Status Report on SB2009 and Accelerator Design & Integration

Ewan Paterson

Presentation to the PAC

for the GDE

May 13, 2010

History of SB2009 and PAC

- PAC Meeting Oct 2008

“Machine Design and Cost Reduction Activities” NJW

- PAC Meeting May 2009

“Minimum Machine is Code for………” EP

- PAC Meeting Nov 2009

“Accelerator Design and Integration Studies towards an updated ILC Baseline for TDP 2”

“ SB2009 Strawman Baseline Studies” MCR

- PAC Meeting May 2010

“SB2009 or is it Accelerator Design and Integration towards “Baseline 2010/11” EP

History of SB2009 cont'd

- SB2009 Proposal published Dec 2009
  http://ilc.kek.jp/SB2009/SB20091217B.pdf

- AAP Review of above Jan 2010 in Oxford

- AAP Report received Feb 2010

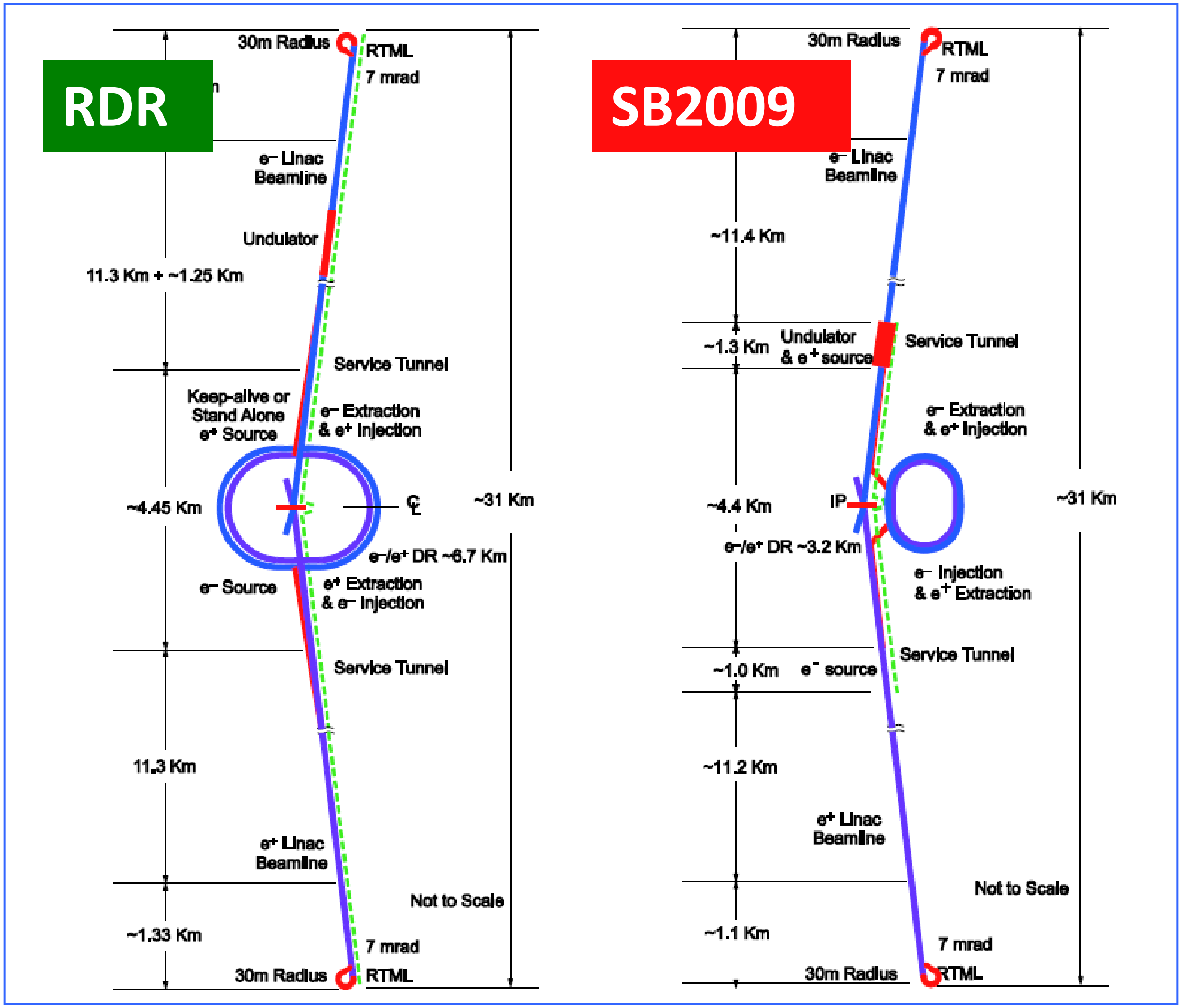
http://ilcdoc.linearcollider.org/record/26987/files/Report-on-AAP-Review_Jan2010.pdf?version=1

My very personal condensed summary of AAP Report with PM (and EC) Response

- The AAP supports the efforts to try to design for reduced cost but is risk averse!
- The AAP believes that there needs to be more study of the impact of components of SB2009 and with more involvement of the physics and detector community.
- Agreed. We will take more time (~year) to further develop and to evaluate the impact of the separate components of SB2009, working closely with physics community, before formally proposing changes to the ILC baseline.

Proposed Components of the SB2009 Design.

Components in RED have the largest impact Physics and cost but not in any order



- Single Tunnel for main linac
- Move positron source to end of linac
- Reduce number of bunches factor of two (lower power)
- Reduce size of damping rings (3.2km)
- Re-evaluate optimum accelerating gradient

- Integrate central region
- Single stage bunch compressor

Single Linac Tunnel Issues

- **Safety**

Q Are there solutions for different regions and layouts for a single tunnel.

YES. Similar but not identical. Can only be finalized with a specific region and site. Comment on Japanese site studies

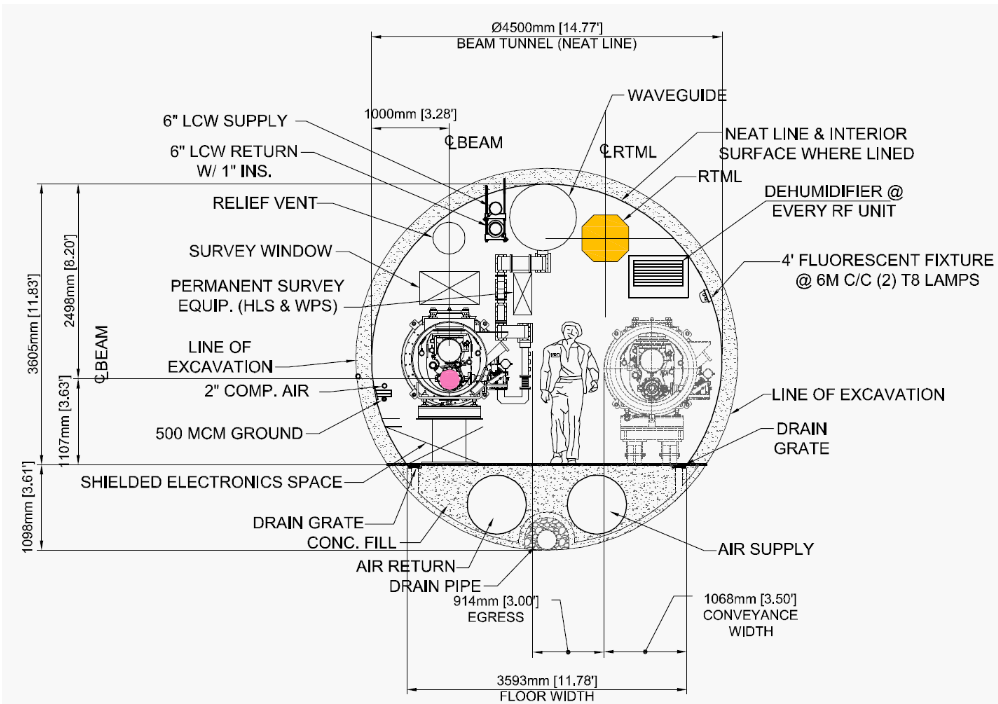
which is in a mountainous region and a second tunnel for some support but not RF.

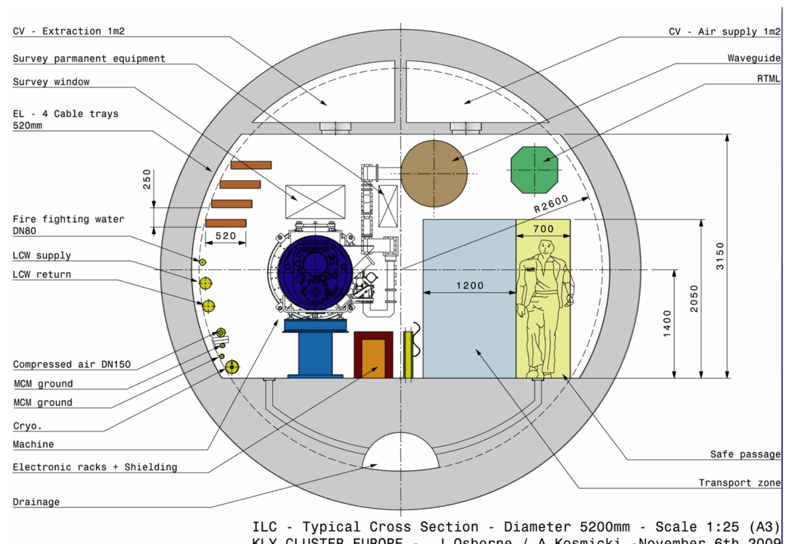
- **Availability** Is OK with--→ Klystron Cluster or

Distributed RF System

Q's Are they viable ? How and when will we know?

Current ML KCS Tunnel Cross Sections



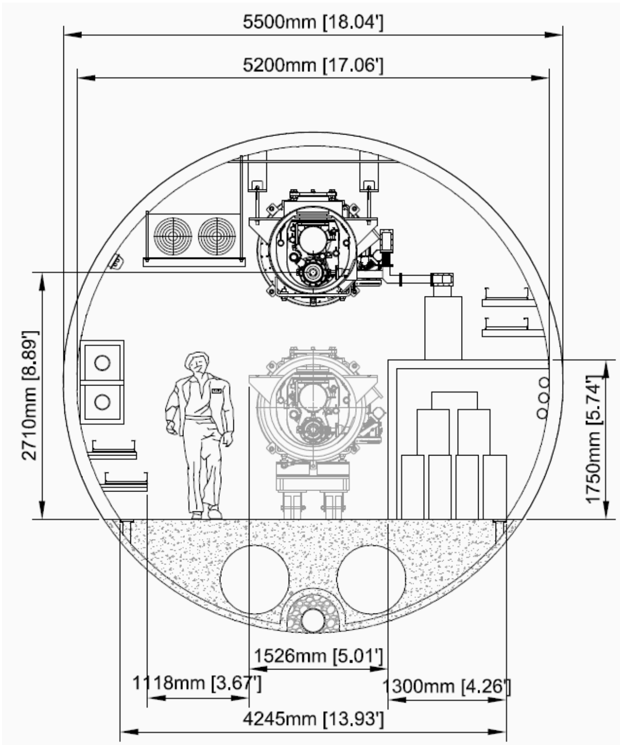


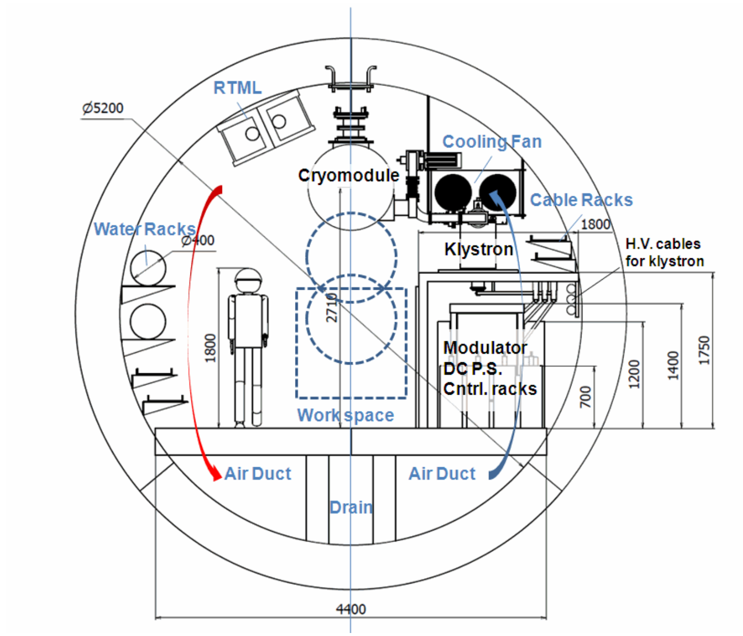
Cross section for Europe (CERN) 5.2m diameter for Kly Cluster

Americas Region 4.5 m Dia.

