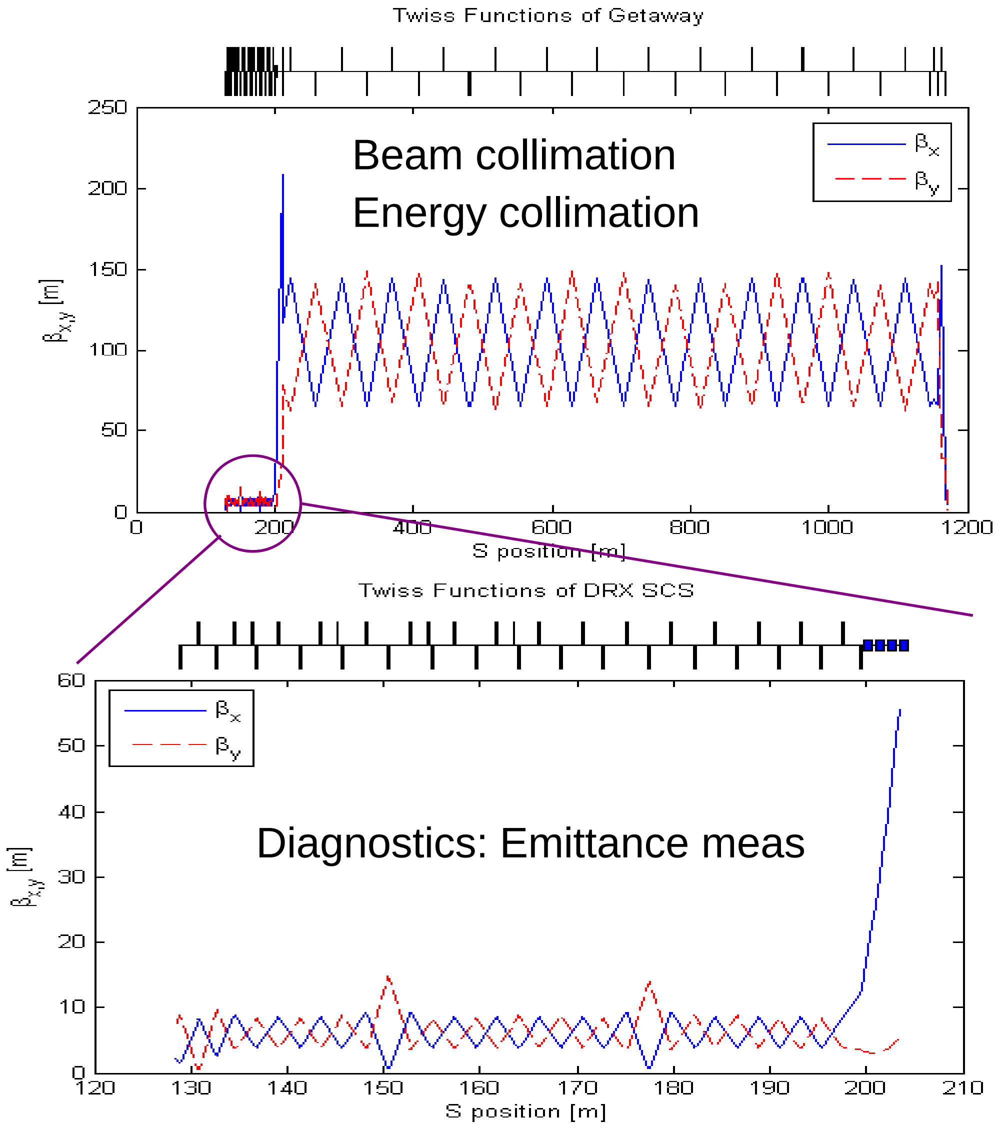
DRX Connection (2)

- Current design is entirely planar
  - **All bending in *xz* plane**
- DRs are in different planes
- Sources need cryomodules and SC solenoids
  - **Big heavy objects which want to sit on the floor**
- Working agreement between sources, DR, RTML, CFS:
  - **Lower ring is e-**
  - **CMs and SC solenoids always sit on floor**
  - **RTML hangs from source tunnel ceiling at same location as in linac tunnel**



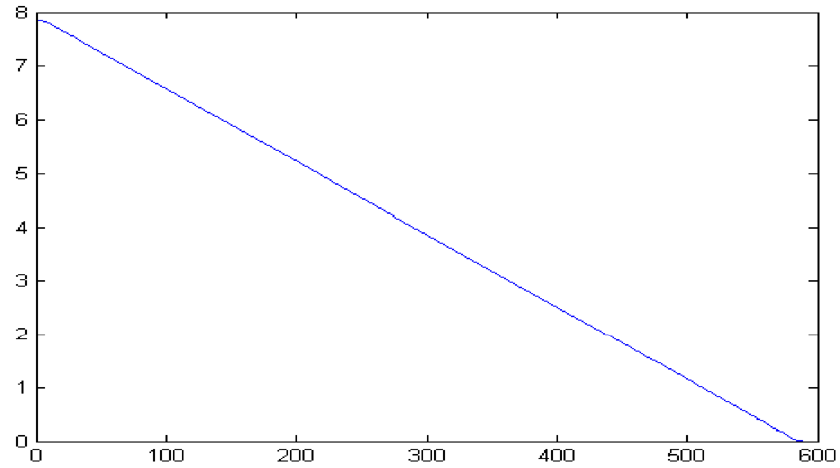
"Getaway" Straight (or "DR Stretch")

