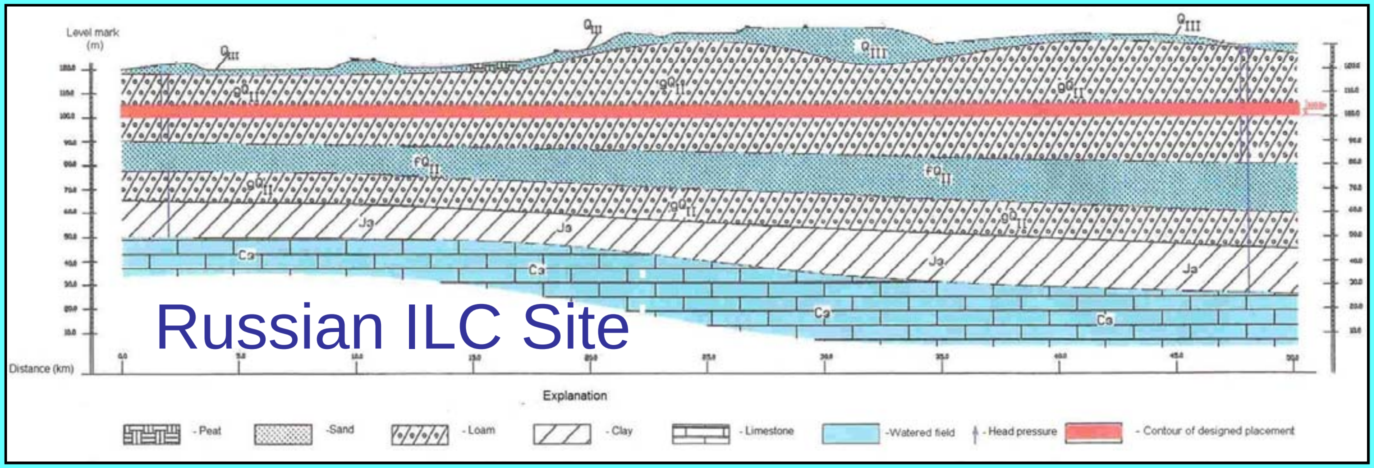
The Path Forward to a Linear Collider



Barry Barish

ECFA Workshop in Warsaw, Poland

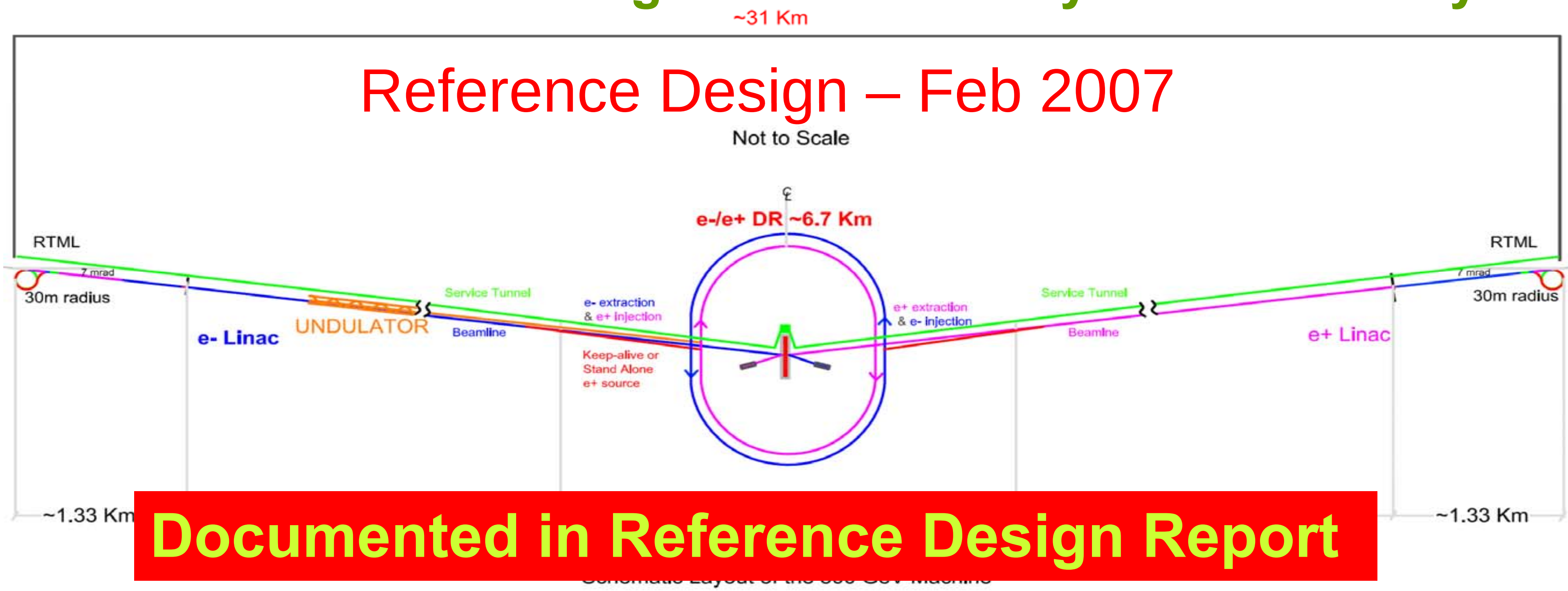
9-June-08

The Path Forward

- Where are we?
  - **Updates on our plans and the global climate**
- Where are we going? (The plan for the GDE)
  - **Technical design phase**
  - **Strategy for the next phase**
- What did we accomplish in Dubna last week?
  - **“Technical Design Phase R&D Plan” released !**
  - **“Uniform Siting”: a new approach to developing ILC convention facilities and siting**
  - **A first look at the Dubna site**
  - **Optimizing cost to performance**

TDR Starting Point: ILC RDR

- **11km SC linacs operating at 31.5 MV/m for 500 GeV**
- **Centralized injector**
  - Circular damping rings for electrons and positrons
  - Undulator-based positron source
- **Single IR with 14 mrad crossing angle**
