Part I of Summary for WG C/D

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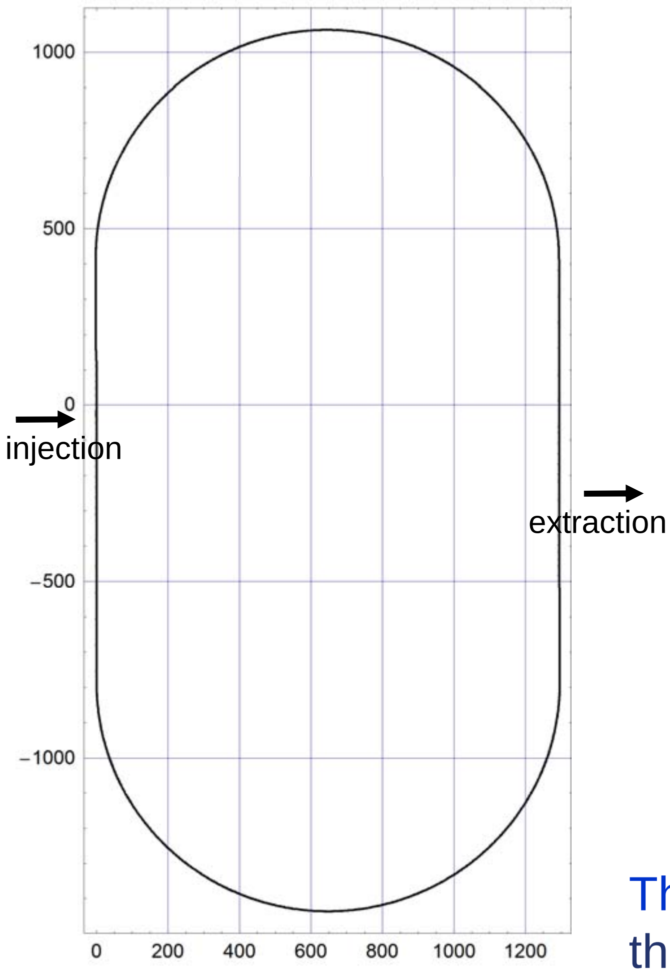
ILC Damping Rings: Configuration, Siting and Staging

- Overview of present damping rings baseline configuration
- Configuration constraints:
  - timing issues; bunch charge & spacing; CFS
- Potential alternative configurations, and their implications
  - Dogbone.
  - 3 km circumference rings.
  - Pre-existing 6 km tunnel.
  - Surface construction.
  - Reduced specifications for subsystems (wiggler, rf…)

Present Configuration: DCO Lattice



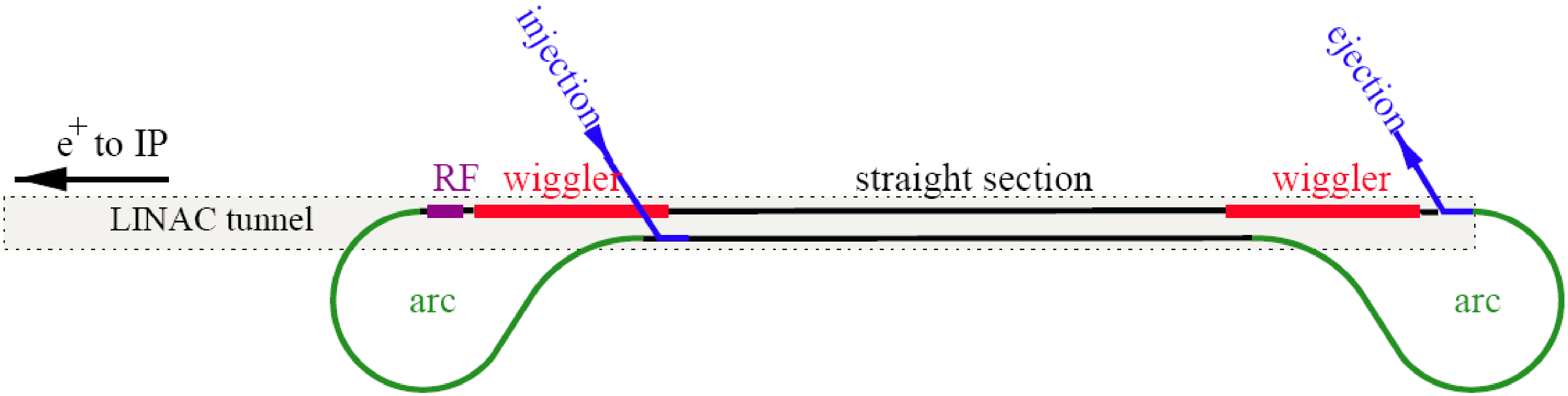
- Two 'identical' rings in a single tunnel.
- Arcs consist of a total of 192 FODO cells
- Flexibility in tuning momentum compaction factor, given by phase advance per arc cell:
  - **72° phase advance: α_p=2.8×10^{-4}**
  - **90° phase advance: α_p=1.7×10^{-4}**
  - **100° phase advance: α_p=1.3×10^{-4}**
- No changes in dipole strengths needed for different working points.
- Racetrack structure has two similar straights containing:
  - **injection and extraction in opposite straights**
  - **phase trombones**
  - **circumference chicanes**
  - **rf cavities, wiggler**
- "doglegs" to separate wiggler from rf

The present baseline is relatively conventional, and limits the risks to issues/components that can be tested at:

electron cloud (CesrTA);

fast injection/extraction kickers (ATF).

Dogbone Damping Ring



- From TESLA TDR (March 2001).
- Straight sections ~ 7.5 km located in ML tunnel+ 2 arcs ~ 1 km
- Reduced total amount of tunnel, while allowing large (20 ns) bunch spacing in the damping rings, relaxing kicker specifications.

  - Specific concerns for the dogbone configuration include:
    - **space charge;**
    - **dynamic aperture;**
    - **stray fields**

Would it be any cheaper than the present configuration?

3 km Damping Rings

- Purely from point of view of the lattice design, a 3 km ring is probably feasible.
  - **Considered in the 2005 Configuration Studies.**
- We can't put the bunches any closer together.
  - **kicker performance, electron cloud, ions…**
- If we halve the circumference, then:
  - **Halve the bunch train length (halves the luminosity?)**
  - **Stack two electron rings and two positron rings all in the same tunnel**
- 3 km rings may provide a possibility for a staged solution.
  - **Start with a single 3 km tunnel with one electron and one positron DR (half luminosity).**
  - **Upgrade by adding additional rings in a new tunnel, or (less desirably) installing additional rings in existing tunnel.**

Pre-existing 6 km tunnel

- Precise circumference is critical to timing issues.
  - **The harmonic number does not have to be exactly 14042, but we will lose some, or even all, operational flexibility (fill patterns, bunch charge) if it is not.**

- Any proposed tunnel would need to be carefully evaluated from point of view of space, services, installation, survey and alignment etc.