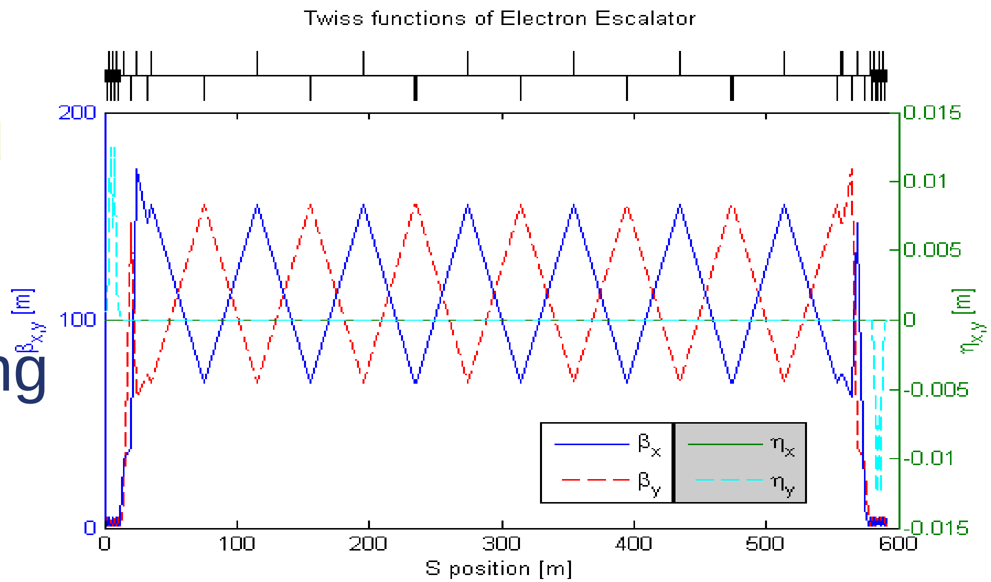
- About 1.1 km long
- Has two parts
  - **"Low-beta" region with decoupling and emittance measurement**
  - **"High-beta" region with collimation system**
- Includes PPS stoppers
  - **For segmentation**
- Good conceptual design
  - **Need to match exact required system lengths**
  - **Need to consider conflicts with source beamlines in this area**
  - **Beta match between low- and high-beta optics not great**



Escalator

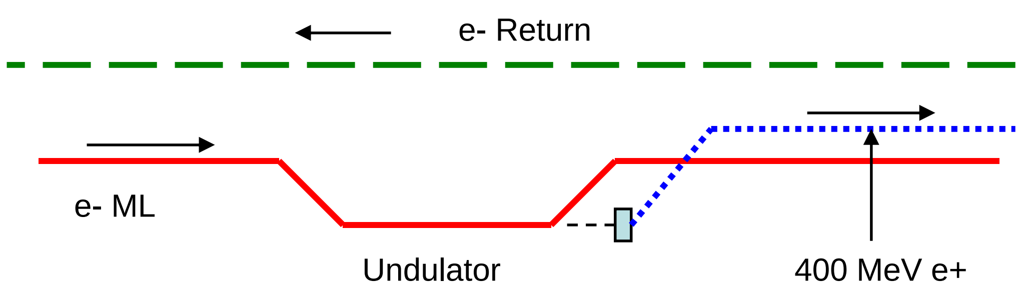
- Vertical dogleg
  - –Descends 7.85 meters over ~590 m
  - –Uses 2 vertical arcs separated by weak FODO lattice
- Good conceptual design
  - –Escalator-linac tunnel connection does not match CFS design
  - –Uses Keil-style eta matching
  - –Beta match between “strong” and “weak” lattices not great
  - –Positron return line confilicts?
- Need to make match according CFS (new?) design

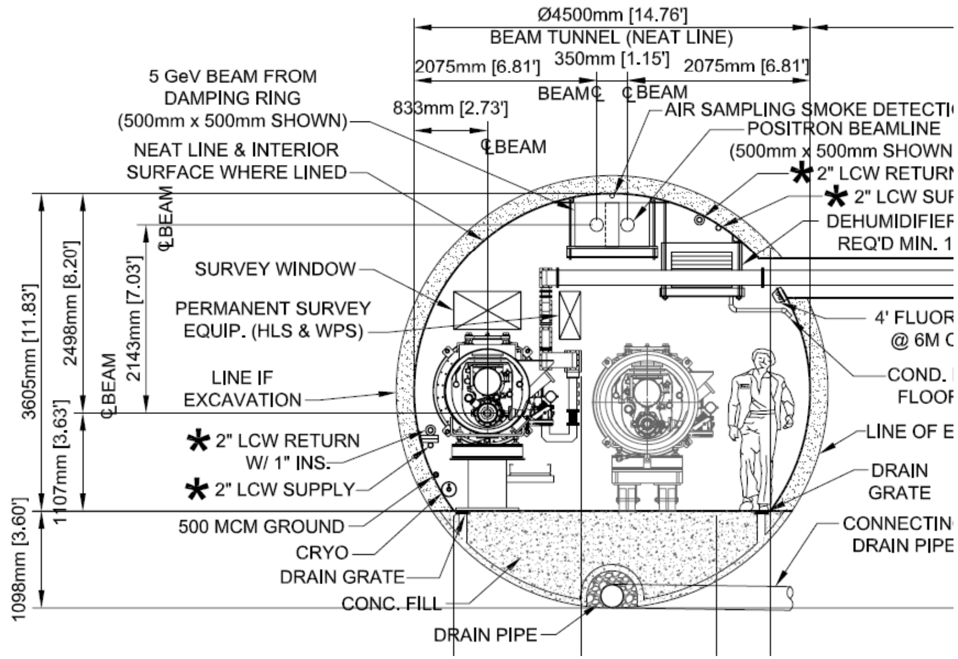




Return Line

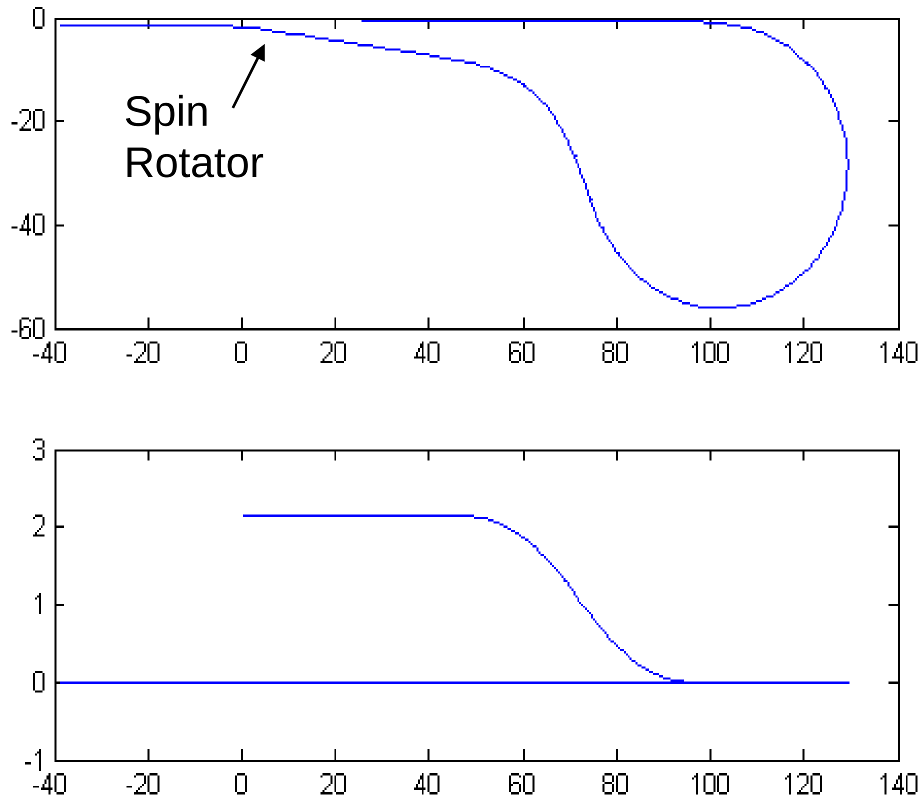
- Weak FODO lattice at ML ceiling elevation (1Q/~36m)
- Vertically curved tunnel thru ML area
  - **Dispersion matching via dipole correctors**
- Laser-straight tunnel thru BC area
- Electron line 1.2 km longer than positron
  - **Goes thru undulator area**
- System lengths probably not exactly right
- Electron Return line and positron transfer line need to be exchanged