- **Dual tunnel configuration for safety and availability**

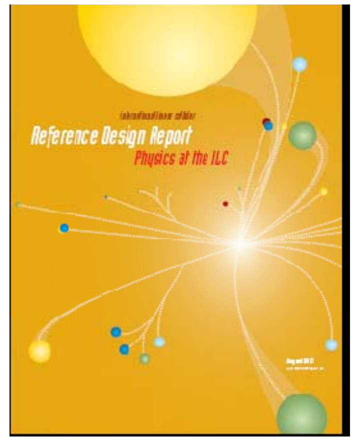


Documented in Reference Design Report

ILC Reference Design

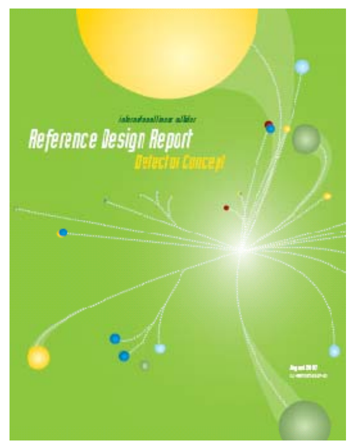
- **Reference Design Report (4 volumes)**

Executive Summary



Physics at the ILC

Accelerator



Detectors

Next Steps: The GDE

- Build on Successes of GDE, RDR and DCR
  - **Be ready to make solid funding proposal compatible with the timescale for scientific results from LHC that could justify proposing a new accelerator construction project.**
- Plan
  - **Re-structured the GDE into a more traditional project management structure, using project tools.**
  - **Our primary program is to carry out a design and R&D program focussed on refining the RDR design through design studies and value engineering, as well as demonstrating key technologies .**