European Region 5.2 m Dia.

Current ML DRFS Tunnel Cross Sections





Americas Region 5.2 m Dia.

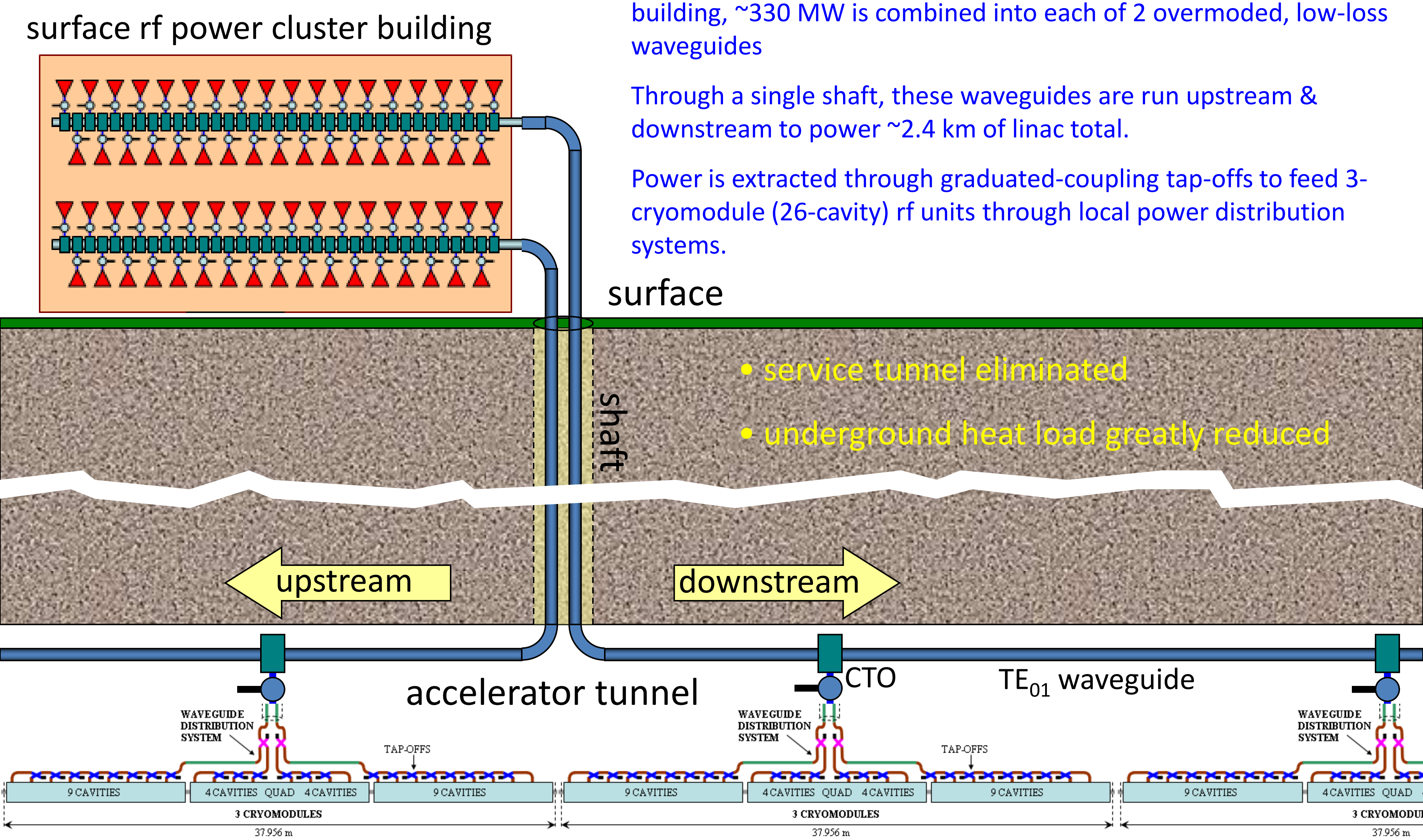
Asian Region 5.2 m Dia.

Klystron Cluster Layout

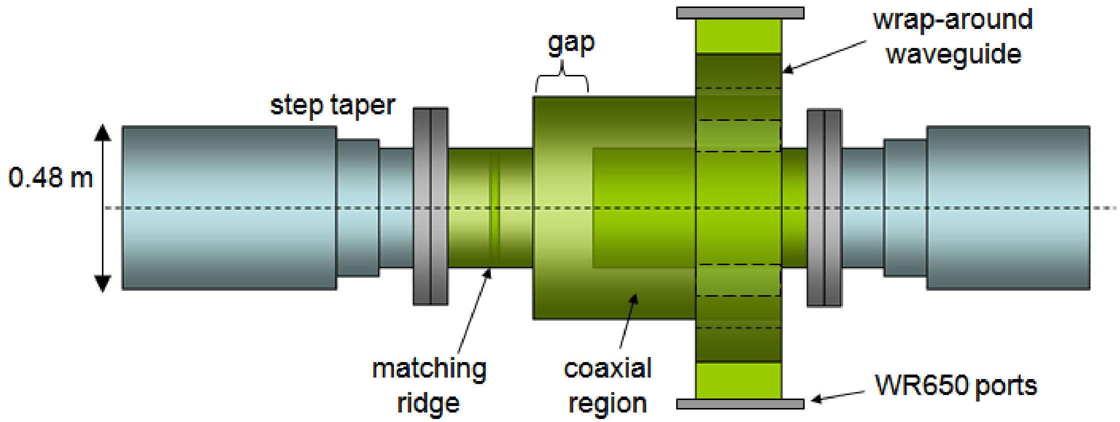
From 2 groups of ~35 klystrons & modulators clustered in a surface building, ~330 MW is combined into each of 2 overmoded, low-loss waveguides

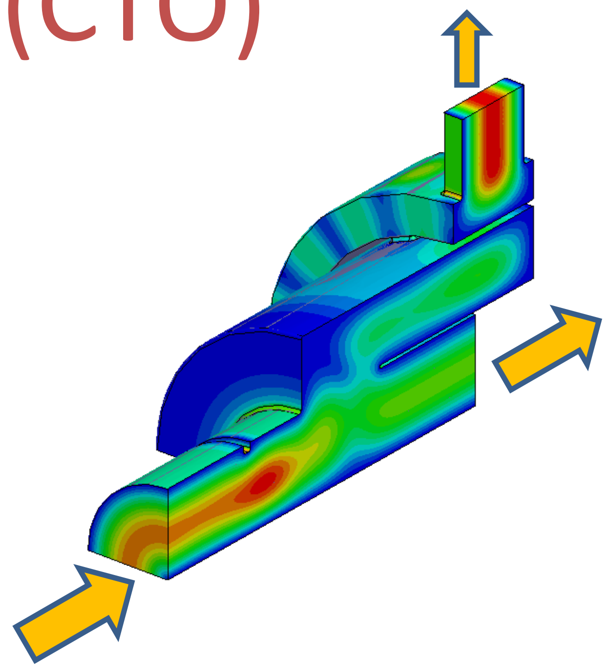
Through a single shaft, these waveguides are run upstream & downstream to power ~2.4 km of linac total.

Power is extracted through graduated-coupling tap-offs to feed 3-cryomodule (26-cavity) rf units through local power distribution systems.



Coaxial Tap Off (CTO)





•Power is tapped off from the circular TE_{01} mode, in 10MW increments, into a coaxial region, without breaking azimuthal symmetry (*no surface E fields*).

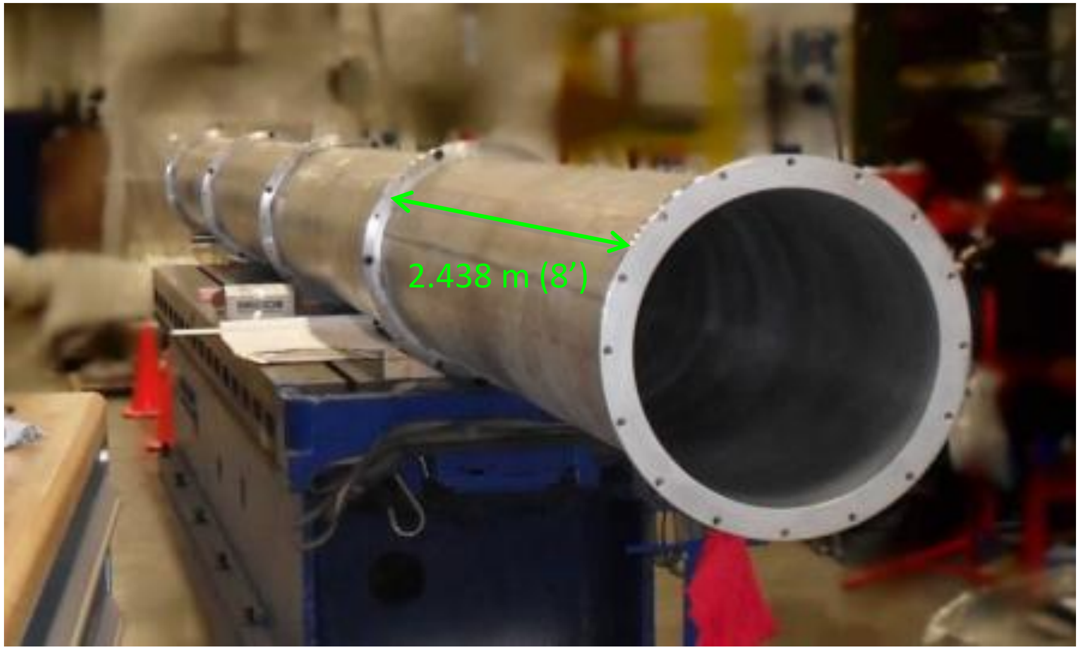
•A wrap-around mode converter extracts this power from the coaxial TE_{01} mode into two output waveguides (5MW each), analogous to klystron output arms.

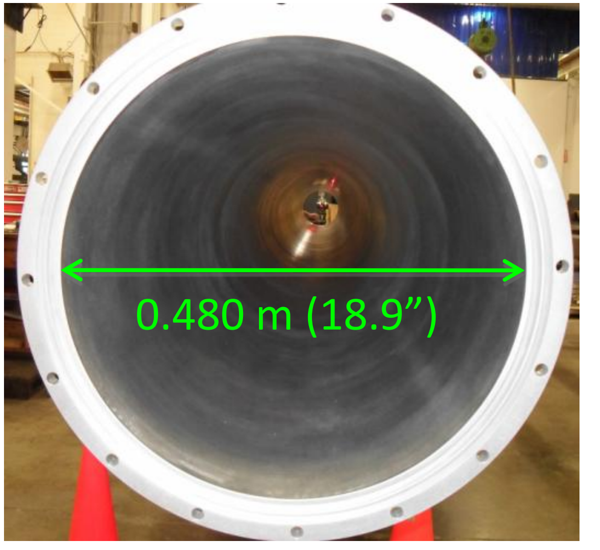
•The various required coupling designs (~3-50%) differ only in a) gap width (~3-8") and b) matching ridge.

•The same devices are used in reverse for combining power into the pipe.

•Appropriately shorting the left port creates a mode launcher (or any coupling).