- Geometry is a tight (and often unpleasant) constraint on the lattice design.

Staging the RF Installation?

Phase advance per arc cell (approx)	72°	90°	100°
Momentum compaction factor	2.80×10^{-4}	1.73×10^{-4}	1.29×10^{-4}
Normalised natural emittance	6.53 μm	4.70 μm	4.27 μm
RF voltage	31.6 MV	21.1 MV	17.2 MV
Bunch length (rms)	6 mm	6 mm	6 mm
RF acceptance	2.35%	1.99%	1.72%
Synchrotron tune	0.061	0.038	0.028
Horizontal tune	64.750	75.200	80.450
Natural horizontal chromaticity	-76.5	-95.1	-106.9
Vertical tune	61.400	71.400	75.900
Natural vertical chromaticity	-75.6	-93.4	-103.5

Possible scenario: start with low momentum compaction factor and (if necessary) low bunch charge; then upgrade rf and momentum compaction factor to push for higher bunch charge.

Conclusions (1)

- Present baseline configuration has been developed to balance cost and technical risk.
  - **Key issues related to the baseline configuration, such as kicker performance and electron cloud, can be addressed at test facilities.**
- Alternatives are possible. Should be considered as we learn more about costs, technical possibilities, limitations.
  - **Dogbone damping ring: costs; a number of dynamical issues may be difficult to address before construction.**
  - **3 km damping rings: provide the possibility of a staged installation; somewhat nervous about four rings in a single tunnel.**
- Pre-existing 6 km tunnel provides the potential for significant cost savings...

  ...but could also impose potentially difficult constraints on geometry and circumference.

Conclusions (2)

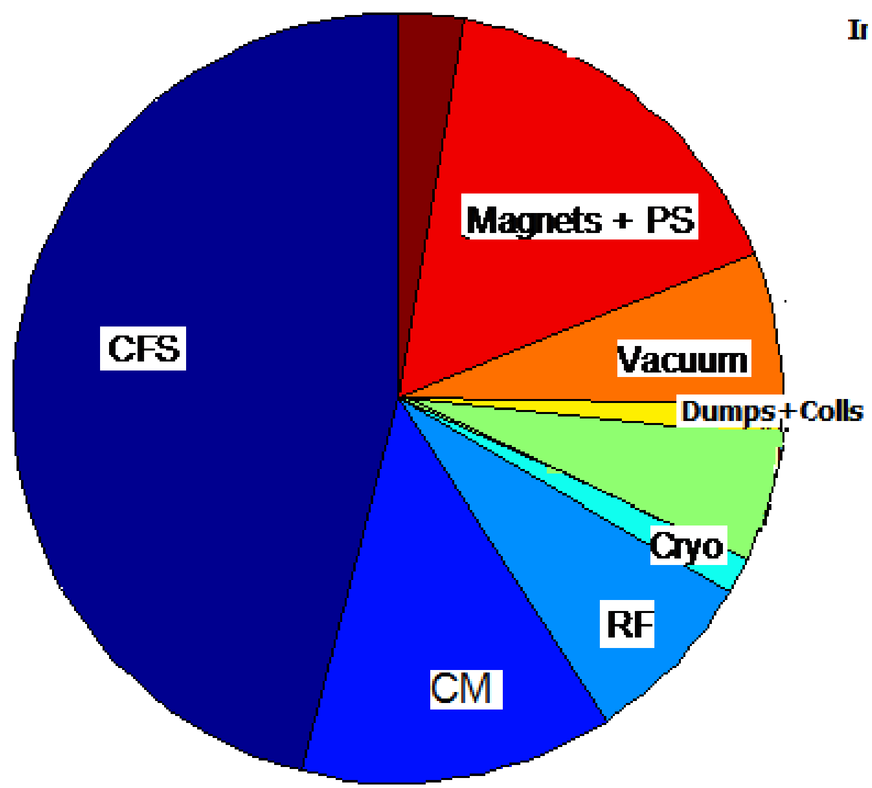
- Surface construction may impact operational performance, by adversely affecting beam stability, and requiring more time for tuning.
- Scope for reducing technical subsystems and component specifications is rather limited.
- There are a couple of possibilities for cutting specifications, at least in the early stages...
  - **Reducing the wiggler: would impact extracted emittances, and increase vulnerability to collective effects.**
  - **Reducing the rf: may be an option if operation at low momentum compaction factor is possible...but cost savings will be rather modest.**

Follow-up Discussion

- Possibility of 6 km ring with dogbone layout (N.Walker)
  - **one of the option considered in 2005 Configuration Studies.**
  - **Lattice exist → base for estimates**
- 3 km options was also considered in 2005
  - **Lattice exist → base for estimates**
- DR position with in ILC has to be considered in context of overall system integration
  - **Same elevation or above BDS tunnel (10, 20… m?), ….**
- Options for positron source
  - **Need to consider impact to the DR**
  - **Stacking is probably OK**
  - **Injected beam size should not be larger than in present specification**