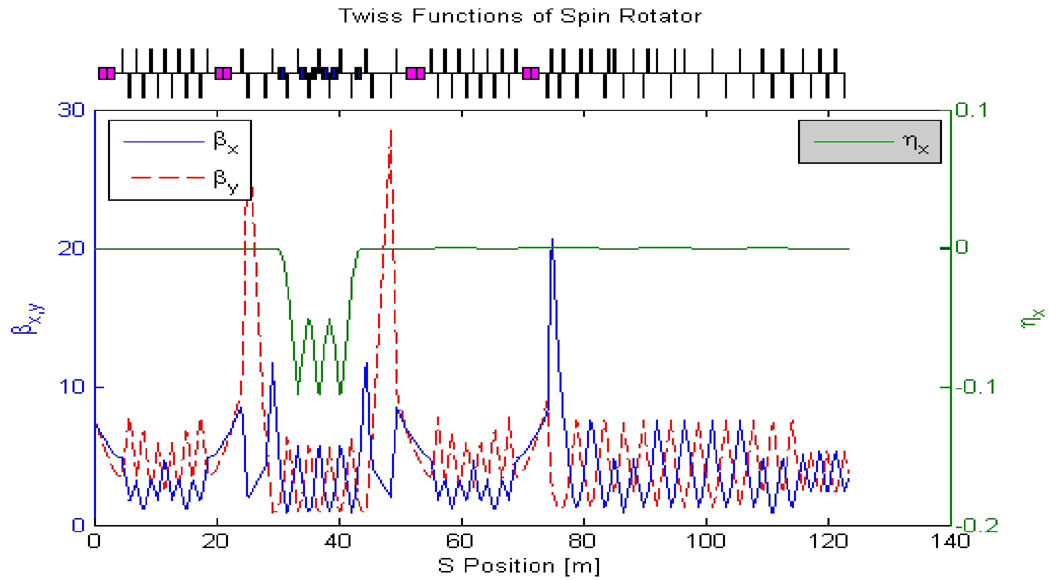
Turnaround

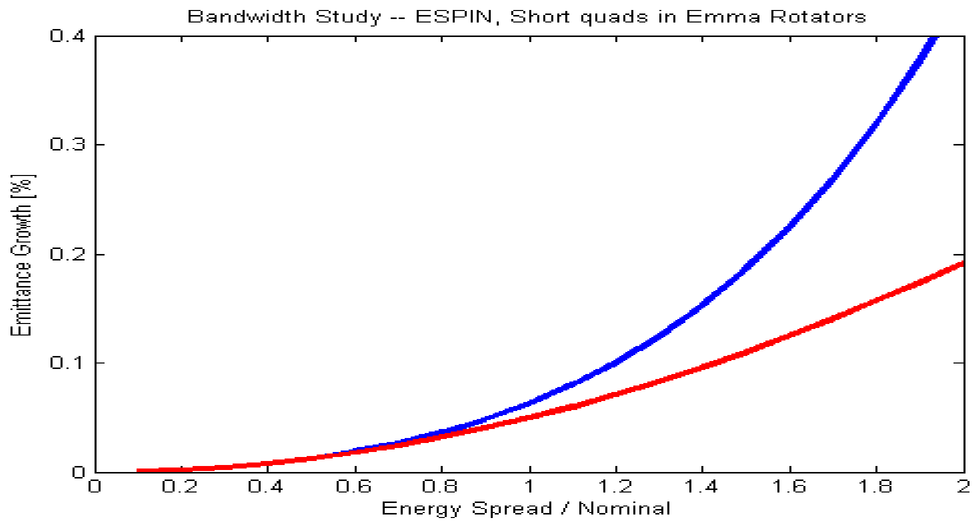
- Actually does 3 jobs
  - **Turns the beam around**
    - Note: need to bend *away* from service tunnel
  - **Brings beam down from ceiling to linac elevation (near floor)**
    - Vertical dogleg
  - **Adjusts x position to meet linac line**
    - Horizontal dogleg
  - **Order: H dogleg, V dogleg, turnaround**
  - **Packing area, ~90% magnets**



Spin Rotation

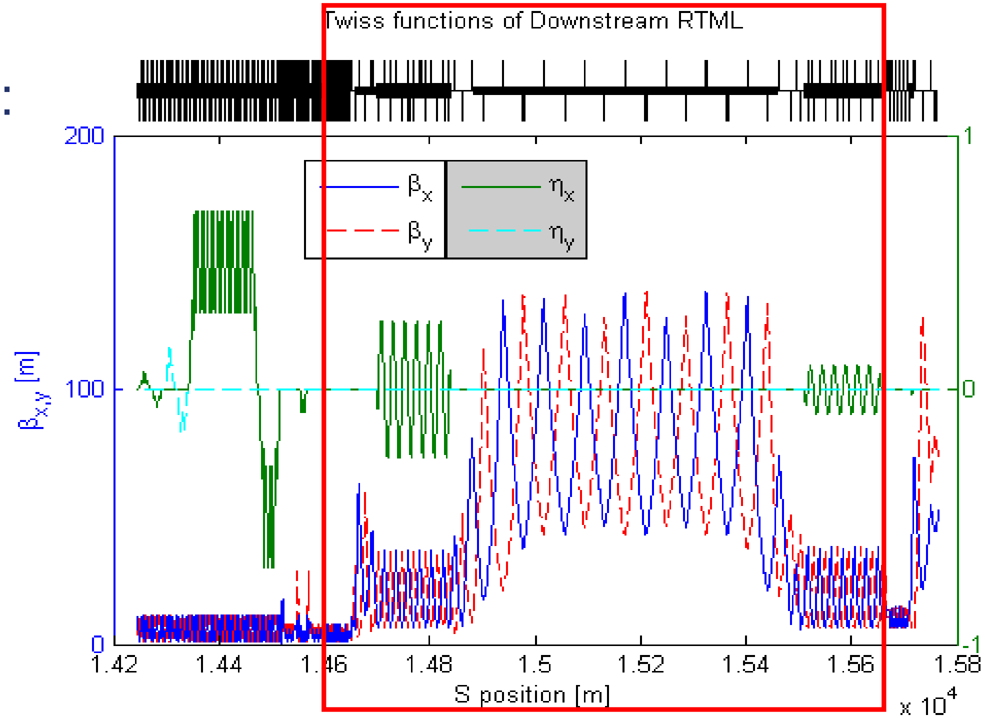
- Design based on Emma's from *NLC ZDR*
  - **2 solenoids with Emma rotator between them**
    - Rotate spin 90° in xy plane while cancelling coupling
  - **8° arc**
    - Rotate spin 90° in xz plane
  - **Another 2 solenoids + Emma rotator**
- Basic design seems sound
  - **Very small loss in polarization from vertical bending in linac tunnel**
- Important issue = bandwidth
  - **Off-energy particles don't get perfect cancellation of dispersion and coupling**