Prototype "Big Pipes" for KCS Tests





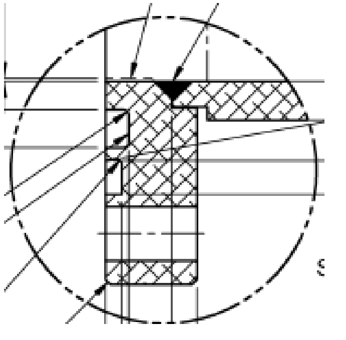
Four 8' sections (9.75 m total) of 0.48 m-diameter waveguide (WC1890).

Fabricated from formed aluminum sheets, welded and machined.

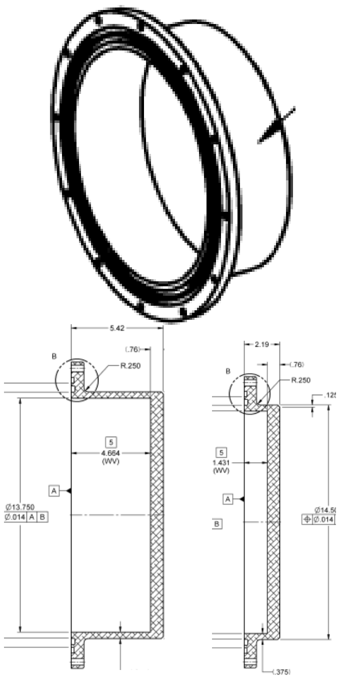
<u>one-side double grooved flanges:</u>

vacuum/pressure seal – Viton® O-rings

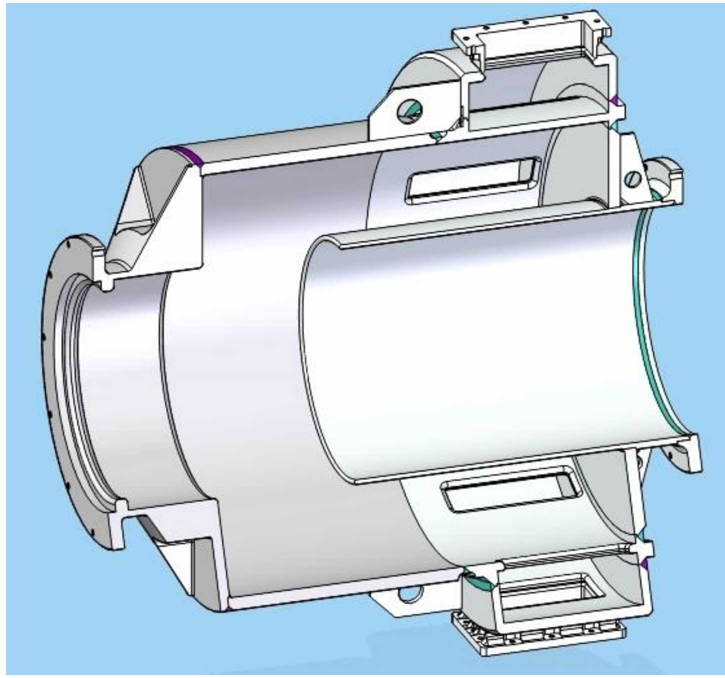
rf seal – Bal Seal® canted coil contact spring



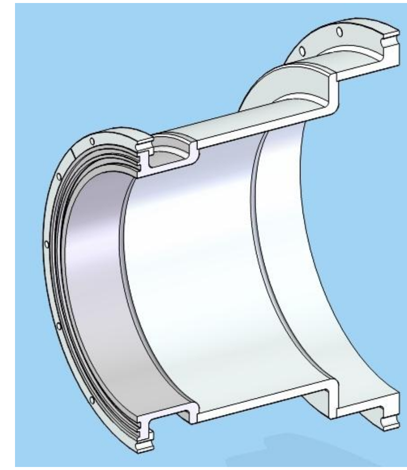
CTO’s and Auxiliary Parts



End caps for launching and resonant coupling. (to be final machined after cold-testing with shims)



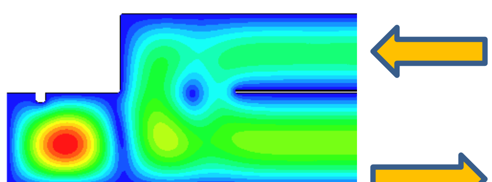
Two welded aluminum 3-dB CTO’s are being fabricated and expected to be shipped next month.



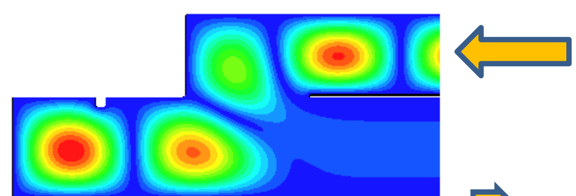
13.75” → 18.90”

Two circular step tapers to connect to main waveguide are in fabrication at SLAC.

launcher



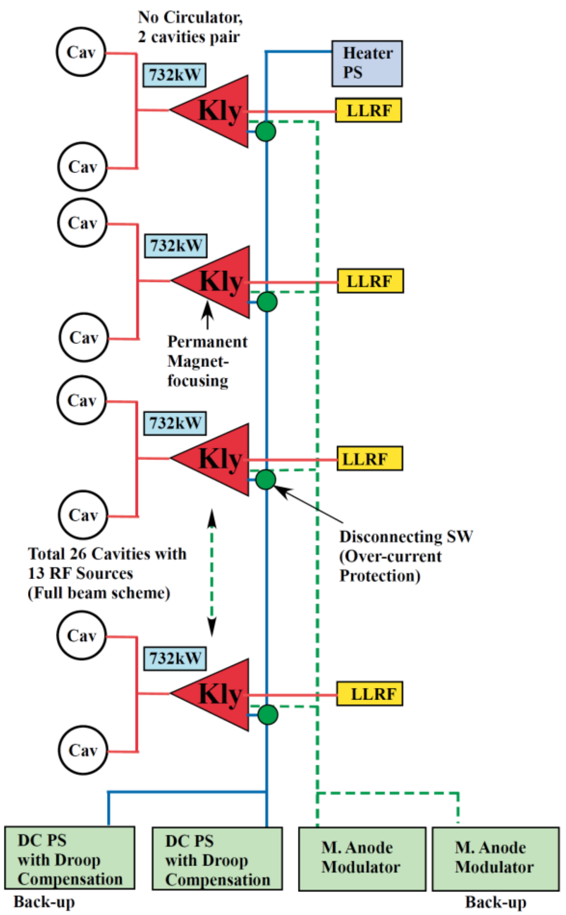
coupler



Concept of DRFS

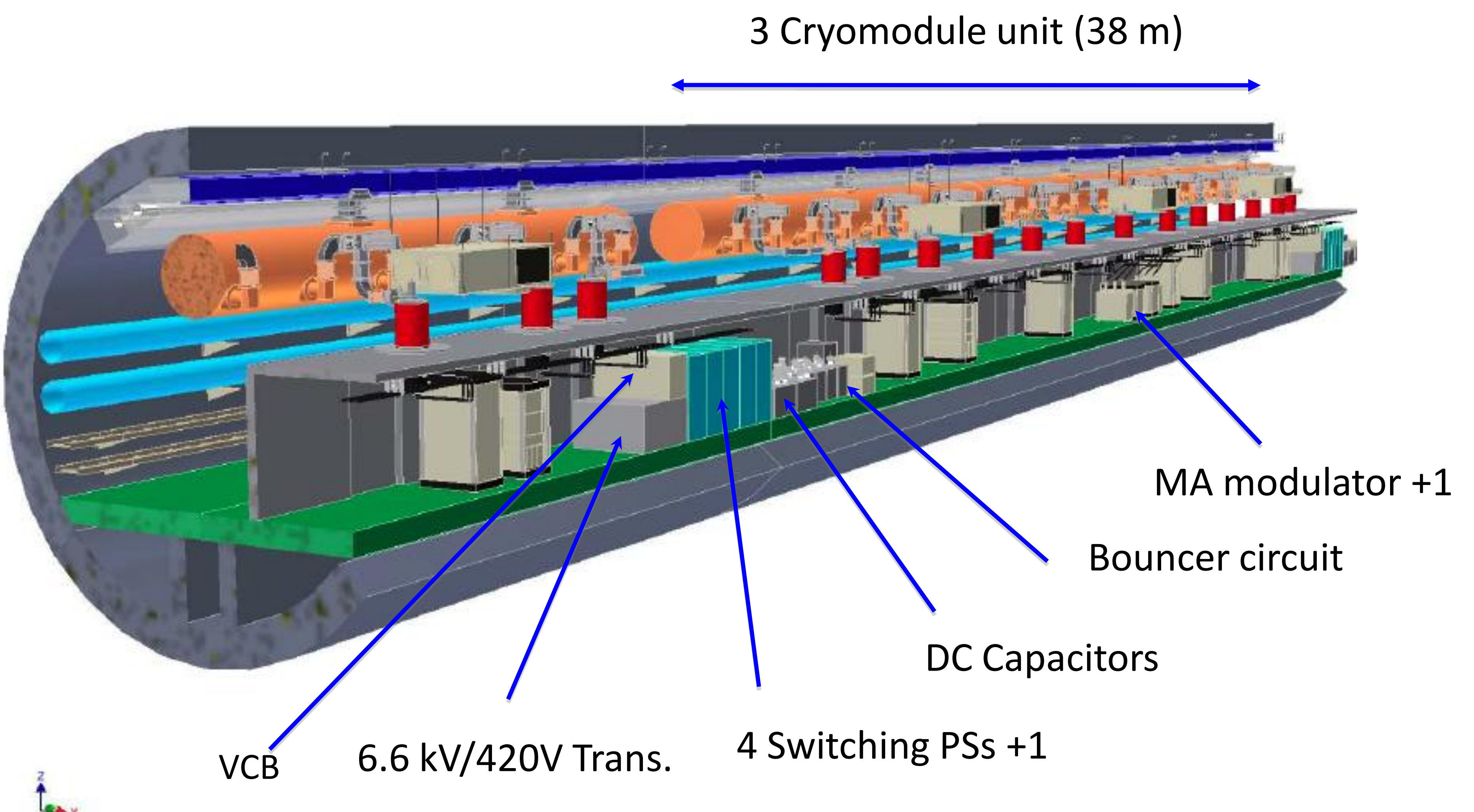
- The Distributed RF System (DRFS) is another possibility for a cost-effective solution in support of a single Main Linac tunnel design.