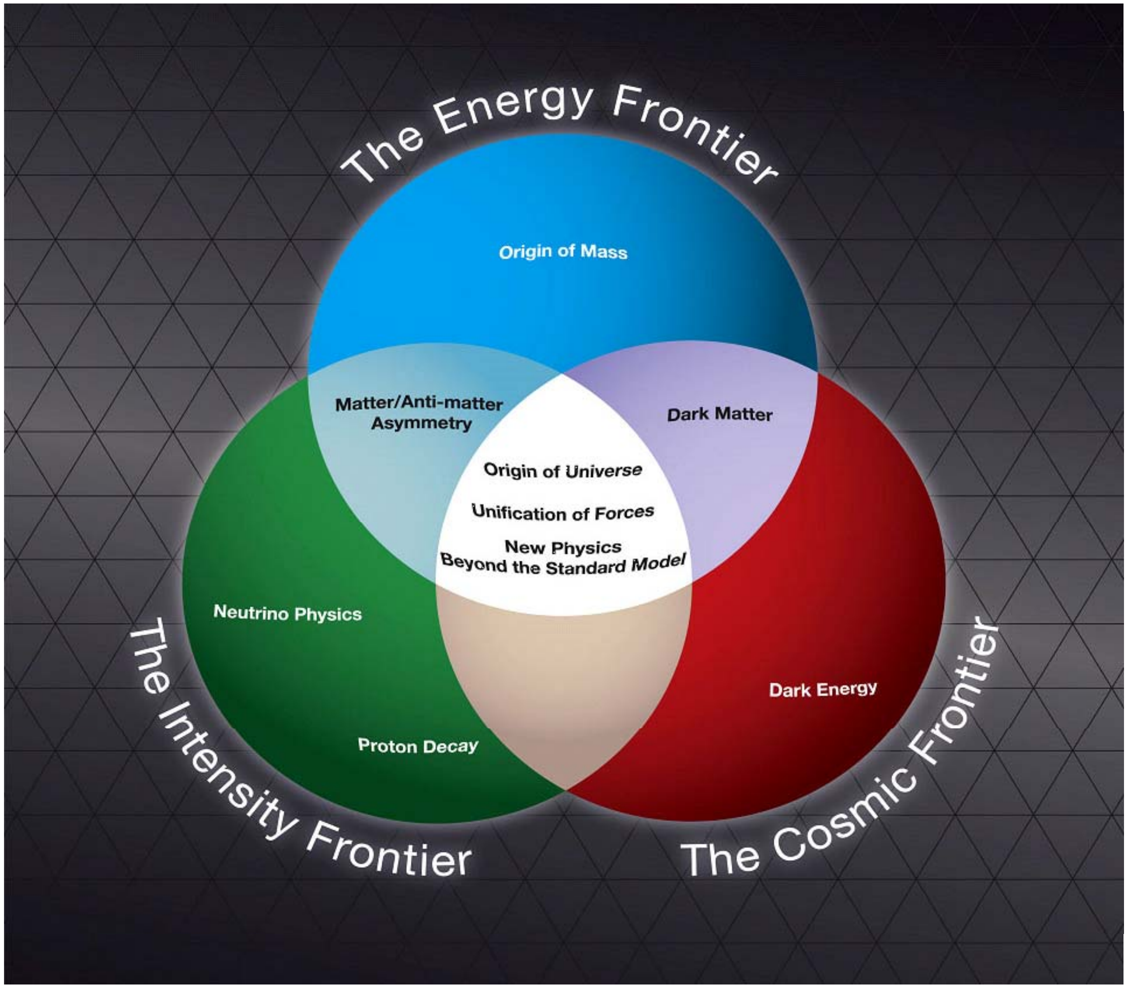
Impacts of US / UK Funding Actions

- UK ILC R&D Program
  - **About 40 FTEs. Leadership roles in Damping Rings and Positron Source, as well as in the Beam Delivery System and Beam Dumps.**
  - **All of this program is generic accelerator R&D, some of which are continuing outside the specific ILC project, <u>retaining key personnel</u>.**