Bunch Compression

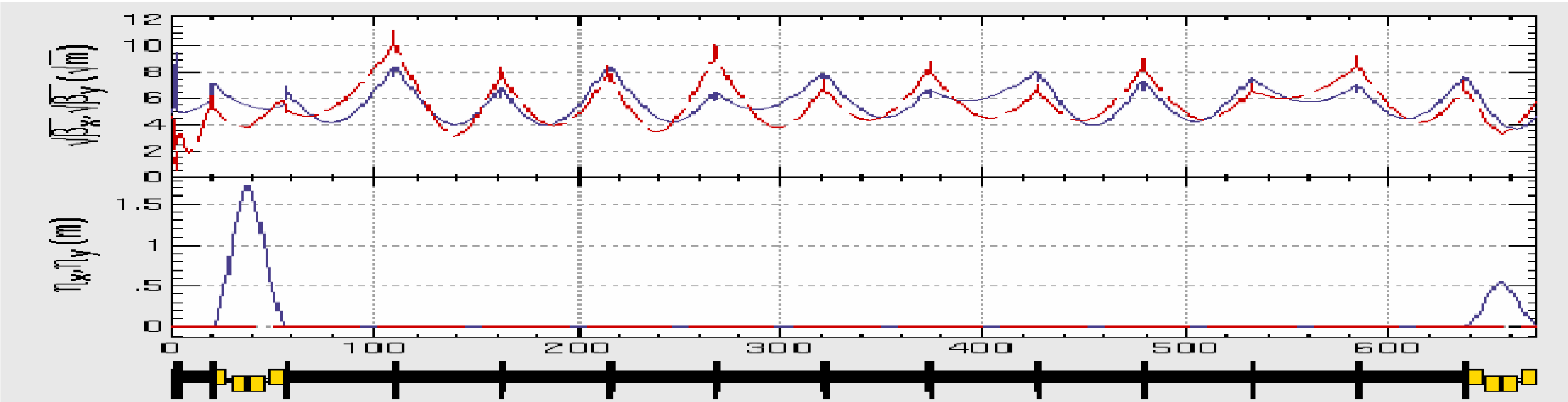
- Longitudinal emittance out of DR:
  - **9 mm RMS length**
  - **0.15% RMS energy spread**
- Want to go down to 0.2-0.3 mm RMS at IP
  - **Need some adjustability**
- Use 2-stage BC to limit max energy spread
  - **Compress to ~1 mm at 5 GeV**
  - **Accelerate to ~15 GeV**
  - **Compress to final bunch length**
- DRX arc and turnaround have R_{56} = 2.9 m
  - **Need to include this in design**



- BC1 has 3 CMs with quads (+ spare kly)
- BC2 has 14 linac-style RF units + 1 spare
- Both stages use 6-cell lattice with quads and bends to achieve momentum compaction (wiggler)
  - **Big aperture of magnets ~40cm**

Alternative Bunch Compressor

- An alternate bunch compressor design exists
  - 6-cell wigglers (~150 m each, 102 bend magnets) replaced by chicanes (~40 m each, 4 bend magnets)
  - Advantages – **Shorter, Simpler, Cheaper (?)**
  - Disadvantages:
    - Big x offset from straight line (~1.8 m)
    - Doesn't have natural locations for dispersion tuning quads
- Need to carefully evaluate the two existing BC schemes
  - Maybe neither one is optimal?



Halo and Energy Collimation

- ILC specification:
  - **Needs to limit halo at end linac to ~10^{-5} of total beam power**
- Halo Collimation after DR
  - **BDS specification as requirement**
    - Halo power ~ 220 W
    - Provide machine protection
      - Collimators stop out-of-control beam from DR
      - Need to keep out-of-control beam from frying collimators, too!

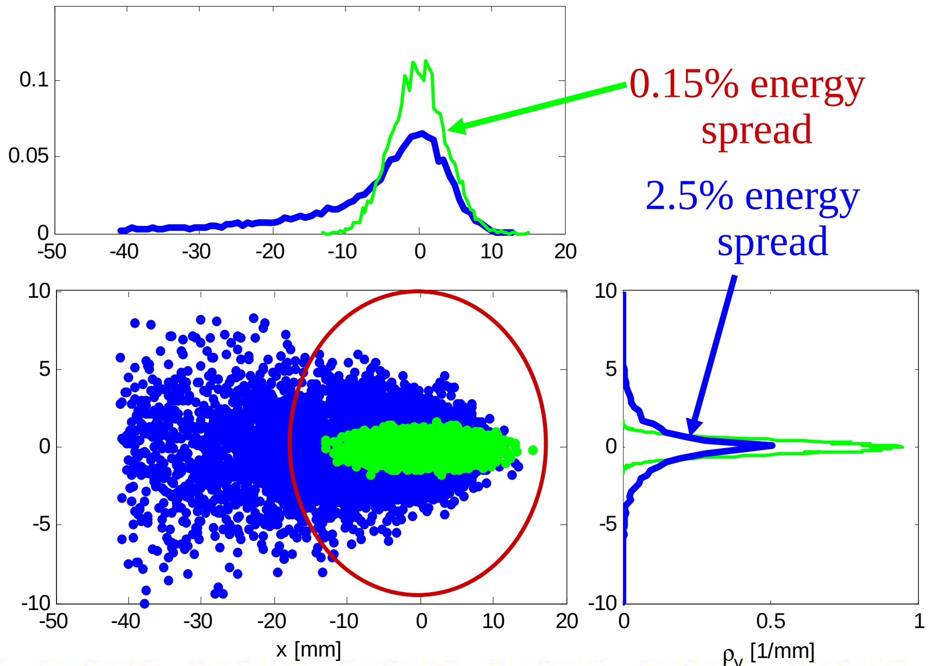
- Need energy collimators after betatron collimation system
  - **Scattered particles**
  - **Off-momentum particles / bunches from DR**
- Additional energy collimators
  - **In BC1 wiggler**
  - **In BC2 wiggler**
- Need to understand machine protection issues for these collimators