- Base line of proposed DRFS
  - **one unit of 750kW Modulating Anode (MA) klystron would drive two cavities (in basic configuration scheme –BCS/HCS).**
  - **totally about 8000 MA klystrons would be used.**
  - **It is based on much simpler and more compact HLRF and LLRF units than the RDR baseline or KCS.**
  - **It offers a good operational flexibility in coupling with performance variations of individual cavities.**
  - **By employing suitable back-up modules for key component, high availability would be expected.**
  - **Complete single tunnel model, no facility in the surface**



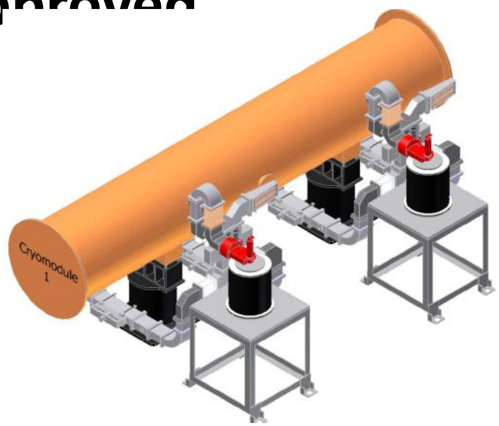
Accelerator Laboratory

DRFS Tunnel Layout



Task and R & D schedule of DRFS in KEK

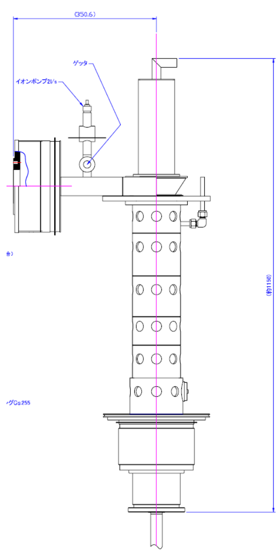
- **R&D study is easy since the DRFS system is not large.**
- **Task force team of DRFS starts and try to solve the problems of DRFS.**
- **Prototype RF unit is manufactured in FY09**
- **Further R&D required for the DRFS RF system is continued from FY09. Three year R&D budget was ap**
- **Permanent magnet, high voltage SW and IGBT will be studied intensively.**
- **Prototype will be evaluated in the S1 global test (2 Klystron DRFS)**
- **And then installed in the buncher section of STF-II aiming for the realistic operation.**
- **More large scale of DRFS (4~5 Klystron DRFS) is planed for STF-II in KEK.**



S1-Global Plan

Prototype DRFS Klystron (S1-G)

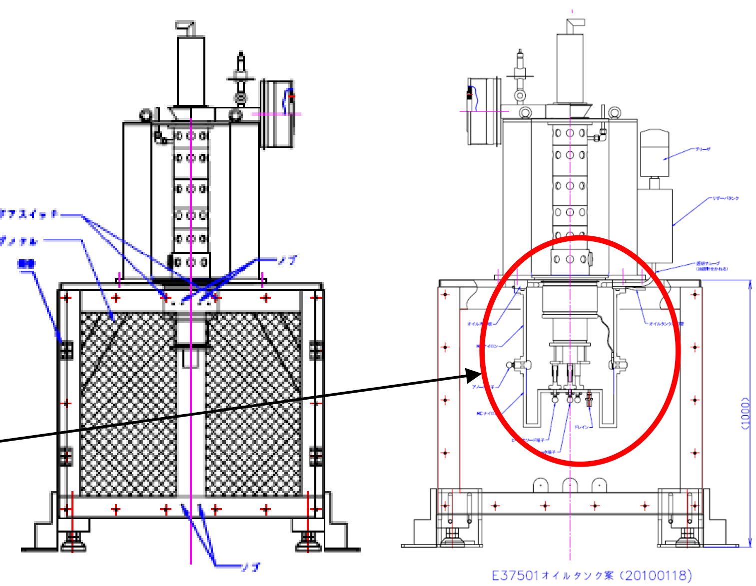
- For S1-global demonstration, KEK will order 2 DRFS klystrons.
- A prototype klystron was ordered in FY09 and will be delivered in around August of 2010. Another klystron will be ordered in April of 2010 and we expect to finish basic performance test till middle of November. Two klystrons and a MA modulator are installed S1-global bench on December and tested.



DRFS klystron

Proto-type employs
Electro-magnet focusing.

HV Ceramic is immersed
In a small oil tank.
Design is now modified from
right figure.



Socket Assembly of DRFS klystron

The Alternate HLRF Systems

- We will know a lot more by end of 2010 as to whether there are engineering or cost problems

  i.e. Are there any show stoppers?
- Larger system tests will take longer
- Some of the operational issues coming from lumped versus distributed RF requirements may be answered from FLASH experiments.
- Most likely scenario is that we will have to carry both R&D programs and two designs through at least 2011.

Barry and Sakue set up complimentary working groups to study SB2009 and Physics Impacts

Physics and Detectors

- Jim Brau (convener)
- Mark Thomson(ILD)
- Mikael Berggren(ILD),
- Stewart Boogert(ILD)
- David Miller(ILD),
- Tom Markiewicz(SiD)
- Tim Barklow(SiD),
- Takashi Maruyama(SiD)
- Noman Graf(SiD),
- Karsten Buesser(MDI)
- Akiya Miyamoto (Software)
- Keisuke Fujii (Physics)

GDE and SB2009

- Brian Foster co-chair
- Andrei Seryi co-chair
- Jim Clarke
- Mike Harrison
- D. Schulte
- T. Tauchi

Q and A's Has been very useful and will continue in some form. More reporting from J. Brau

Questions from SB2009 WG

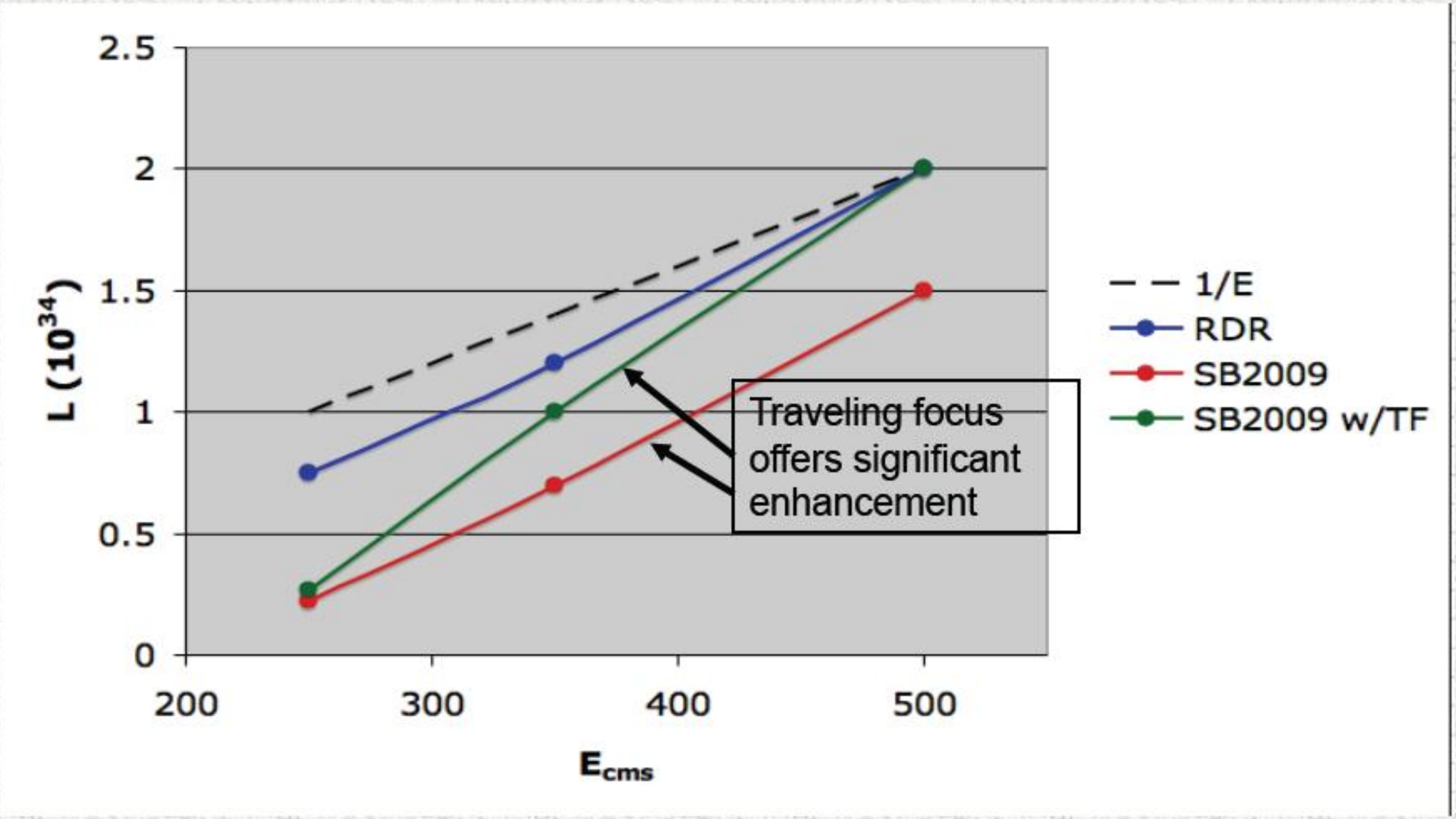
1. To assess the physics impact, we need beam parameters at several key energies:
    1. 250 GeV (to compare with LoI),
    2. 350 GeV (a likely operating energy for SB2009),
    3. 500 GeV (again to compare with the LoI).
2. Beam parameters should include electron/positron beam energy spread.
3. We would like to understand the effect on backgrounds/luminosity spectrum for SB2009 with vs without traveling focus.
4. Despite the questions of feasibility, the conventional positron source remains very interesting in order to maximize yield and therefore luminosity. Please provide estimates of the expected luminosity and beam energy spread that would be possible with either a conventional positron source, or an undulator source, at cms energies between 200 and 300 GeV. Will the conventional source possibility remain an option in the re-baselined design? What R&D will be pursued either within the GDE or by other groups to ensure its development?
5. How stable would the Luminosity, Energy spread, and positron polarization be during a threshold scan, for example for ttbar or Susy?
6. Can you provide a rough sketch of L(Ecm), Energy spread(Ecm), and Pol e+(Ecm) showing how they might be expected to vary between Ecm=91 and 500 GeV?

Some of the Beam Parameters

	RDR			SB2009 w/o TF				SB2009 w TF			
CM Energy (GeV)	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
Ne- ($*10^{10}$)	2.05	2.05	2.05	2	2	2	2.05	2	2	2	2.05
Ne+ ($*10^{10}$)	2.05	2.05	2.05	1	2	2	2.05	1	2	2	2.05
nb	2625	2625	2625	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	370	370	370	740	740	740	740	740	740	740	740
F (Hz)	5	5	5	5	2.5	5	5	5	2.5	5	5
γex ($*10^{-6}$)	10	10	10	10	10	10	10	10	10	10	10
γey ($*10^{-6}$)	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
βx	22	22	20	21	21	15	11	21	21	15	11
βy	0.5	0.5	0.4	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
σz (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
σx eff ($*10^{-9}$ m)	948	802	639	927	927	662	474	927	927	662	474
σy eff ($*10^{-9}$ m)	10	8.1	5.7	9.5	9.5	7.4	5.8	6.4	6.4	5.0	3.8
L (10^{34} $cm^{-2}s^{-1}$)	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.25	0.27	1.0	2.0

There are many more parameters—energy spread, emittance growth, luminosity spectrum, etc, etc --- too large a spreadsheet to be readable

Luminosity vs. E_{cm}



As the energy is lowered the luminosity becomes limited by the E+ single bunch charge (E+ yield) and cannot be recovered with stronger IP focusing (collimator wakes) & TF