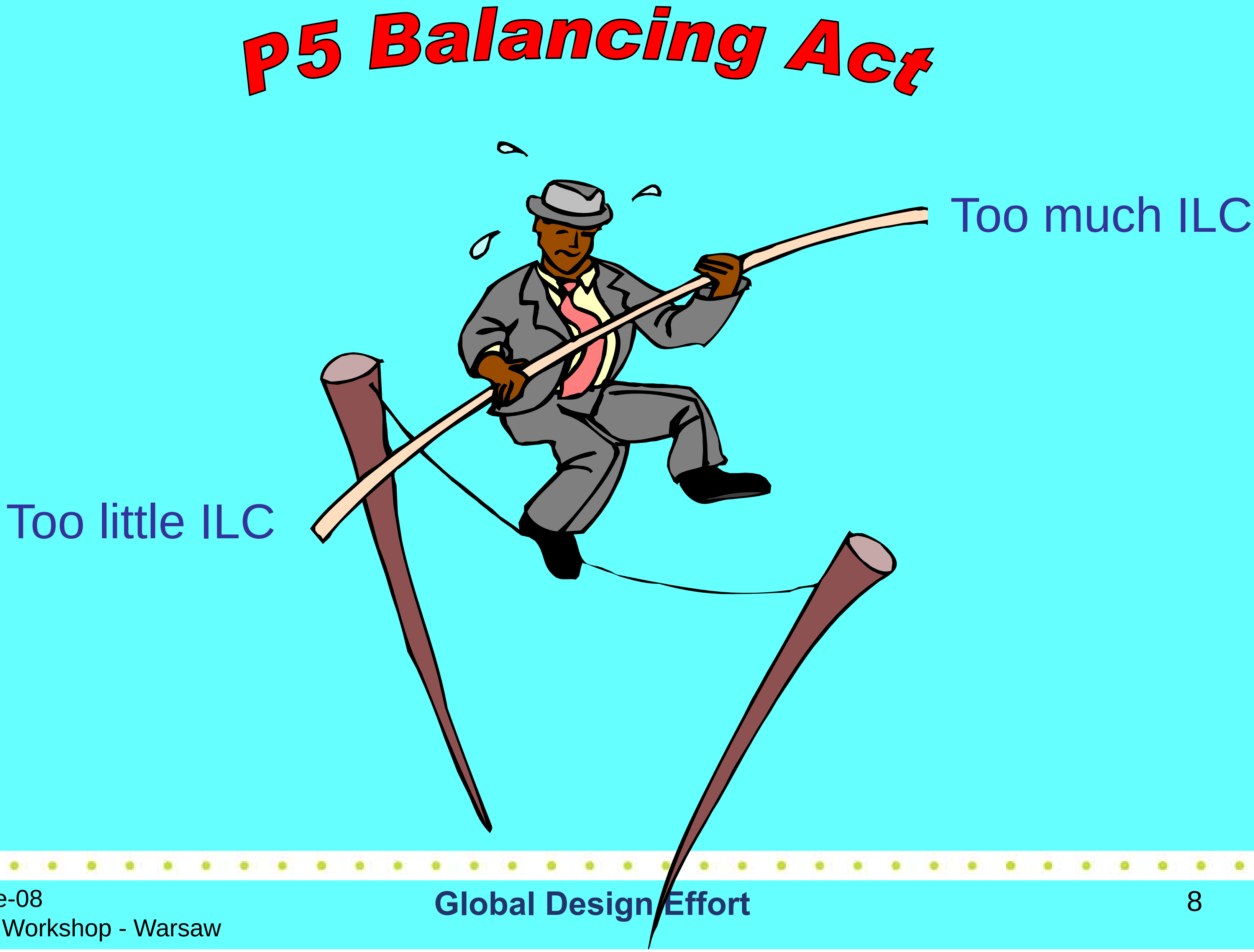
- US Program
  - **ILC R&D reduced \$60M → \$15M for FY08. Planning a reduced level program for FY09 and beyond. <u>US President's FY09 budget proposal is \$35M</u>**
  - **Generic SCRF also terminated in FY08, but is proposed to be revived in FY09 to \$25M. and separated from ILC R&D.**

New U.S. HEP Long Range Strategy

P5 presentation to HEPAP 29-May-08



The Role of ILC in the Ten Year Plan



P5 Report: The Balancing Act

- The panel reiterates the importance of the energy frontier and the need for a next generation lepton collider.. But, they go on to say …

- ***"The large cost estimate for the International Linear Collider, a centerpiece of previous reports, has delayed plans for a possible construction start and has led the particle physics community to take a fresh look at the scientific opportunities in the decade ahead."***

P5 Report: The Balancing Act

- The report acknowledges the expectation that the LHC will validate the physics case and determine the energy. But, they fail to note any of the reasons and projections that indicate the ILC energy range. Nevertheless, the recommendation is the right one, in my opinion.