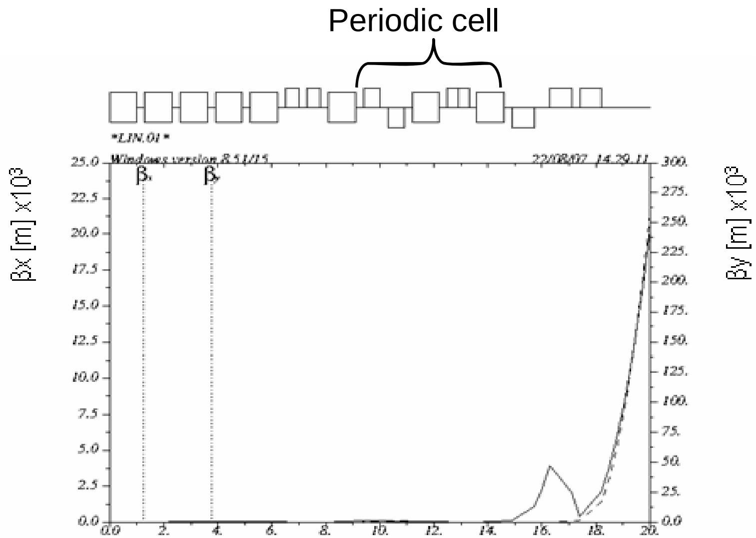
Pulsed Extraction Lines

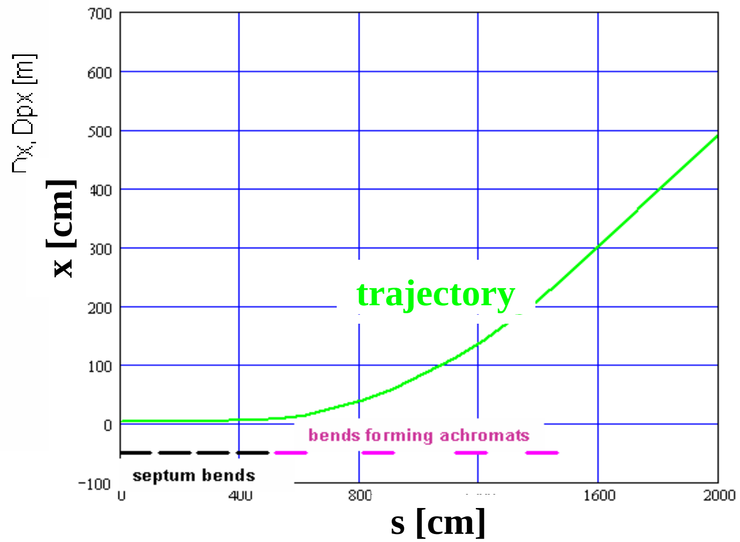
- Current design calls for 3
  - **After DR Ext, diagnostics, global correction**
    - Keep DRs running @ full power during access
    - Keep DRs and extraction tuned during access
    - MPS abort
  - **After BC1**
    - Tune up BC1 without beam in BC2
    - MPS abort
  - **After BC2**
    - Tune up BC2 without beam in linac
    - MPS abort
- All have 220 kW beam handling power
  - **Full power for DRX, BC1**
  - **1/3 power for BC2**

Recent Dump Line Design

- Separation of the two lines at CM location -2m;
- Separation of the dump and the ML is 5 m;
- Size of the beam on the dump window ~9 mm^2
- DL2 with two collimators (12mm and 30 mm fixed apertures), intercepts 3kW/train and 9.5kW/train of beam power respectively.
- DL3 (15GeV) will be ~5m longer