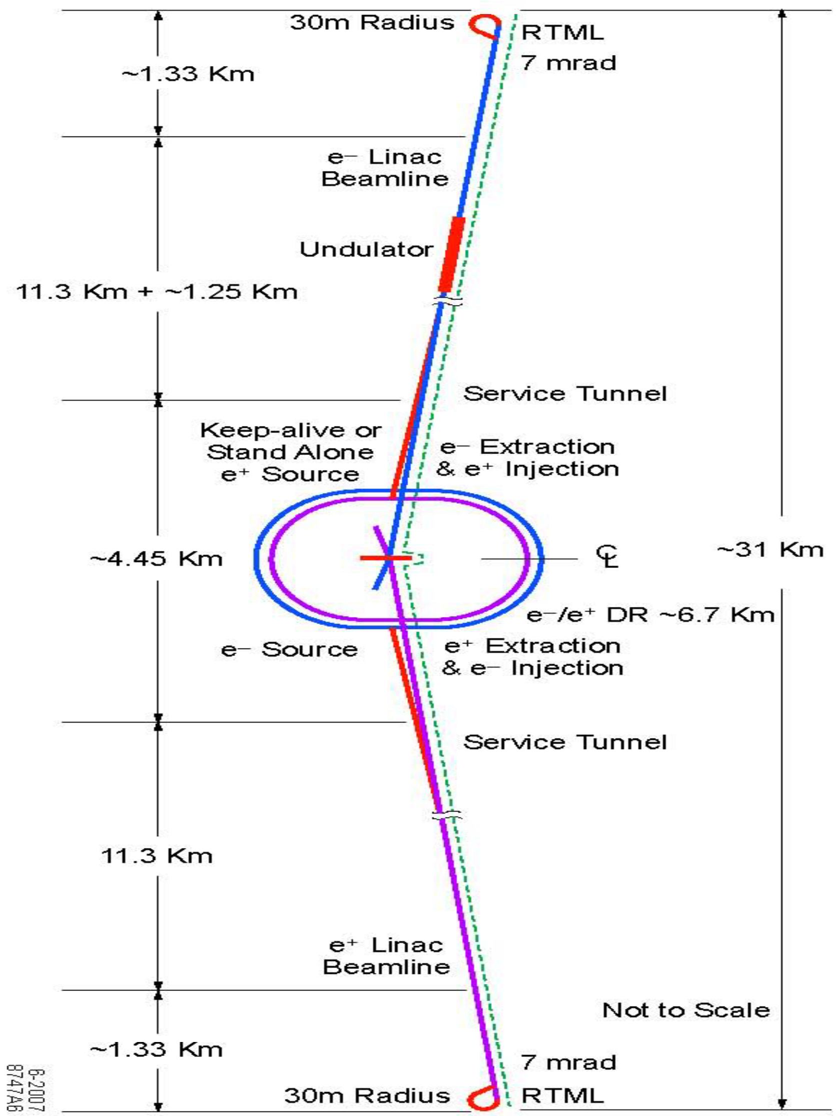
RTML
Design and Cost reduction

- CFS+BC RF system = 68% of costs
  - **Correlated – much of CFS cost is housing for BC cryomodules**
  - **Specific tunnels: Turnaround and RTML/source tunnels. Expensive D & B technology**
- Remainder dominated by RT beam transport
  - **Quads, correctors, BPMs, vacuum**
- Small amount of “exotica”
  - **Non-BPM instrumentation, controls, dumps, collimators**

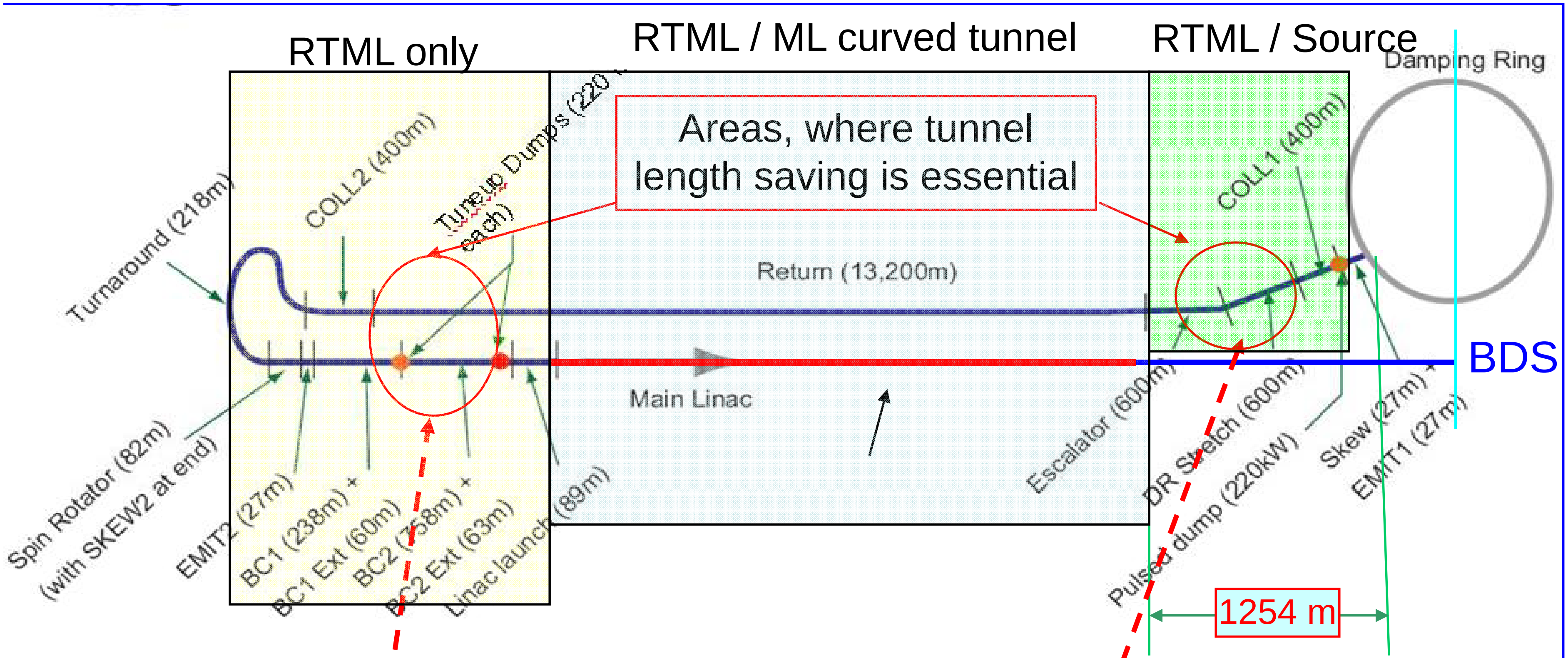


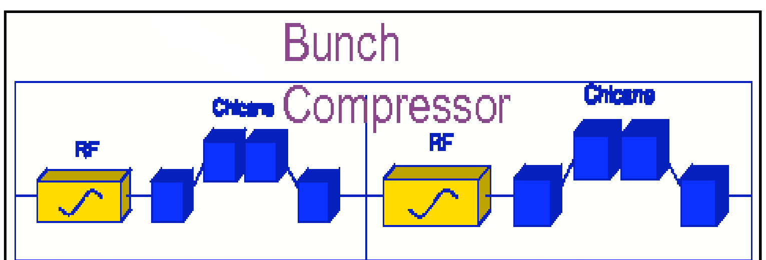
RTML Functions

- *Transport Beam* from DR to ML
  - *Match Geometry/Optics*
- *Collimate Halo*
- *Rotate Spin*
- *Compress Bunch (6mm→0.3mm)*
- *Preserve Emittance*
  - *- Budget for Vert. norm. emittance < 4nm*
- *Protect Machine*
  - *3 Tune-up / MPS abort dumps*
- *Additional constraints:*
  - *Share the tunnel with e-/e+ injectors*
  - *Need to keep geometries synchronized*



RTML Schematic (RDR)