- ***"If the optimum initial energy proves to be at or below approximately 500 GeV, then the International Linear Collider is the most mature and ready-to-build option with a construction start possible in the next decade. A requirement for initial energy much higher than 500 GeV will mean considering other collider technologies."***

An Integrated Effort to a Linear Collider

- Meetings at CERN in November when I visited CERN to give an ILC colloquium
  - **Meeting with the CLIC Extended Steering Committee, where I suggested we explore areas of joint work, where both stand to gain.**
  - **Meeting with R Aymar, who also endorses the general idea of increasing areas of joint work**
- Follow up meeting in February and May to organize and identify areas of joint interest
- Dubna meeting focused on joint ILC-CLIC site studies and costing methodology

Initiating Joint Areas

- **Co-conveners of the CLIC-ILC working groups**
  - **Civil Engineering and Conventional Facilities (CFS):** Claude Hauviller/CERN, John Osborne/CERN, Vic Kuchler (FNAL)
  - **Beam Delivery Systems and Machine Detector Interface:** D.Schulte/CERN, Brett Parker (BNL), Andrei Seryi (SLAC),, Emmanuel Tsesmelis/CERN
  - **Detectors:** L.Linssen/CERN, Francois Richard/LAL, Dieter.Schlatter/CERN, Sakue Yamada/KEK
  - **Cost & Schedule:** John Carwardine (ANL), Katy Foraz/CERN, Peter Garbincius (FNAL), Tetsuo Shidara (KEK), Sylvain Weisz/CERN
  - **Beam Dynamics:** A.Latina/FNAL), Kiyoshi Kubo (KEK), D.Schulte/CERN, Nick Walker (DESY)

P5 Report: The Balancing Act

- The most important part of the report is the following recommendation, which strongly supports restoring ILC R&D support over the coming few years (**at all budget levels**). It does not however, even indicate elements of a plan to realize the machine or to host it in the U.S.

- ***"The panel recommends for the near future a broad accelerator and detector R&D program for lepton colliders that includes continued R&D on ILC at roughly the proposed FY2009 level in support of the international effort. This will allow a significant role for the US in the ILC wherever it is built."***

P5 Report: The Balancing Act

- Finally, the report endorses ILC detector R&D, but only in the report section on "enabling technologies." In my opinion, we have an unsolved problem in the U.S. that the DoE supports generic R&D, but not detector and LOI efforts . <u>DoE must be educated regarding the importance of the detector efforts and Letters of Intent. This report doesn't help in that regard!</u>

- ***The panel recommends support for a program of detector R&D on technologies strategically chosen to enable future experiments to advance the field, as an essential part of the program. (in the context of ILC and broader lepton collider R&D support)***

So, where do we stand?

- In the UK we have retained the key ingredients (e.g. intellectual leadership) in our efforts toward a linear collider.
- In the U.S., our budget should be restored at a level presently proposed for FY09, and we can expect support at that level through technical design phase.
- This restored support will likely be further delayed by a continuing resolution in the US in an election year.
- Neither the U.S. or U.K. presently have a long range goal of supporting LC construction. We will need both exciting validating **science** results from the LHC, and we will need a very successful TDP, cost reduction, a realistic siting plan, detector LOIs, and an attractive project implementation plan

The Plan - Technical Design Phase

ILC Research and Development Plan for the Technical Design Phase

Release 2

June 2008

ILC Global Design Effort

Director: Barry Barish

Prepared by the Technical Design Phase Project Management

Project Managers: Marc Ross, Nick Walker, Akira Yamamoto

- First Official Release
- Released in Dubna
- Next review and release: December 08

How do we propose to move forward!

General Theme: ***RISK REDUCTION***

- We must re-examine our design and optimize for cost to performance.
- This will require aggressive studies of the major cost drivers, reducing scope, staging, etc. We will do this openly and in full coordination with experimentalists.
- We must develop our technical design, such that major technical questions (gradient, electron cloud, etc) are positively resolved
- We must develop the technical design in preparation of making a construction proposal (plug compatible designs, value engineered concepts, etc.)
- Finally, we must develop an attractive, realistic and flexible Project Implementation Plan

Essential Elements of TDP

- Draft Document
  - ***"ILC Research and Development Plan for the Technical Design Phase"* Release 2 June 2008**

- Key Supporting R&D Program (priorities)
  - **High Gradient R&D - globally coordinated program to demonstrate gradient for TDR by 2010 with 50%yield**
  - **Electron Cloud Mitigation – Electron Cloud tests at Cornell to establish mitigation and verify one damping ring is sufficient.**
  - **Final Beam Optics – Tests at ATF-2 at KEK**