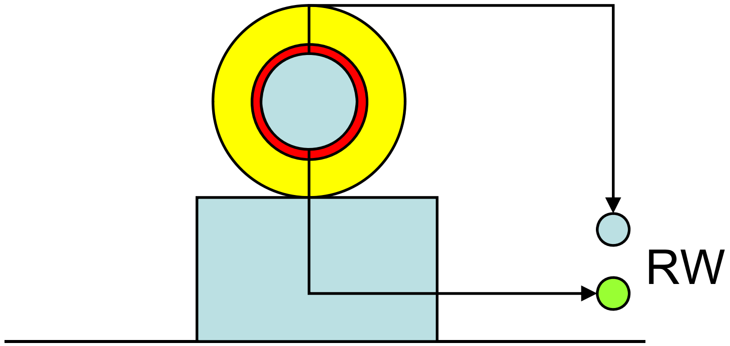






Six ~220kW Aluminum Ball Dumps

50cm Diameter x 2m long Aluminum Ball Dump with Local Shielding

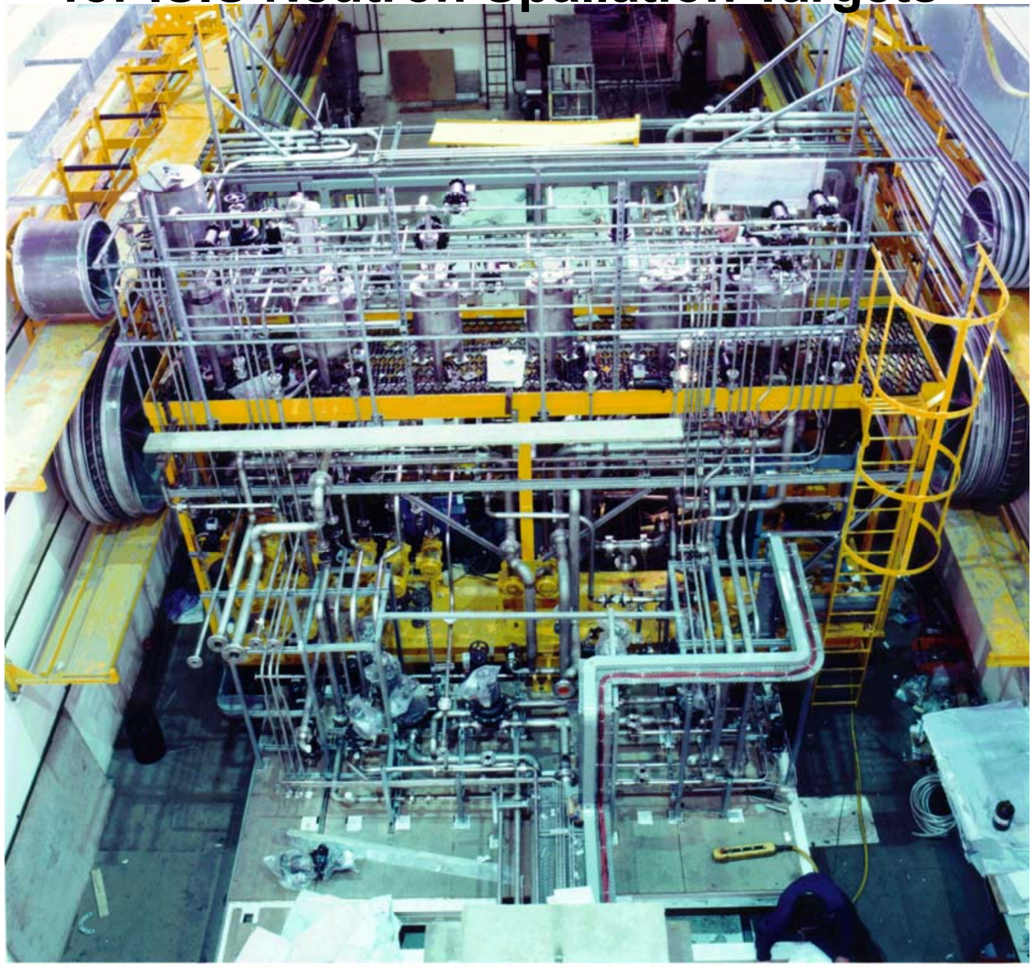


Cost Basis

- **100k$ vessel (Walz)**
- **300k£ ISIS plumbing**
- **150k£ ISIS controls & monitoring**

Total $1M each

50kW 3-loop 2006 Rad Water Cooling for ISIS Neutron Spallation Targets



Technical Systems

- Magnets and power supplies (~4600 Magnets)
  - **SC quads/correctors/solenoids,**
  - **RT quad, correctors,**
  - **Pulsed magnets, kickers, bends, FB correctors**
- Vacuum system
  - **Current baseline**
    - 2 cm OD stainless chambers
      - Exceptions: BC bends, extraction lines, CMs
    - 20 nTorr in long line from DR to turnaround
      - Passivated to reduce outgassing rate
    - 100 nTorr in balance of system (turnaround to linac)
    - Not *in situ* baked
    - No photon stops or water cooling in bend areas
- Dumps and Collimators
  - **3 dumps per side with 220 kW capacity**
  - **Betatron and energy spoilers / absorbers with ~200 W capacity**
  - **Few collimators with ~10 kW capacity**

Technical Systems (2)

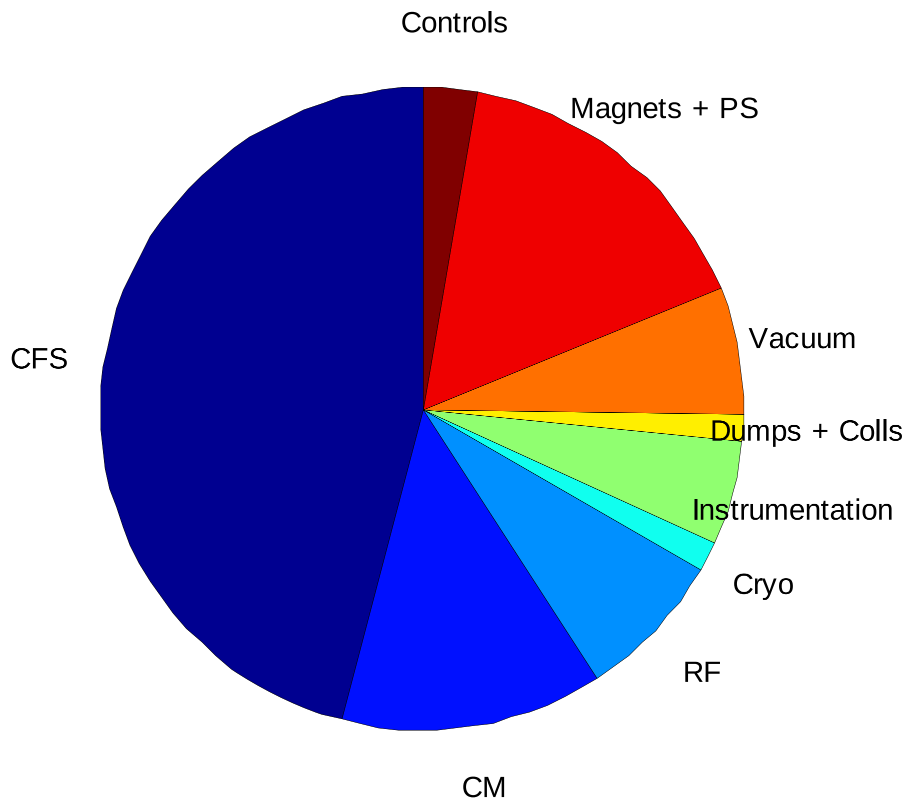
- Instrumentation
  - **BPMs at every quad, plus high dispersion points in wigglers**
    - Serve a number of functions: feedback, feed-forward, beam-based alignment and steering, energy diagnostic
    - Original plan: dominated by room-temp C band cavity BPMs
    - Long DR bunches $\rightarrow$ L-band cavities may be more suitable upstream of BC2
      - Larger cost, larger tunnel footprint, lower natural resolution?
  - **3 suites of laser wires in each RTML**
    - 4 wires per suite, set up for 2D emittance measurement
  - **Bunch length measurement**
    - LOLA + screens in each BC
      - Originally used 2.9 GHz SLAC cavities as model
      - Want to go to either 2.6 or 3.9 GHz – need to choose!
    - Possibly EO monitors (not in RDR baseline, I think)
  - **SLMOs in BC wigglers for energy spread measurement**
  - **3 dedicated phase monitors per side**