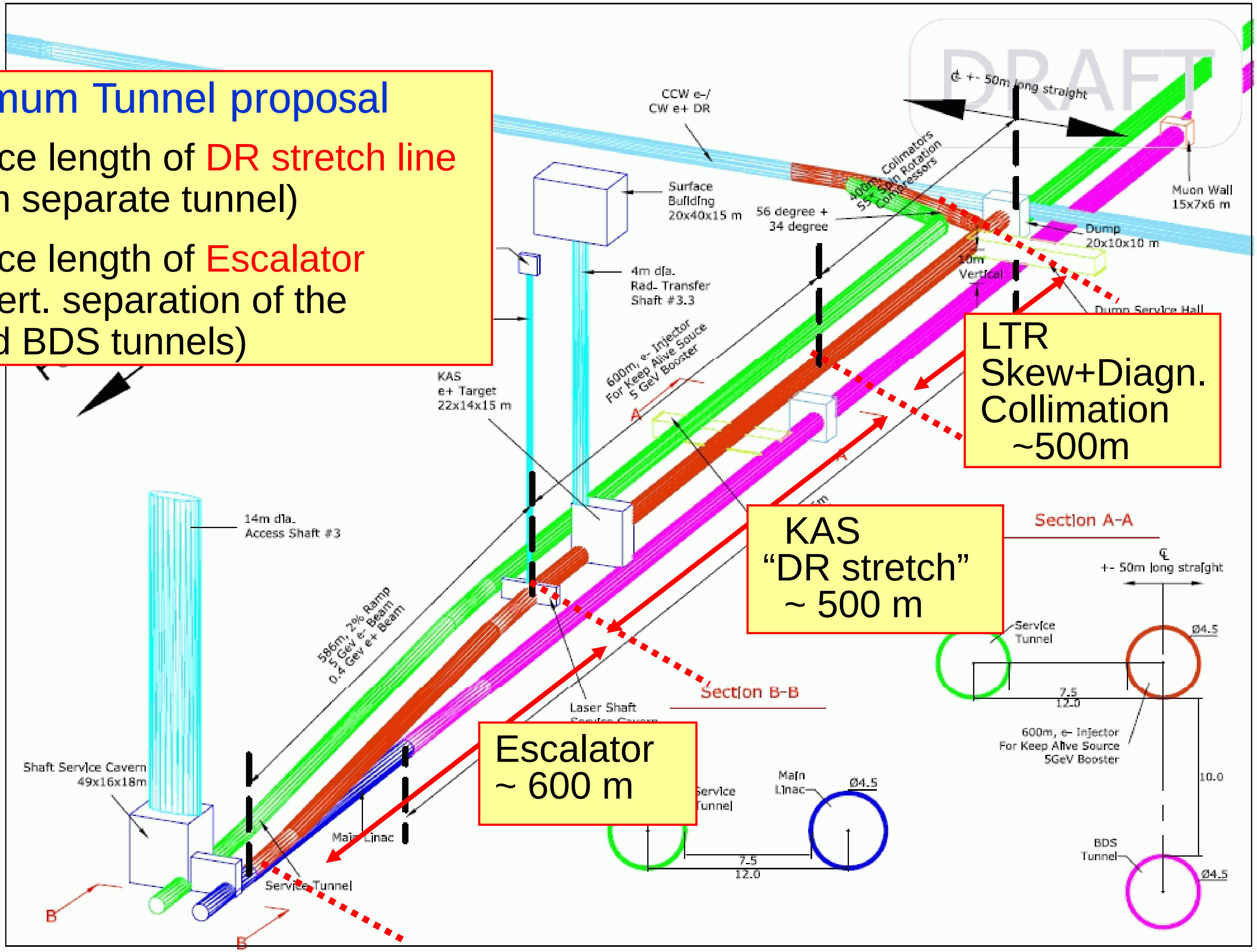


"DR stretch" and Escalator

DR connection (RDR)

Minimum Tunnel proposal

- Reduce length of DR stretch line (KAS in separate tunnel)
- Reduce length of Escalator (less Vert. separation of the DR and BDS tunnels)