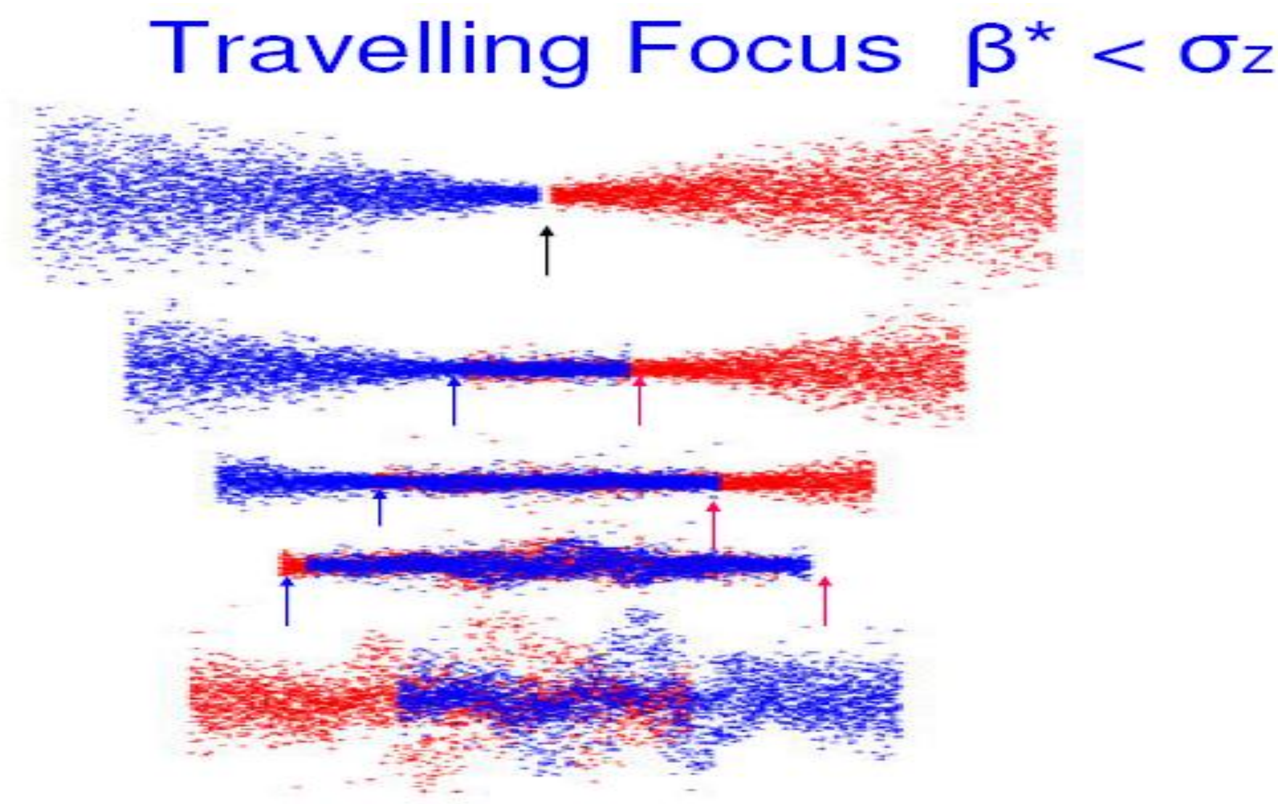
Impact on Physics Capability

- Obviously the running conditions at low energies becomes either :-

  inefficient or **inadequate** or **impossible**

  depending on who is talking and the physics model you assume for the first years of running.
- Jim Brau will discuss this in his talk tomorrow. ??
- In addition to physics impact, we also want to mitigate this situation in order to maintain some of the benefits, cost or accelerator preferences, for components of SB2009 design.

Some comments on the Beam-beam Interactions, Disruption and Travelling Focus



These simulations (Guinea-Pig and CAIN) are also used in the calculations of the Luminosity Enhancement for all parameter cases, including the RDR

Examples of Luminosity Enhancement in the RDR Design

Energy cms	250	350	500
Hd	1.75+00	.1.69E+00	1.71E+00
Geo Lum (cm-2 s-1)	4.52E+33	7.40E+33	1.19E+34
Lum. (cm-2 s-1)	7.66E+33	1.22E+34	2.01E+34

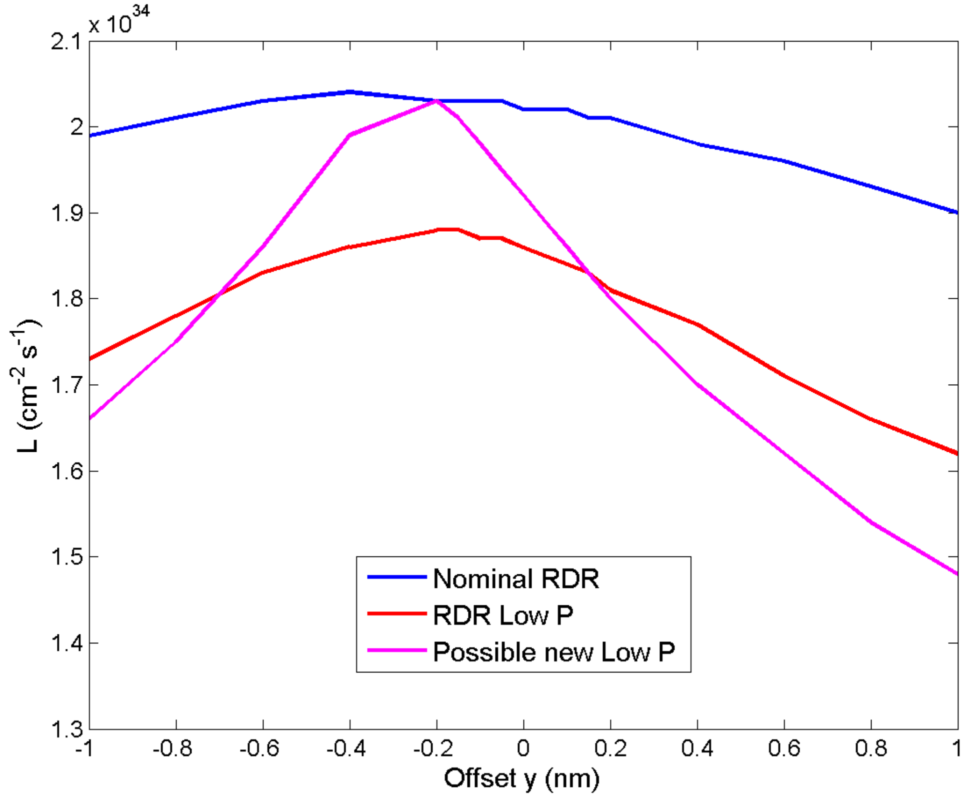
This is a regime of very strong beam-beam interaction dynamics. However these are single pass interactions unlike storage rings.

Simulations with "GUINEA-PIG" & "CAIN" & analytic calculations , where possible, agree within a few % .

The related "Crab Waist" scheme for storage rings as been simulated and experimentally verified in 'DAPHNE"

Some concerns of Low P Parameter Set with Traveling Focus

- Higher Disruption
  - Higher sensitivity to Δy
  - Intratrain Feedback more challenging
  - Vertical bunch-bunch jitter to be <200pm for <5% lumi loss
  - However, twice longer bunch separation will help to improve bunch-bunch uniformity & jitter
- $\beta x(LP) \sim 50\% \; \beta x(RDR)$
  $\beta y(LP\text{-}TF) \sim 50\% \; \beta y(RDR)$
  - Collimation depth 1.4x deeper (smaller apertures)
  - May have more muons
  - however, have space to lengthen muon walls if needed

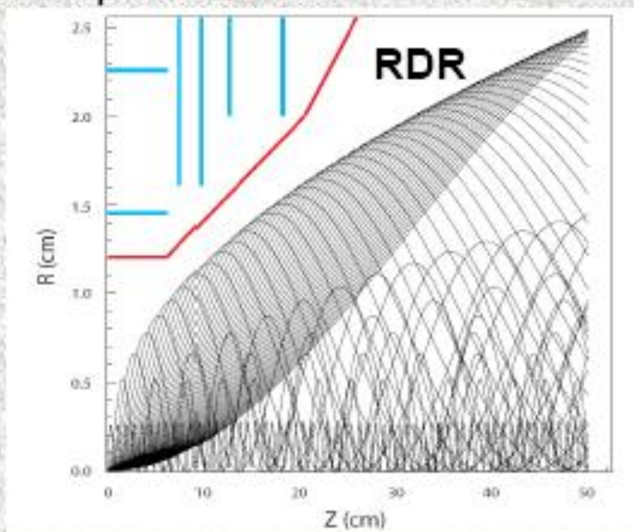


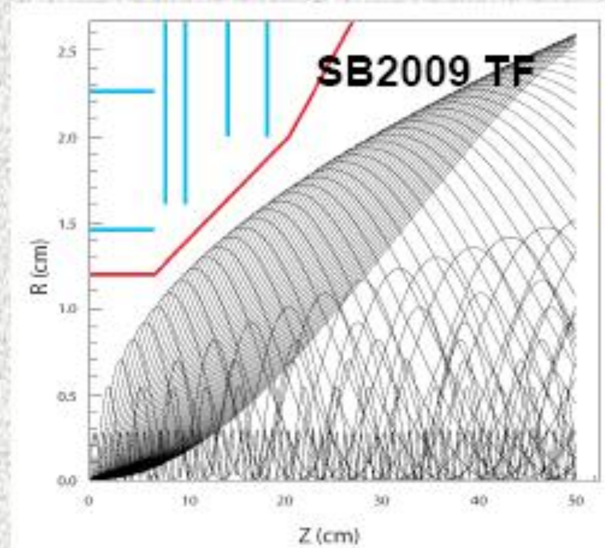
Beamstrahlung background

- The number of beamstrahlung pairs increases for SB2009, with or without traveling focus turned on
  - (T. Maruyama Guinea Pig study)

	E_{tot}(TeV)	No.(e±)	<E>(e±)
RDR	215	85.5k	2.5 GeV
SBTF	635	203k	3.1 GeV

- SiD beam pipe and the vertex detector are compatible with the SB2009 beam parameters





SB2009 w/o TF nearly identical to SB2009 TF

- Pairs will impact forward detection of electrons for two-photon veto - needs to be assessed (see slide)

J. Brau LCWS 2010 Mar 27, 2010 14

Several approaches to increasing the Luminosity at lower energies, < 300 GeV, are being evaluated for technical feasibility, operability and cost.

- Positron Yield QWT vs Flux Concentrator in RDR

    Flux concentrator --- increase R&D

    Liquid Targets, Conventional Sources ---- continue R&D

- IP parameters 1) Design in Travelling Focus Hardware

    2) Shorter Final Doublet for low E operation or Dual Design

Reduced Collimation depth at lower E is responsible for large fraction of reduction of luminosity (w.r.to ideal curve)

Shorter, matched to lower E, final doublet, will give reduction of beam size in IP region, thus increase the collimation depth

- Operating Modes Vary repetition rate vs Energy?

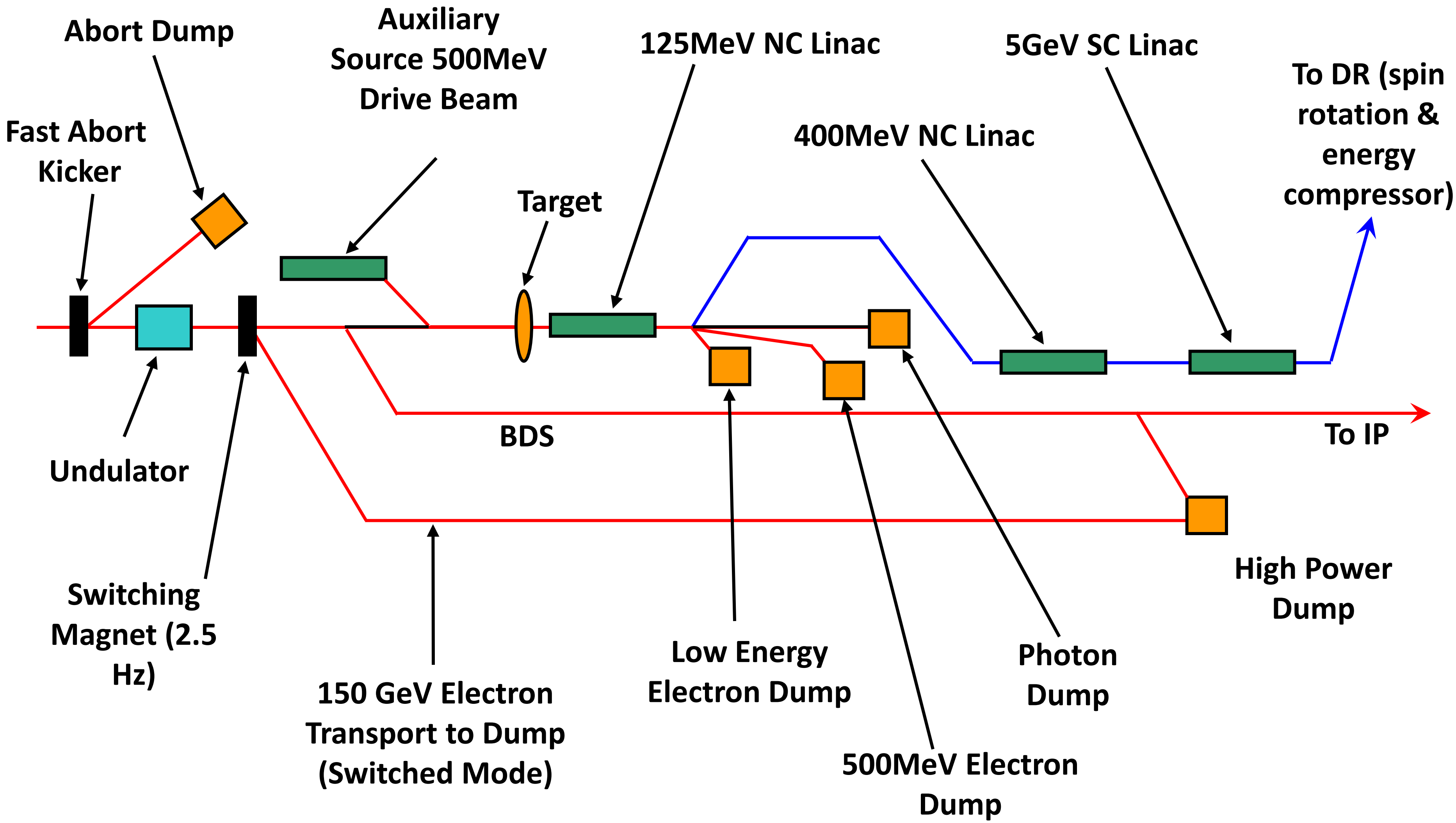
10/8 Hz Operation at 250 GeV com

Is the following operating scenario feasible?