Technical Systems (3)

- 1.3 GHz SC RF system plus supporting utilities
  - **48 CMs per side (1 RF source per 3 CMs, as in ML)**
    - 3 “8Q” in BC1
    - 15 x “9-8Q-9” in BC2
    - BC1: 2nd source with RF switch for redundancy
  - **LLRF issues**
    - Phase stability, as discussed before
    - Beam loading compensation
      - Beam loads RF at decelerating phase
      - Unlike ML, need to “jump” both amplitude and phase of RF source @ beam time
  - **Cryo system (~6.5% cost of ML Cryo system)**
    - Part of ML cryogenic system
      - Also supports SC solenoids in spin rotator
    - BCs are laser-straight
      - Probably OK – only ~1 km long

Cost and its Distribution

- CFS + BC RF system = 68% of costs
  - **Correlated – much of CFS cost is housing for BC cryomodules**
- Remainder dominated by RT beam transport
  - **Quads, correctors, BPMs, vacuum system**
- Small amount of "exotica"
  - **Non-BPM instrumentation, controls, dumps, collimators**



RTML Risk Areas

- **Single-Bunch Beam Dynamics**
  - **Static Tuning: Studies of beam tuning in BC optics missed emittance target by a factor of 2**
  - **Effects of dynamic misalignments (GM, vibrations, jitters) not studied yet**
  - **Feedback/Feedforward corrections**
  - **Stray fields in Return line**
  - **Annoying collective effects not yet resolved**
    - Space charge incoherent tune spread – could cause some failure of global tuning methods
    - Resistive wakes in the vacuum chamber not looked at for Return line yet
  - **Cavity fields**
    - Wakefield and RF kick from asymmetric coupler

RTML Risk Areas (2)

- Beam-beam collision timing
  - **Need ~0.25° (0.53ps) RMS stability of RF systems in each RTML wrt common master oscillator for 2% loss in integrated luminosity**
    - For nominal – shorter bunch parameters need correspondingly tighter tolerances
  - **Time scale of a few seconds**
    - Assume direct measurement of arrival time at IP + feedback to correct drifts which are slower than this
  - **Beam loading compensation**
    - RTML runs far off-crest
    - When beam arrives, need to change phase and power of RF station to compensate beam-induced fields and stay at correct voltage and phase

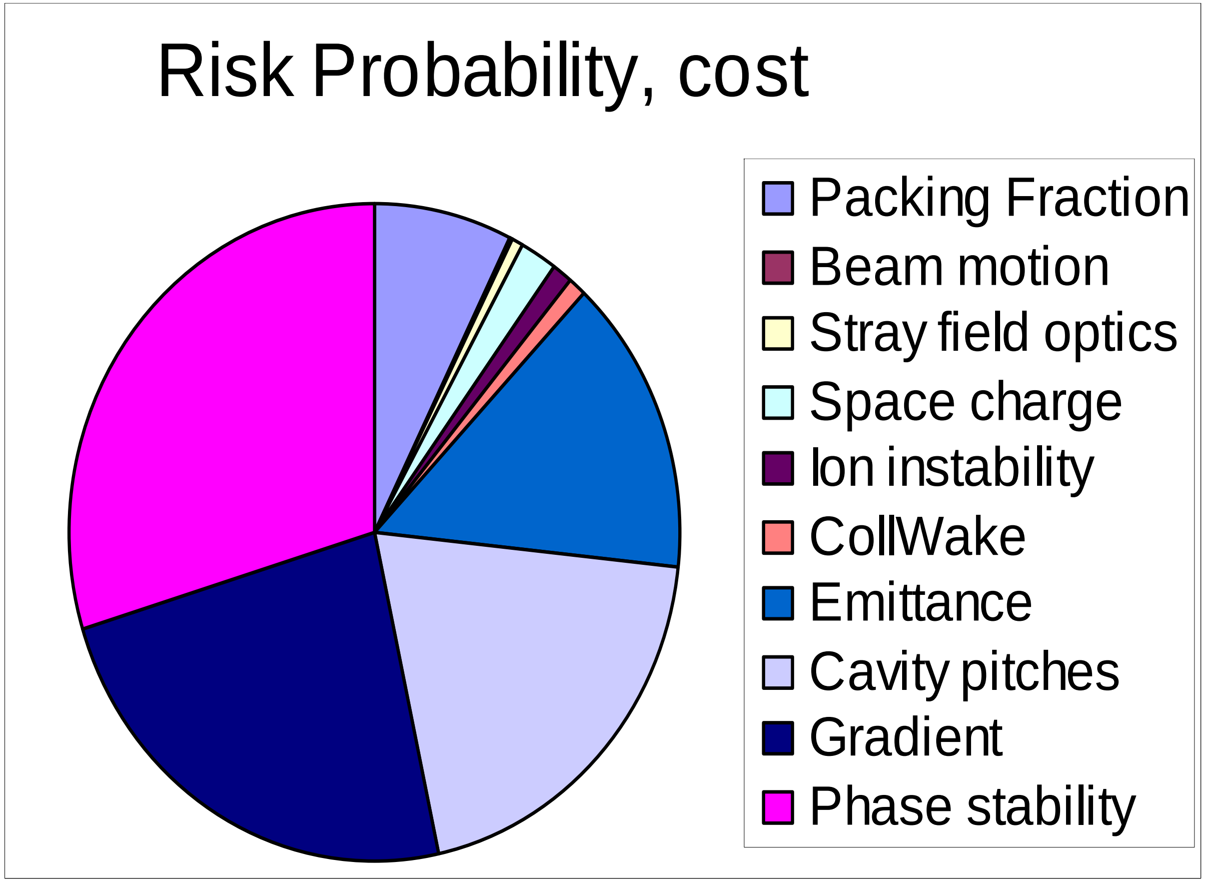
RTML Risk Areas (3)

- Attainable voltage
  - **BC2 runs at high gradient**
    - **30.2 MV/m for nominal, 31.0 MV/m for LowN**
  - **If attainable voltage after R & D program is lower, changes are required**
- Packing factor of dense areas
  - **Turnaround and DRX arc in particular**
  - **If desired packing factor is impossible, either more beamline length or less optimal optics is needed**
- BC1 Wiggler bend magnets
  - **Very wide (~40 cm) good field region desirable**
    - Do we still need 40 cm? Would 10-20 cm be enough?
  - **Highly unusual magnets may be needed!**