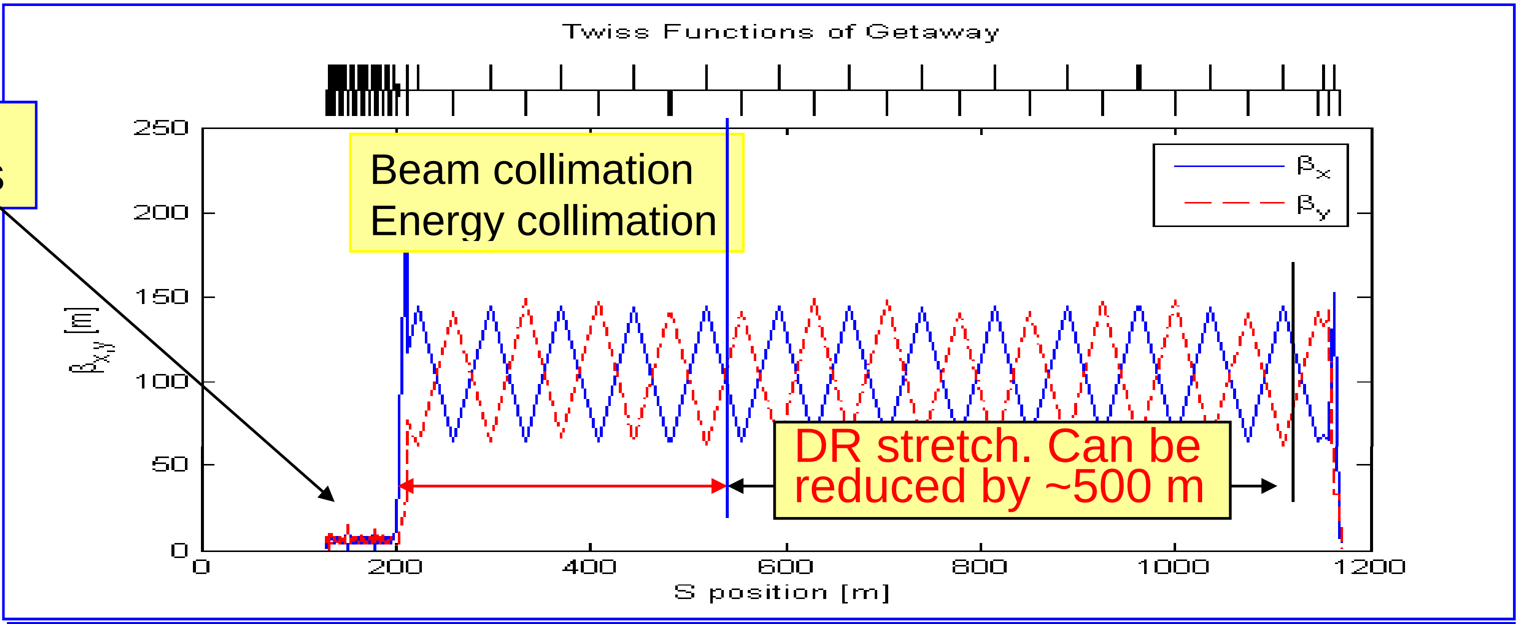


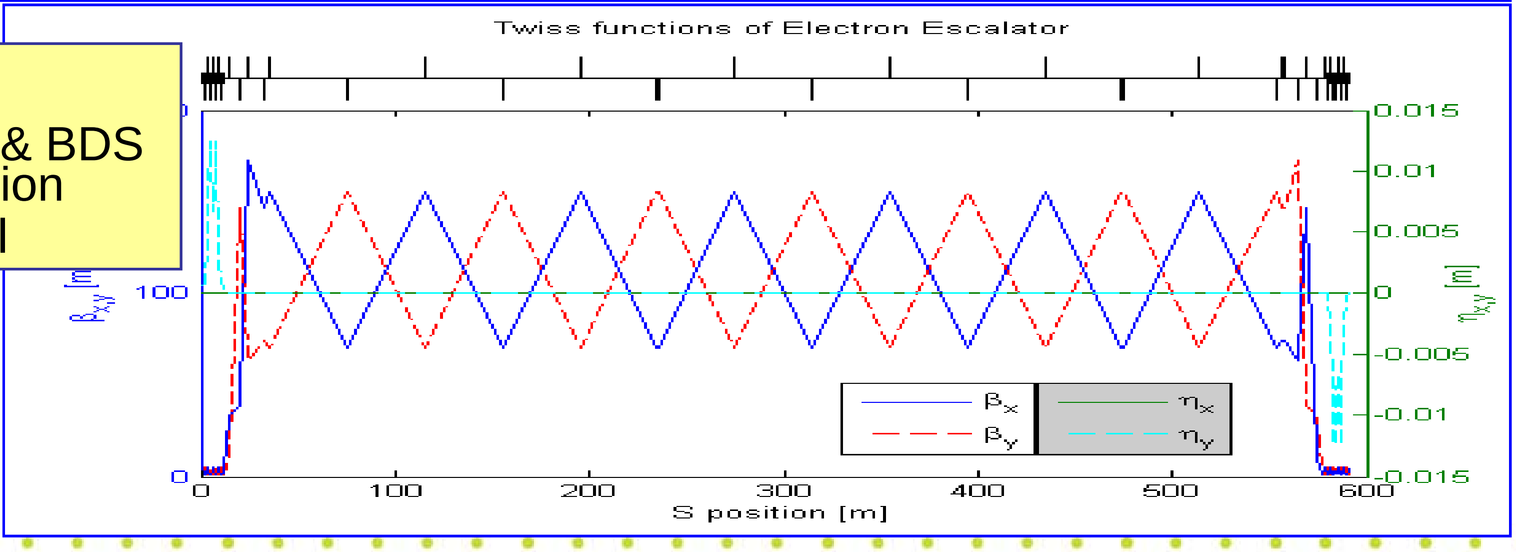
LTR
Skew+Diagn.
Collimation
~500m

KAS
"DR stretch"
~ 500 m

Escalator
~ 600 m

Minimum "Getaway" and Escalator





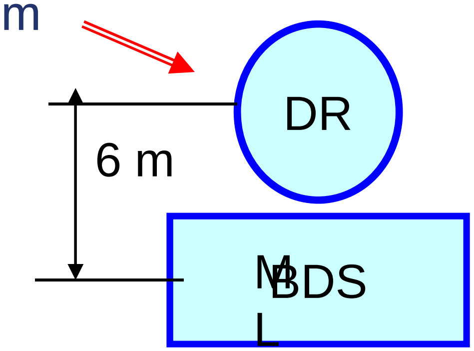
Length Saving:

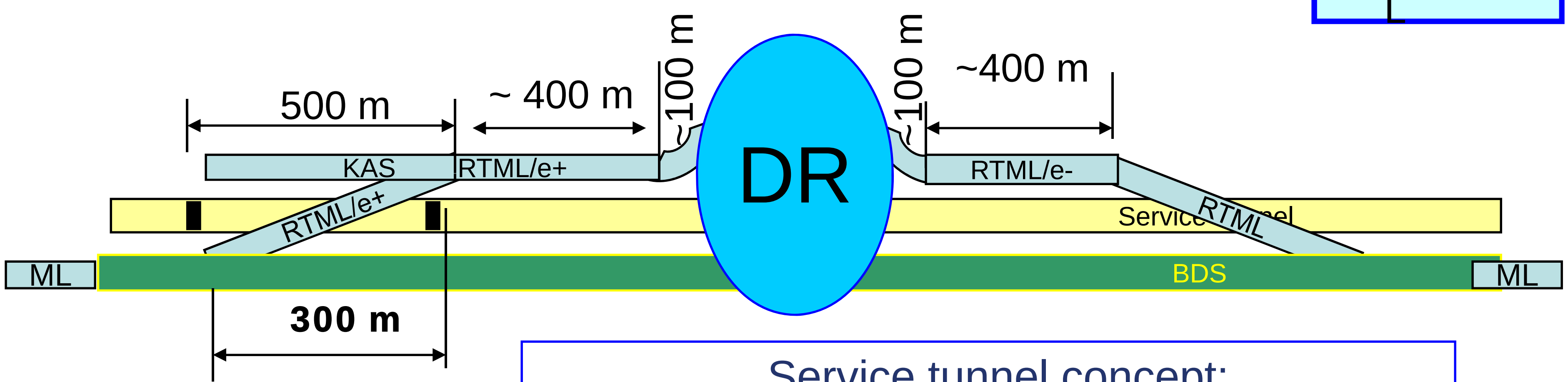
- Less vert. DR & BDS tunnel separation
- Steeper tunnel

Possible configuration of the RTML/source tunnels

Minimum length of the separate RTML/source tunnel

- Smaller vertical separation of DR and BDS tunnels: 10m → 6 m
- Length constraints:
  - Electron source side (straight) ~ 500 m
  - Positron source: 950m =500m(KAS)+450m (SCL/TRL)
- Min RTML tunnel length here ~ 800 m (now ~1250 m)





Service tunnel concept:

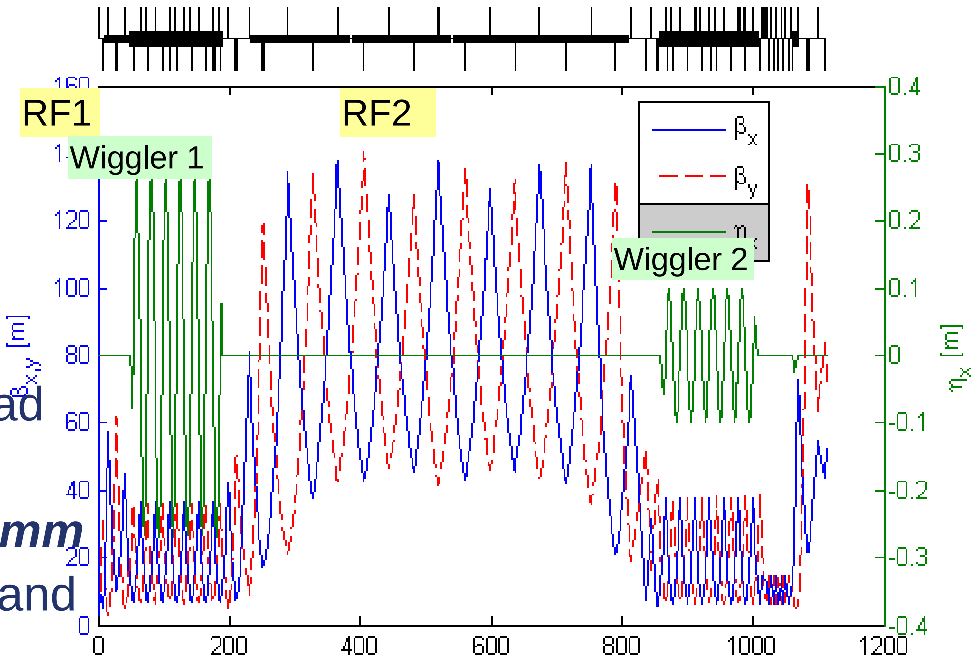
- Straight →good for TBM technology
- RTML tunnel crosses service tuning
- Radiation issues ???