Operate the E- linac at 10 Hz at an energy of 150 GeV with 5 Hz producing E+, interleaved with 5 Hz at </= 150 GeV going to the IP and colliding with the 5 Hz E+ from the E+ linac, doubling the luminosity.

- Power and Cryo ………………………………………**OK**
- E- Source ………………………………………………**OK**
- E+ Source …….Needs more study but looks…..**OK?**
- DR's …..The 3.2km DR with minor mods is …..**OK**
- Linac's ..Needs more study but should be ……**OK?**
- FF and IP….No change ……………………………**OK**

Schematic Layout



More on 10 Hz Operation at Low E

- The whole E- linac is used to produce a ≈150-200 GeV drive beam at a relaxed gradient because the undulator source is at the end of linac
- In the RDR with E+ source in the middle, the first part of the linac always runs flat out and the beam is accelerated or <u>decelerated</u> in the second half.
- At operating energies between 250 and 350 GeV c.o.m the repetition rate can be varied from 10 to 8 to 5 Hz optimizing the luminosity.

DR Parameters for 10 Hz Operation

S. Guiducci (LNF)

	RDR	TILC08	SB2009	High Rep
Circumference (m)	6695	6476	3238	3238
Damping time τ_x (ms)	25.7	21	24	13
Emittance ε_x (nm)	0.51	0.48	0.53	0.57
Emittance ε_y (pm)	2	2	2	2
Energy loss/turn (MeV)	8.7	10.3	4.4	8.4
Energy spread	1.3×10^{-3}	1.3×10^{-3}	1.2×10^{-3}	1.5×10^{-3}
Bunch length (mm)	9	6	6	6
RF Voltage (MV)	24	21	7.5	13.4
Average current (A)	0.40	0.43	0.43	0.43
Beam Power (MW)	3.5	4.4	1.9	3.6
N. of RF cavities	18	16	8	16
B wiggler (T)	1.67	1.6	1.6	2.4
Wiggler period (m)	0.4	0.4	0.4	0.28
Wiggler length (m)	2.45	2.45	2.45	1.72
Total wiggler length (m)	200	216	78	75
Number of wigglers	80	88	32	44

Energy = 5 GeV

Cost related modifications for 10 Hz operation

Damping Ring	N. of RF cavities	$8 \Rightarrow 16$
	Wiggler field	$1.6 \Rightarrow 2.4$ T
	Wiggler period	$0.4 \Rightarrow 0.28$ m

E- Source and Injector Double Rep Rate

Beam Parameters & possible mitigation at low energy

	RDR			SB2009 w/o TF				SB2009 w TF			
CM Energy (GeV)	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
Ne- ($*10^{10}$)	2.05	2.05	2.05	2	2	2	2.05	2	2	2	2.05
Ne+ ($*10^{10}$)	2.05	2.05	2.05	1	2	2	2.05	1	2	2	2.05
nb	2625	2625	2625	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	370	370	370	740	740	740	740	740	740	740	740
F (Hz)	5	5	5	5	2.5	5	5	5	2.5	5	5
γex ($*10^{-6}$)	10	10	10	10	10	10	10	10	10	10	10
γey ($*10^{-6}$)	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
βx	22	22	20	21	21	15	11	21	21	15	11
βy	0.5	0.5	0.4	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
σz (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
σx eff ($*10^{-9}$ m)	948	802	639	927	927	662	474	927	927	662	474
σy eff ($*10^{-9}$ m)	10	8.1	5.7	9.5	9.5	7.4	5.8	6.4	6.4	5.0	3.8
L (10^{34} cm^{-2}s^{-1})	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.25	0.27	1.0	2.0

- Tentative! At 250 GeV CM the mitigations may give
  - * 2 L due to double rep rate
  - * about 1.4 L due to FD optimized for low E

Back to the RDR values ? Must continue to study and evaluate.

Review of Central Region

RDR	SB2009
• 2 Beam + 1 Support Tunnel	• 1 Beam + 1 Support Tunnel
• Includes E- Source and Injector, E+ Keep alive source and Injector, RTML and BDS.	• Includes E- Source and Injector, E+ source (incl AUX source) and injector, RTML and BDS.
• Beam abort, tune-up and main full beam dumps.	• Beam abort, tune-up and main full power beam dumps.
• Spin rotation and measurement equipment.	• Spin rotation and measurement equipment.
• Machine protection systems LINAC to BDS	• Machine Protection systems LINAC to BDS shared with LINAC to Undulator E+ source

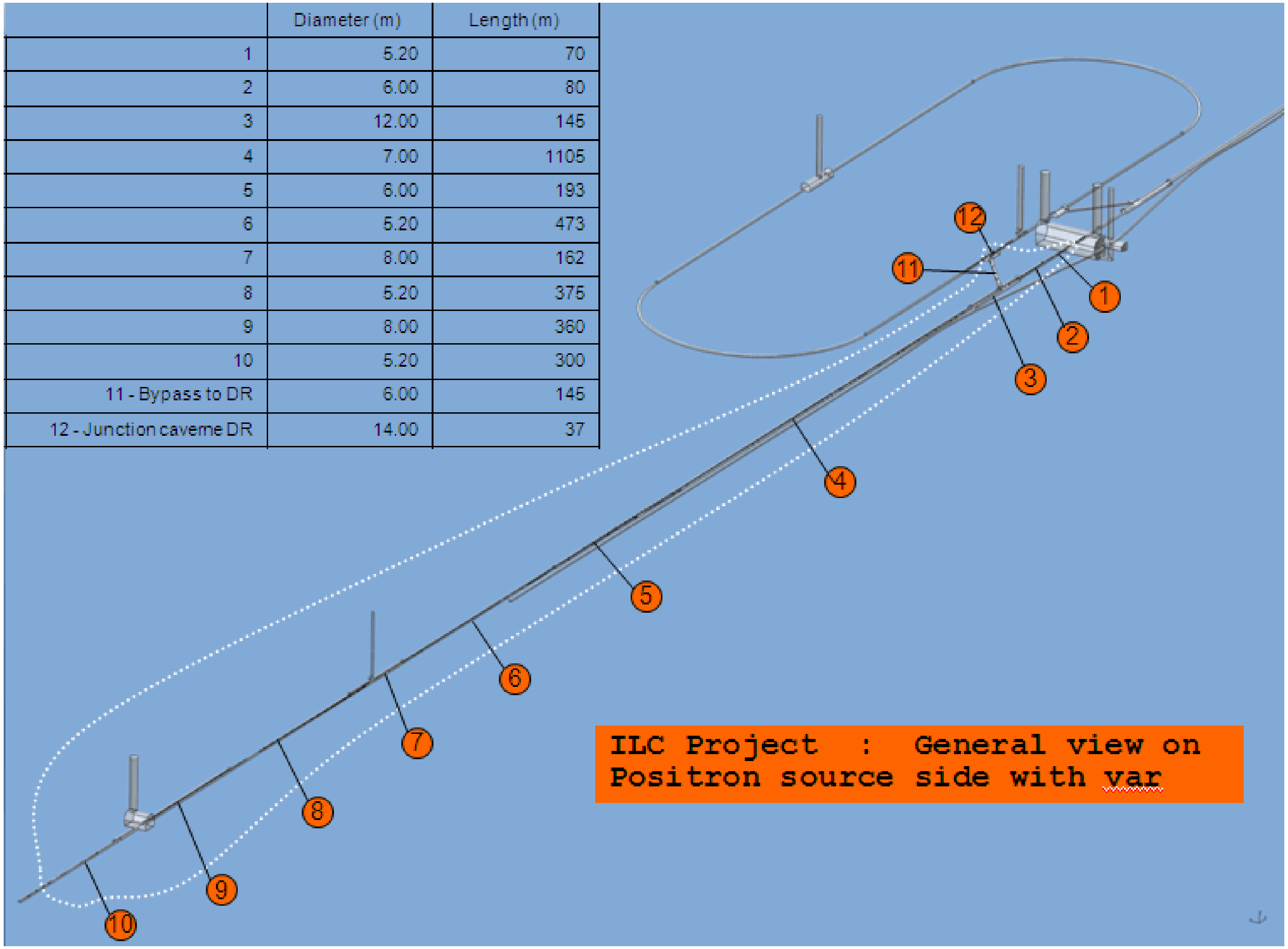
Differences in Red

Primary CFS Goals for LCWS10

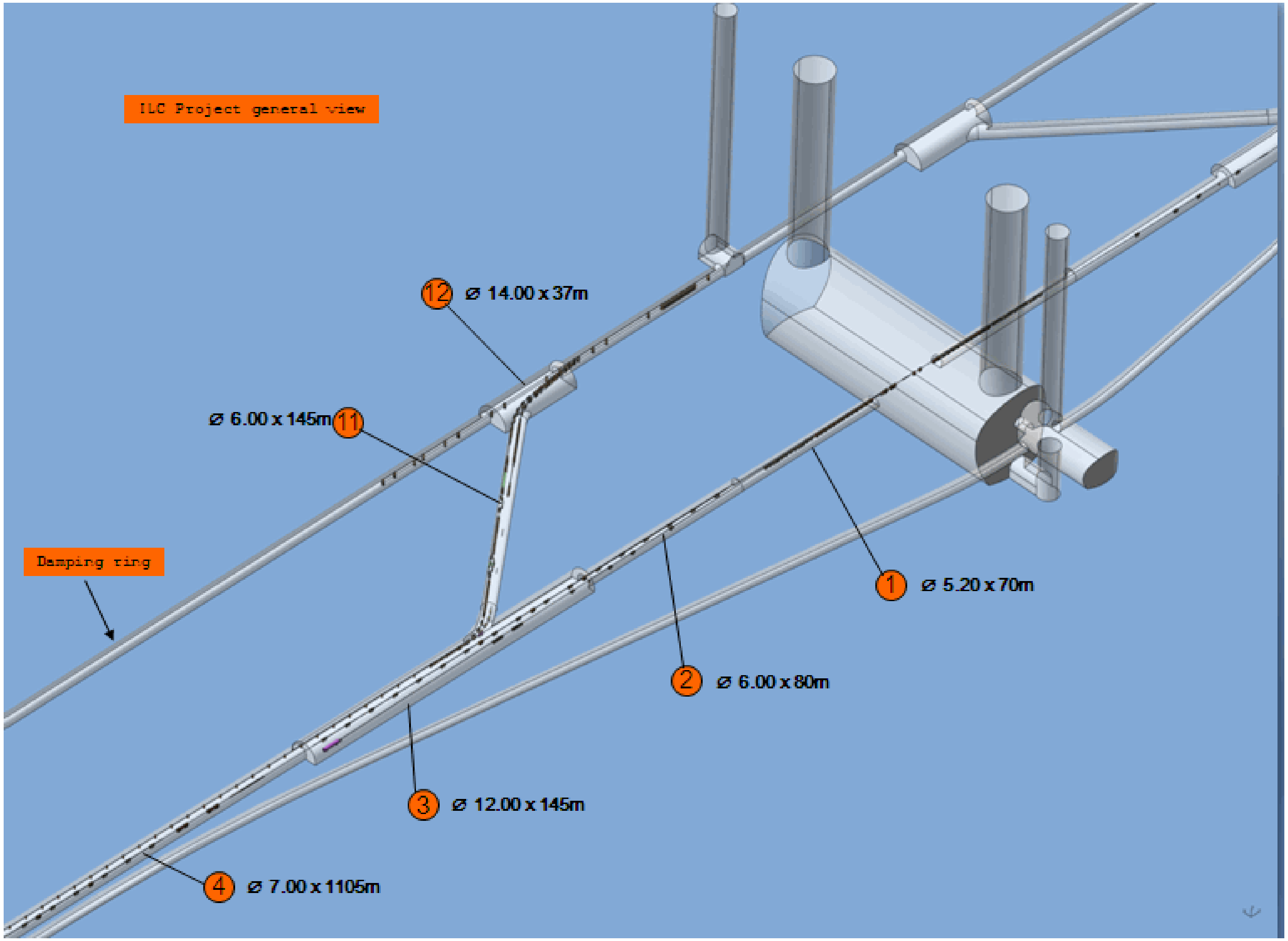
- Central Region SB 2009 Layout
  - Joint Parallel Sessions with Sources, RTML, Damping Ring and BDS Working Groups
  - Update Criteria for Physical Equipment Size and Spacing
    - Area System Beam Lattices and Equipment Layout
    - Aisle Spacing and Required Clearances
    - Installation and Maintenance Access
    - Electrical Support, Cable Trays
    - Electronics Racks Location and Spacing in Support Tunnel
    - Absorber and Dump Locations and Requirements
  - Update Criteria for Cooling and Electrical Requirements
    - Cooling Water Temperature and DT
    - Temperature Stability Requirements in Common Areas
    - Electrical Loading and Access to Connections