RTML system Risks

Rough estimation

Acc. Phys	9.5
Phase stability	15
Gradient	12
Cavity pitches	10
Magnet	3.6
Collimator	0.5



Wrap-Up from RTML KOM

- RTML is a large system by any standard
  - **Total length > ILC footprint**
  - **Total number of components enormous**
  - **Combined e+,e- RF systems**
- Impressive amount of design work done for RDR, nonetheless…
- …Technical maturity of RTML design is lagging
  - **Missing beamlines**
  - **Performance studies out of date and inadequate**
  - **Area, Technical, Global, Cost information are not consistent with each other**
  - **Many hardware performance specifications unknown**
  - **Required functions of various subsystems not reviewed**

RTML EDR work packages

- Working assumptions
  - **Address to solve Valuable Risks, Design and Cost issues**
  - **Not cover work already covered by ML or other technical groups, unless RTML requirements are different from RTML needs**
    - Cavities, Cryomodules, HLRF, LLRF, Cryogenic
    - Most diagnostics: Laserwire, OTR, Lola, L-band BPM
  - **Leading/coordination each Work packages by one person/one institution**
  - **Result oriented WP with goals/deliverables/milestones**
  - **Resources are limited**
    - need priorities

RTML work packages (Draft Oct.17, 2007)

1. **RTML managing and Specifications development**
   - **Specs for all technical groups, CFS**
2. **Engineering Lattice design for EDR geometry**
3. **Accelerator Physics**
   - Static Tuning study
   - Errors sensitivity study
   - Failure mode analysis
   - Specify, Study Magnetic stray fields
   - Study space-charge effects
   - Study of beam halo in the RTML
   - Dynamic tuning. Specify and develop FB/FF system
   - Beam Loss and radiation load simulations
   - Design, Specify MPS
4. **R&D on phase stability in BC1/BC2 (beam timing)**

RTML WP's (cont.)

5. Alternative Ultra-short Bunch Compressor.

- **Lattice design**
- **Control of emittance growths**
- **Sensitivity studies on machine errors**

6. Magnets and PS

- Design, specify & optimize DC conventional magnets
- Optimize number of types and apertures
- Design warm quads, bends and correctors
- Design and prototype BC wiggler wide aperture magnet
- Design, prototype quad/corrector for return line
- Design tune-up Septa and PS
- Design and Specify pulsed magnets
- Design tune-up extraction kickers and pulsers
- Design feed-back, feed-forward correctors and PS
- Design/prototype SC quad/corrector for BC1/BC2
- Design, specify SC solenoid
- Optimize PS and cabling
- Design, specify DC PS
- Design stable supports for magnets

7. **Collimation system**
   - Optics design
   - Theoretical and computer simulations of wakefields
   - Engineering design of the collimator

8. **Beam Dump system (5-15 GeV; 220kW)**
   - Energy deposition and radiation shielding simulations
   - Engineering design of the dump
   - Design / costing handling system

9. **RTML Vacuum system**
   - Engineering design of the vacuum system in RT transport line
   - Impedance design of vacuum system

10. **RTML Instrumentation**
    - Specify Instrumentation requirements, interfaces, locations
    - Specify warm BPMs
    - Alignment system design
    - Design of FF/FF system

Express of Interest process

- US participants
  - **SLAC, FNAL, Cornell Univ, ANL,**
- None US
  - **KNU, Korea**
  - **Russia - JINR, Efremov Inst., BINP**
  - **UK**
  - **Canada**
- Just started, need more efforts, wider geographic

Example: WP6 Magnets and PS

- Total number of magnets 4576.
- Number of magnet styles: 15
- plus septum, kicker.

Major Tasks and Objectives

1. Magnets and PS specifications
2. Magnets and PS conceptual design
3. Design Magnets and PS fabrication, test, installation, repair
4. Magnets and PS optimization to reduce total cost
5. Magnets and PS prototyping at the level of available funds
6. Magnets and PS tests
7. Writing EDR collaborative report

Deliverables from WP6

1. All Magnets and PS conceptual drawings, schemes
2. Conceptual drawings of magnets mounting in the tunnel
3. Drawings of all prototypes
4. Documented Prototypes test results
5. Documented Results of optimization
6. RTML Magnets and PS section of EDR

WP6: Major Milestones

1. Magnet and PS specifications	Feb. 2008
2. RT magnets and DC PS conceptual design	Oct. 2008
3. SC quadrupole package design	Oct. 2008
4. SC and pulsed magnets, PS conceptual designs	Feb. 2009
5. Magnets and PS optimization and cost analysis	Oct. 2009
6. Magnets and PS prototypes fabrication and tests	Feb. 2010
7. Finish writing EDR RTML Magnets section	May. 2010

Required Resources, Facilities

1. Experienced in Magnet Technology: Engineers, Designers, Drafters, Scientists

2. Design, Test, and Fabrication facilities

3. Who is interested and contact persons at the moment:

FNAL – N. Solyak (Area Leader), J. Tompkins, V. Kashikhin – Magnets Design, Prototyping and Tests
KEK – K. Tsuchiya – Magnets Design
SLAC – P. Bellomo – Power Supplies
UBC – T. Mattison – Pulsed Magnets/PS Design
Efremov Institute – E. Bondarchuk – Magnet Design/Prototyping
JINR – E. Syresin, N. Morozov – Magnets Design

Estimated FTE for magnets and PS: ~11 FTE

	Tuesday, Oct.23, 2007	Wednesday, Oct.24, 2007
08:30 - 09:00	Joint w Simulation (K.Kubo) – WH1E	Dumps, Collimator, stopper (T.Markiewicz)
09:00 - 09:30		Vacuum (J.Noonan)
09:30 - 10:00		Cryogenic (T.Peterson) – WH9SE
10:00 - 10:30	Coffee	Coffee
10:30 - 11:00	Magnet & PS (J.Tompkins) WH9SE	BC phase stability R&D (S.Nagaitsev)
11:00 - 11:30		Instrumentation (RTML & MLI) M.Wendt WH9SE
11:30 - 12:00		
12:00 - 13:30	Lunch	Lunch
13:30 - 14:00	joint with CF&S and BDS (Tom Lackowski) WH9SE or	Instrumentation (BDS/ML/RTML) M.Wendt - WH3NE
14:00 - 14:30		
14:30 - 15:00		EDR Planning – WH9SE
15:00 - 15:30	Coffee	Coffee
15:30 - 16:00	EDR Planning (N.Solyak) WH9SE	Beamline Lattice Formats (PT)
16:00 - 16:30		
16:30 - 17:00		

Summary