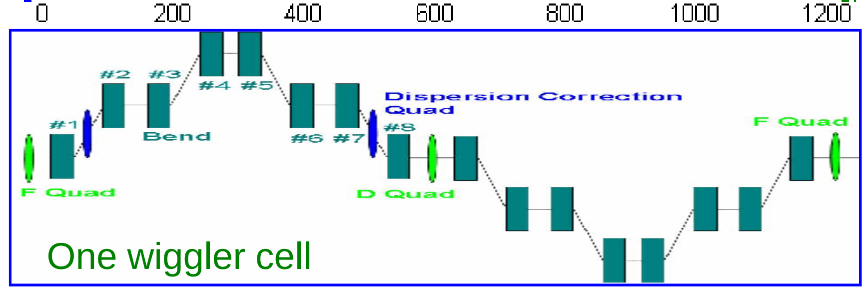
ILC Baseline Bunch Compressor (2-stage)

- Longitudinal emittance out of DR:
  - ***6mm (or 9 mm) RMS length***
  - ***0.15% RMS energy spread***
- Want to go down to 0.2-0.3 mm
- *Need some adjustability*
- Use 2-stage BC to limit max energy spread
  - ***1st: Compress to 1 mm at 5 GeV***
  - ***2nd: 5→15 GeV; compress to 0.2-0.3mm***
- Both stages use 6-cell lattice with quads and bends (wiggler)

- Total Length ~1100 m (incl. matching and beam extraction lines):

- Minimum design is possible if compression 6→0.3 mm only
  - Shorter 2-stage BC
  - Single-stage BC (+post acc to 15GeV)