3D Examples Of Central Region Layout Done in few Hundred meter segments

	Diameter (m)	Length (m)
1	5.20	70
2	6.00	80
3	12.00	145
4	7.00	1105
5	6.00	193
6	5.20	473
7	8.00	162
8	5.20	375
9	8.00	360
10	5.20	300
11 - Bypass to DR	6.00	145
12 - Junction caverne DR	14.00	37

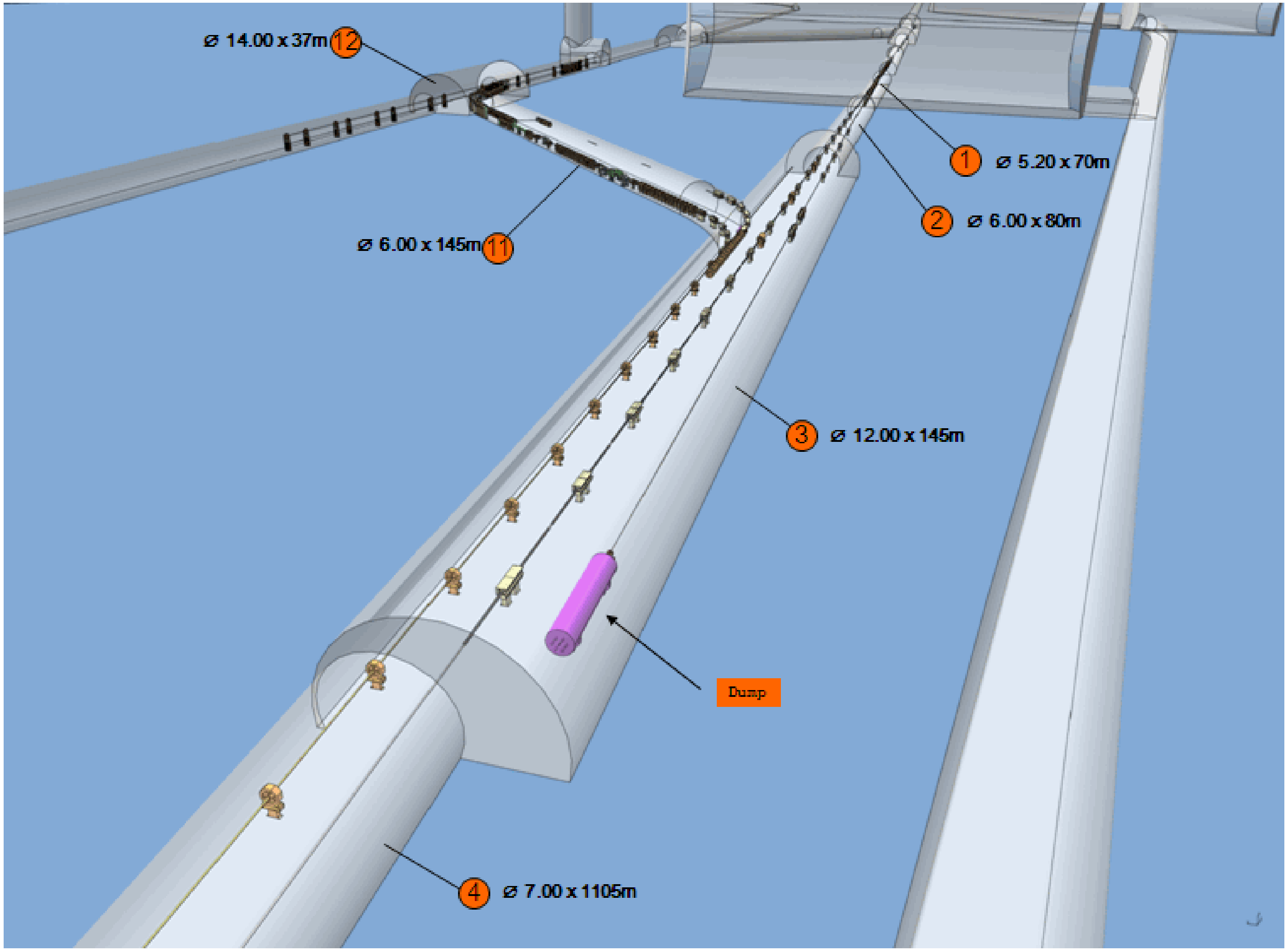


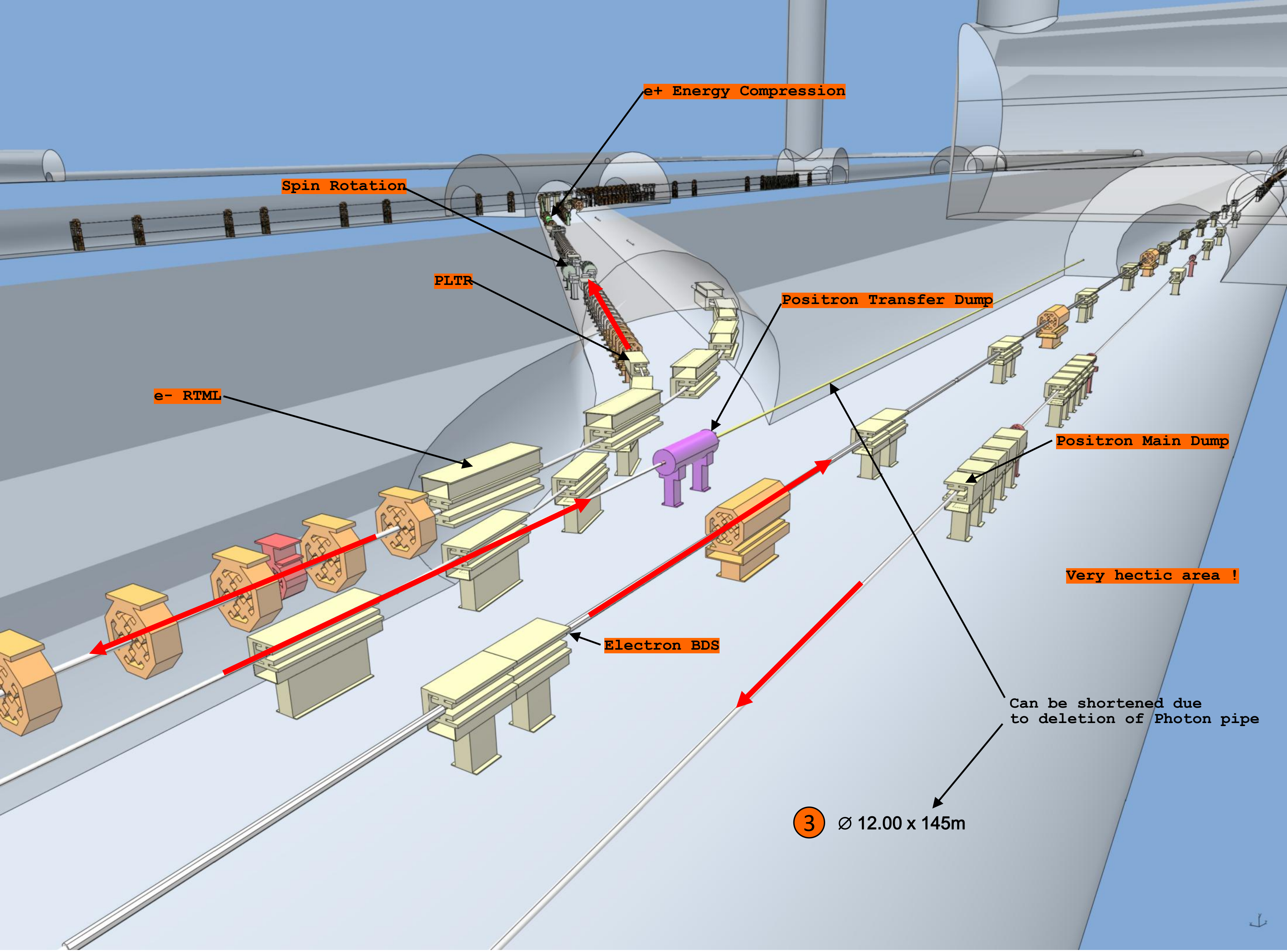
3D Examples Of Central Region Layout

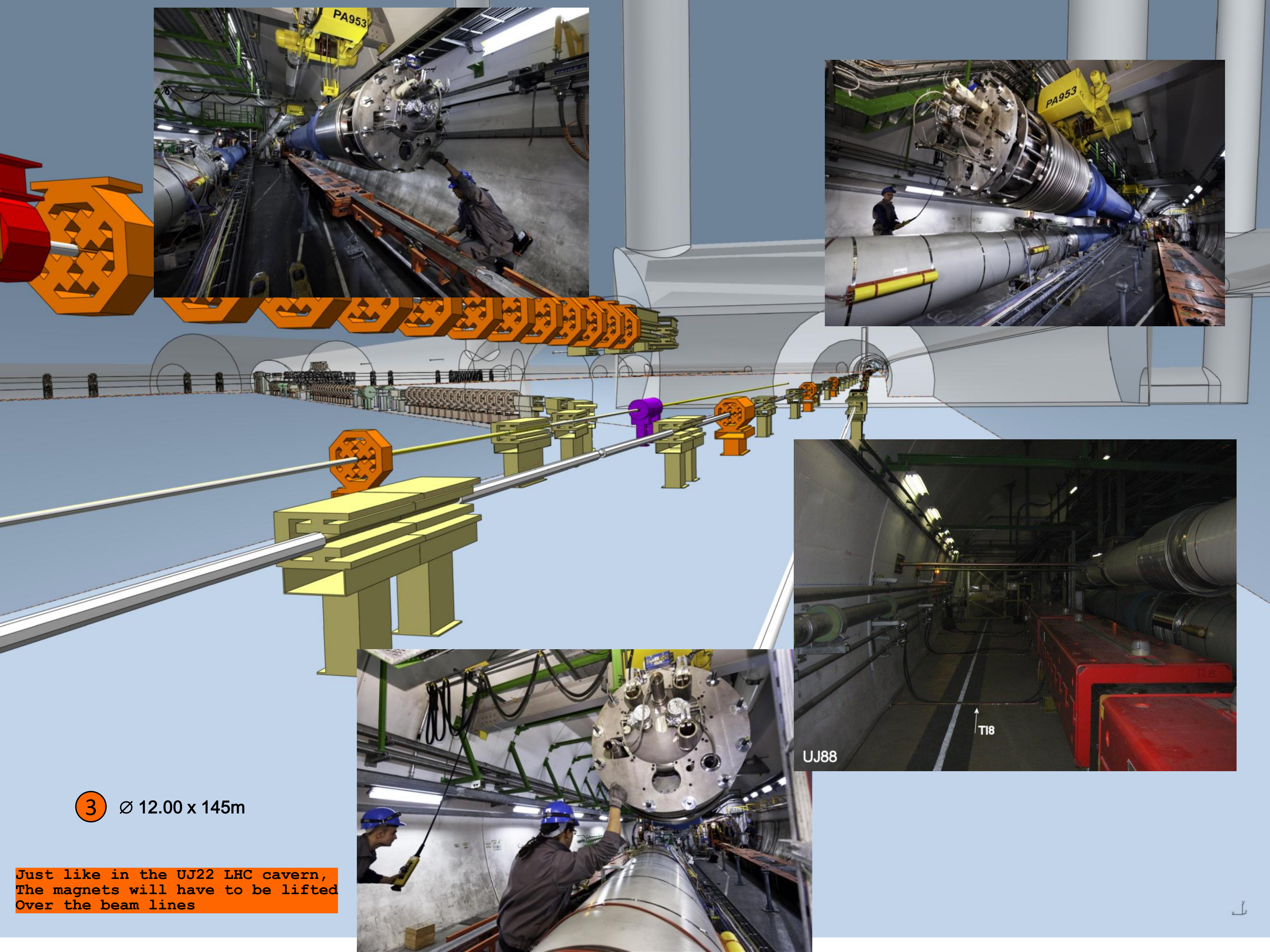


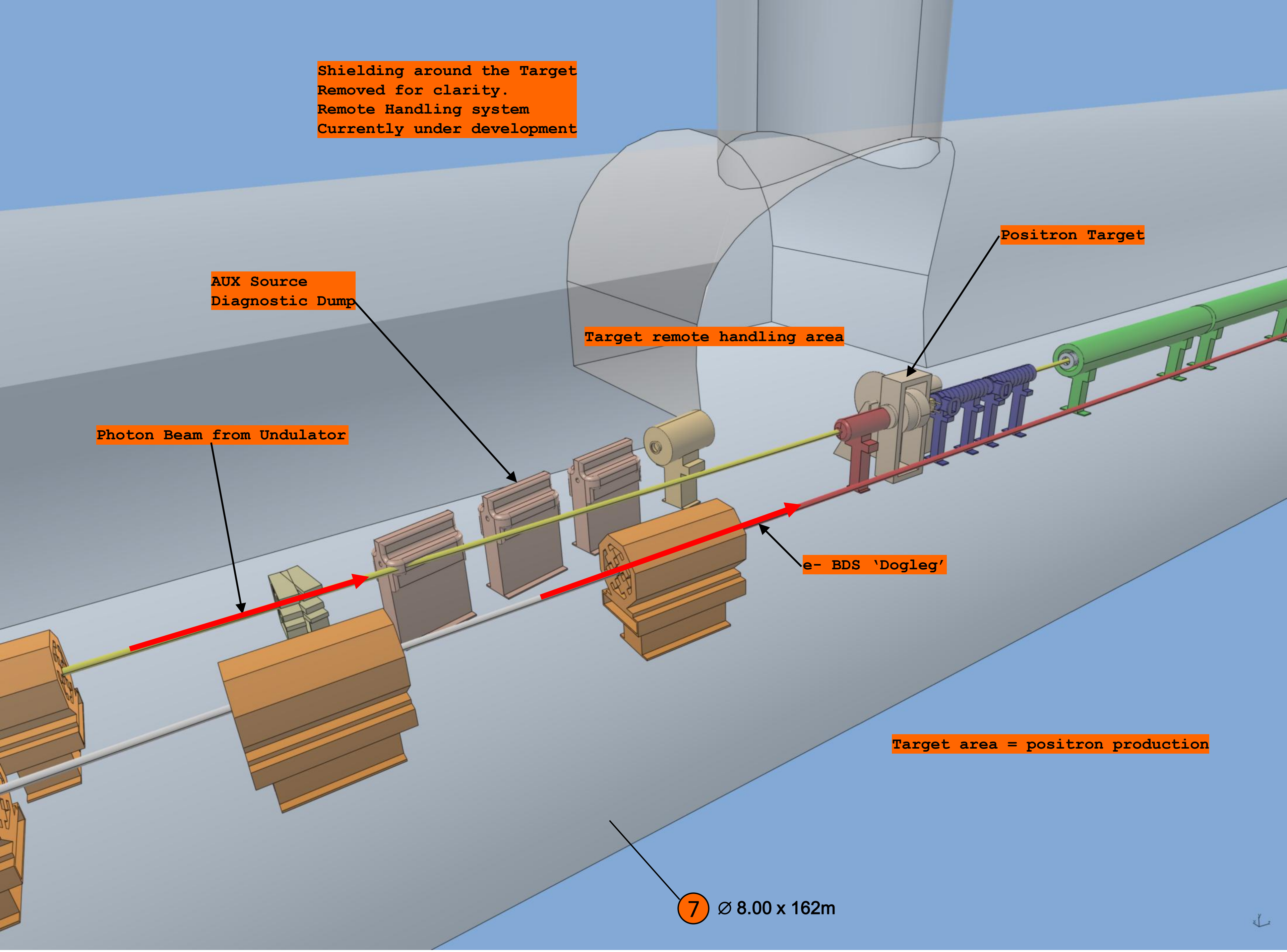
3D Examples Of Central Region Layout

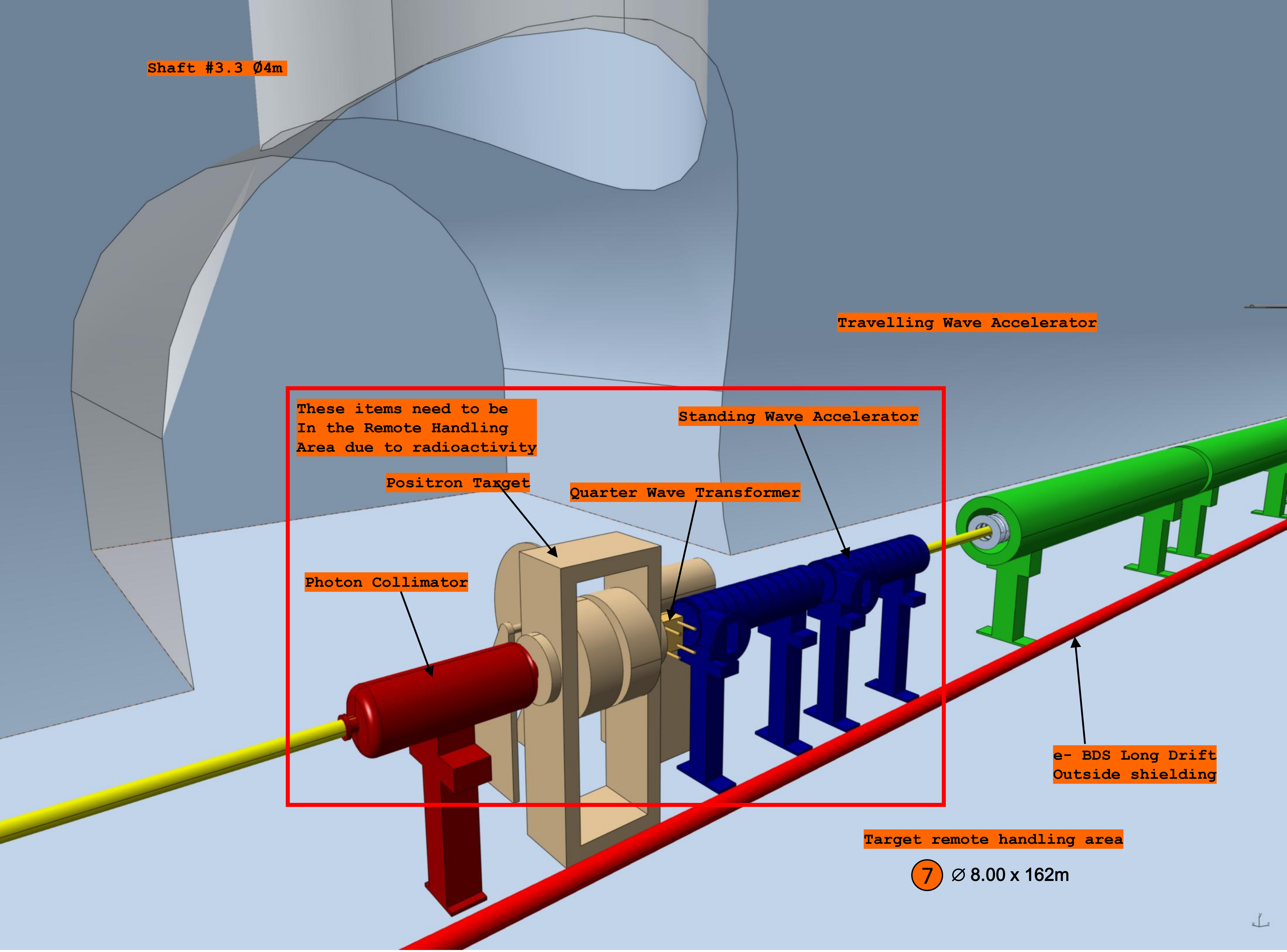
Possible widened section




e+ Energy Compression
Spin Rotation
PLTR
Positron Transfer Dump
e- RTML
Positron Main Dump
Very hectic area !
Electron BDS
Can be shortened due
to deletion of Photon pipe
3
∅ 12.00 x 145m


PA953
PA953
UJ88
TI8
3
∅ 12.00 x 145m
Just like in the UJ22 LHC cavern,
The magnets will have to be lifted
Over the beam lines


Shielding around the Target
Removed for clarity.
Remote Handling system
Currently under development
AUX Source
Diagnostic Dump
Target remote handling area
Positron Target
Photon Beam from Undulator
e- BDS 'Dogleg'
Target area = positron production
7
∅ 8.00 x 162m


Shaft #3.3 Ø4m
Travelling Wave Accelerator
These items need to be
In the Remote Handling
Area due to radioactivity
Standing Wave Accelerator
Positron Target
Quarter Wave Transformer
Photon Collimator
e- BDS Long Drift
Outside shielding
Target remote handling area
7 ∅ 8.00 x 162m

Central Region Issues (1)

- Many CFS layout issues have been identified in the concentrated design effort between CFS and technical systems. Some issues are independent of the E+ source and others associated with the E+ source are independent of whether this source is in the linac or the central region.
- In the +/- 2.5 km either side of the IP there are several required alcoves or widened tunnel sections. The optimal solutions are site or geology dependent.

Central Region Issues (2)

- There are many tune-up and abort dumps which along with very high radiation target and main dumps, fill the tunnels with shielding. These can complicate installation and operation.

- Fewer dumps means more transport lines to them or less functionality in commissioning, tuning and operation

- These CFS efforts with detail 2D and 3D drawings are proving invaluable in exploring options and two more CFS/Tech systems workshops are scheduled for July/Aug

Next Steps

TODAY WE HAVE

- A report on **SCRF R&D and path to gradient choice**
- Reports from R&D facilities **FLASH, CesrTA and ATF**
- Report on Collaboration with **CLIC**

THE REST OF THIS YEAR Continuing studies of SB2009 component designs and impacts

- All of which are the AD&I process and feed into the Baseline Assessment Workshops and

Top Level Change Control (TLCC) in 2010/11