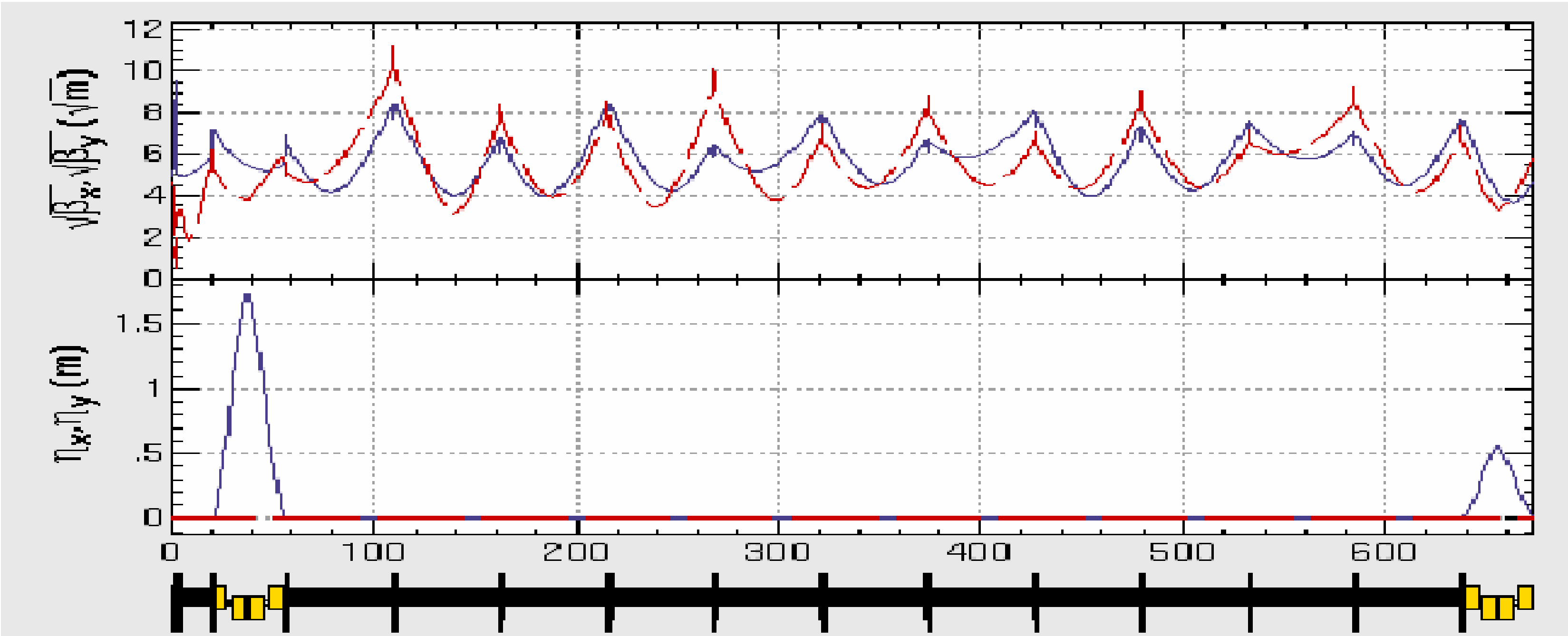


RF system

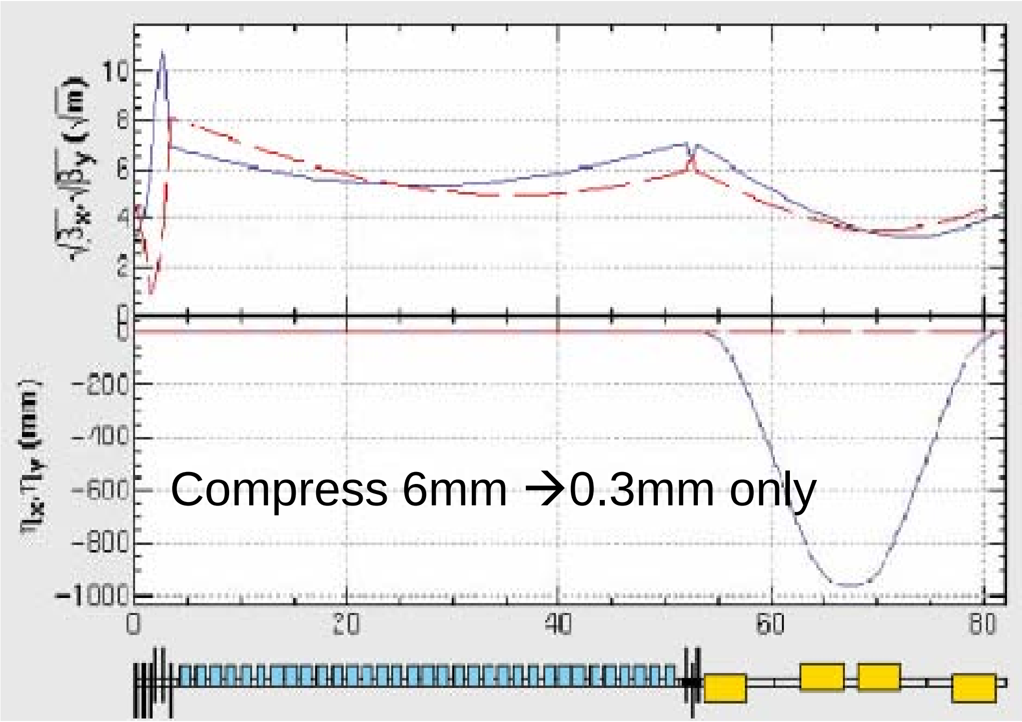
- BC1: 3 CMs with quads (+spare kly)
- BC2: 14 RFunits (3CM's each)+1spare
- Total 48 CM's per side

Alternative 2-stage Bunch Compressor

- An alternate bunch compressor design exists (~700m)
  - ***6-cell wigglers (~150 m each, 102 bend magnets) replaced by chicanes (~40 m each, 4 bend magnets)***
  - ***Advantages:*** *Shorter, Simpler, Cheaper (less magnets)*
  - **Disadvantages:** *Big x offset from straight line (~1.8 m)*
    - » *Doesn't have natural locations for dispersion tuning quads*
- *Length Saving: ~ (200 ÷ 300 m)*



Short Single stage BC (Eun-San Kim) - 2005



Parameter	Units	Values
Legnth	m	80
Initial beam energy	GeV	5
Initial bunch charge	nC	3.2
Initial rms energy spread	%	0.15
Inital rms bunch length	mm	6
Initial emittance (H/V)	μm	8 / 0.02
RF phase	degree	-118
Chicane R_{56}	mm	-190
Bending angle	deg.	6
Length of a bend	m	4.16
End rms bunch length	mm	0.3
End energy	GeV	4.5
End bunch charge	nC	3.2
End emittance (H/V)	μm	8.3 / 0.02
End energy spread	%	3.5

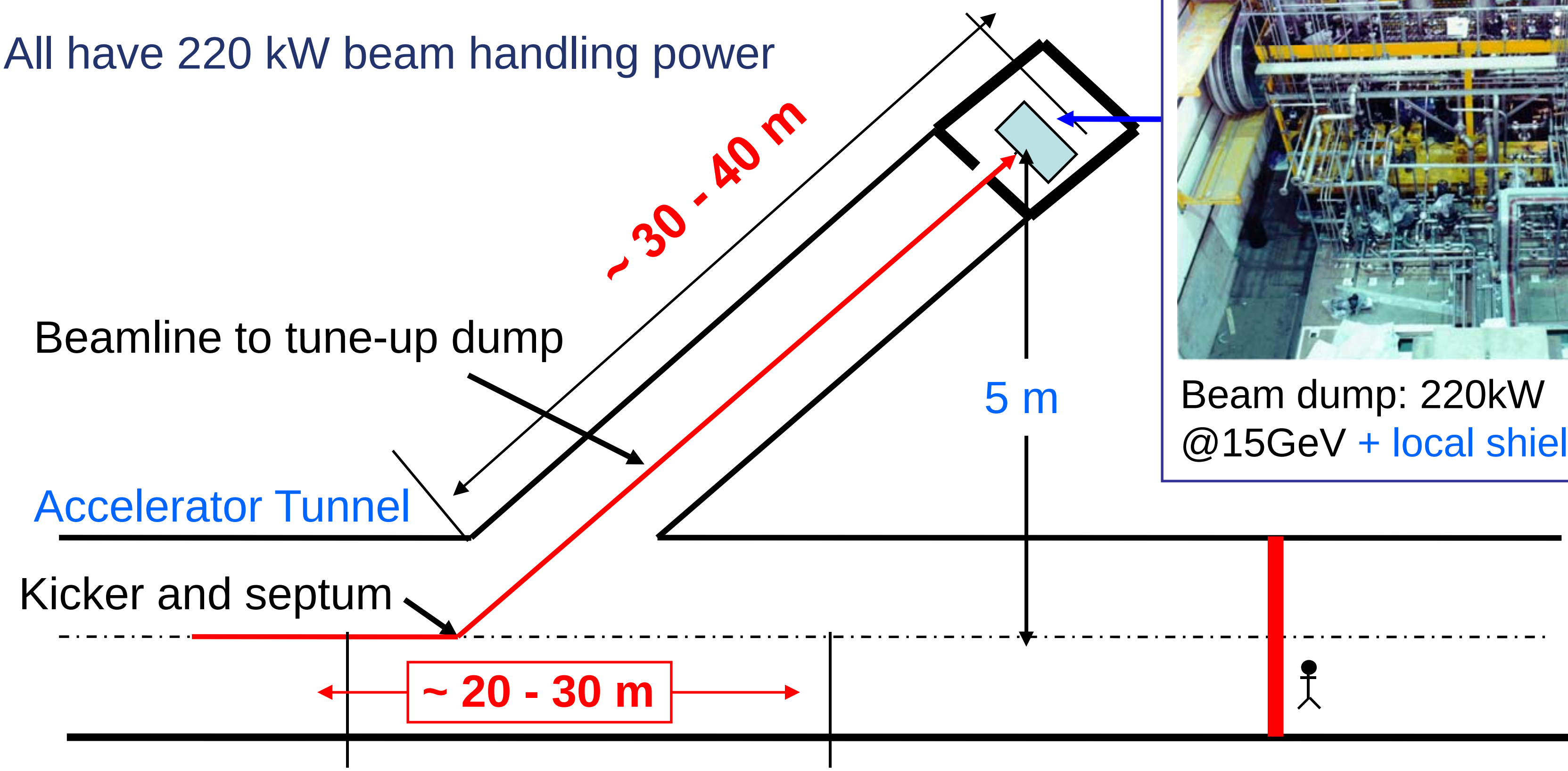
- BC+ post-acceleration 5→15 GeV ~ 700m. Saving ~ 400m
- Energy spread @ 15 GeV 3.5%*(4.5/15) ~ 1%
- No ELBC2 extraction line
- Key Issues: flexibility, tunability, emittance growth, ...

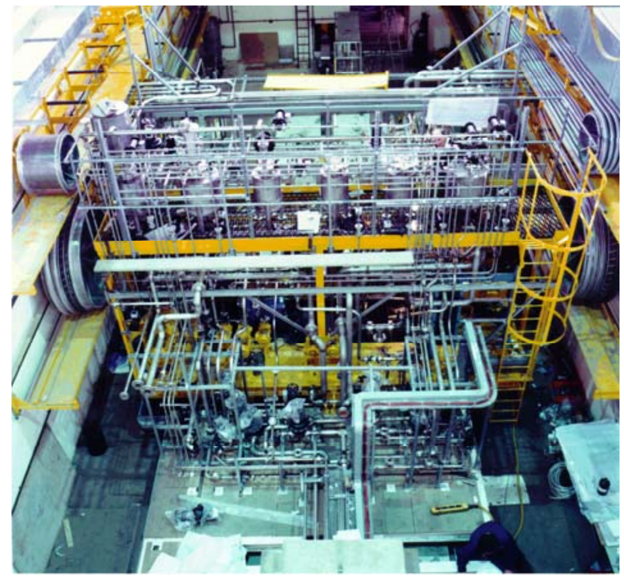
Reduce One Pulsed Extraction Line @15GeV

Now - 3 Extraction Lines in each RTML side for emergency beam abort (MPS) and tune-up

- EL1 - after DR exit; 5 GeV, σ = 0.15%
- ELBC1 - after BC1; 5 GeV, σ= 0.15% and 2.5%
- ELBC2 - after BC2; 15 GeV, σ = 0.15% and 1.8%

All have 220 kW beam handling power



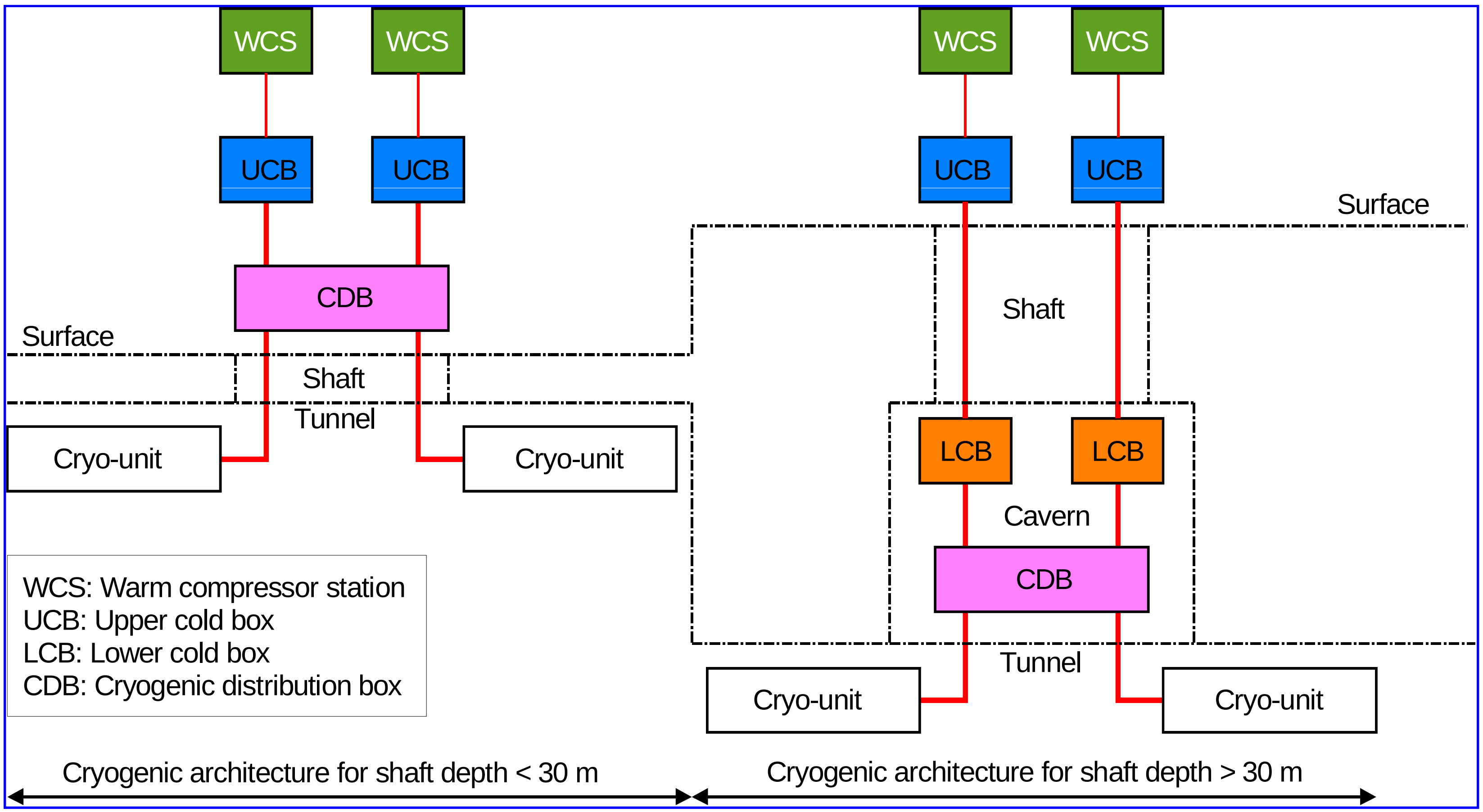


Beam dump: 220kW @15GeV + local shielding

Conclusion

- New DR increases length of RTML system by ~300 m from each side, with minor cost increasing (cost of the tunnels still the same)
- Possible Cost saving options:
  - Minimize length of RTML / Source tunnel (D & B) from 1254 m to ~ 900 m per each side
  - Alternative 2-stage or 1-stage bunch compressor
  - Reduce pulsed extraction Lines from 3 per side to 2 per side
- Need discussion with CFS, e+/e- source, BDS, ML and technical groups
- Need Lattice design ?

ILC Cryogenic System Shallow versus Deep Tunnel



Lower coldbox installation at CERN

Lower coldbox installation at CERN

About 7 m long and 7 m tall, 2 m dia

Piping into ATLAS cavern

Deep Site > 30 m

Contents of lower cold box for deep site

- Heat exchangers
- Valves
- Cold compressors
- Turbo-expanders
- Assuming as much hardware on the surface as possible, minimal in the caverns, still means effectively the sub-20 Kelvin part of the cryogenic plant below ground

Vertical transfer line for the deep site

- About 300 - 600 mm OD vacuum jacket
- Inner lines include

  ~20 K to and from lower cold box

  40 K supply and 80 K return thermal shield lines

  Auxiliary piping for cool-down and off-design operation

Comments

- Shallow site (<30 meters deep) allows most cryogenic plant hardware to remain on the surface
  - **Just distribution in the tunnel**
- Reduces cavern occupancy
- Not a big cost difference in terms just of cryogenic hardware
- Additional installation costs for cold box in deep tunnel