TD Phase 1

- Timescale: Interim report mid 2010
- Major theme: High-priority risk-mitigating R&D
  - **Superconducting RF linac technology – technical demonstration of gradient, plug compatiblity and identifying potential cost reductions**
  - **Confirm mitigation of electron cloud effects**
  - **The re-baseline will take place after careful consideration and review of the results of the TD Phase 1 studies and the status of the critical R&D.**

TD Phase 2

- Timescale: Produce report mid-2012
- **First goal:** New baseline design
  - **SCRF – S1 Test of one RF unit**
  - **Detailed technical design studies**
  - **Updated VALUE estimate and schedule.**
  - **Remaining critical R&D and technology demonstration**
- **Second Goal:** Develop a Project Implementation Plan.

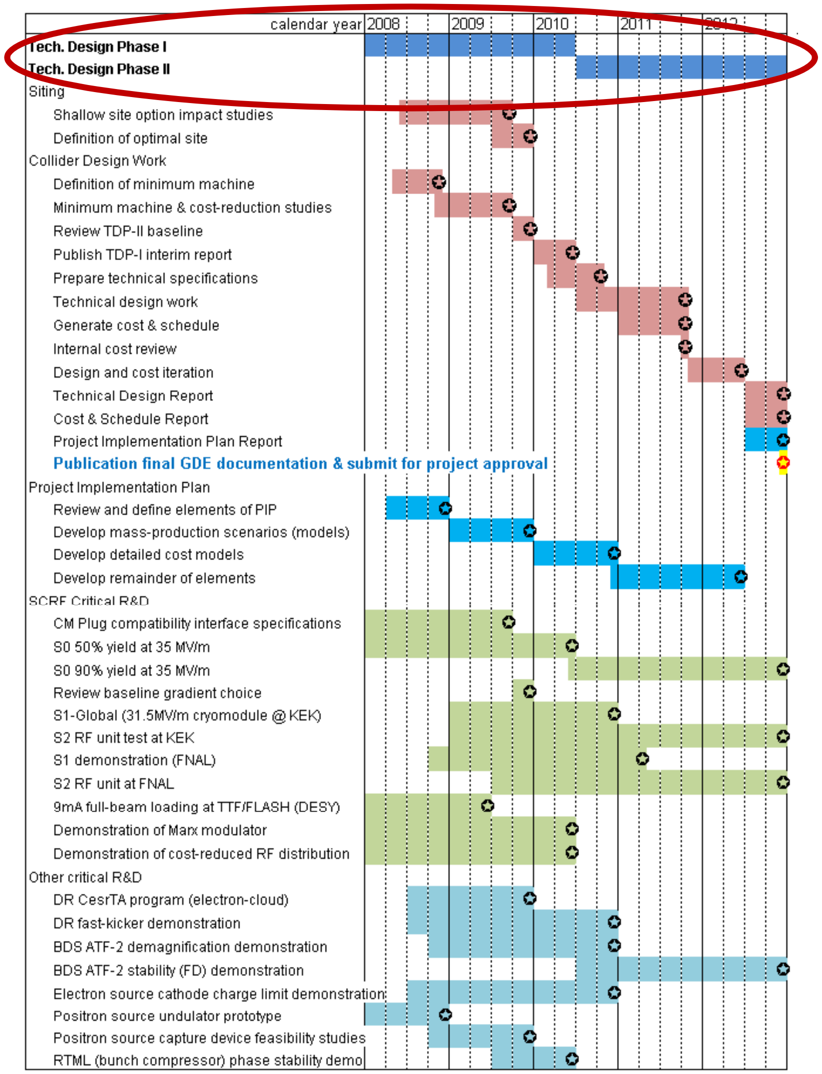
ILC R&D Major Test Facilites

Test Facility	Acronym	Purpose	Host Lab	Operation start	Organized through:
Accelerator Test Facility	ATF	Damping Ring	KEK	1997	ATF Collaboration
Cornell Test Accelerator	CESR-TA	Damping Ring	Cornell	2008	Cornell
Superconducting RF Test Facility	STF	Main linac	KEK	2008	KEK
TESLA Test Facility/ Free Electron Laser Hamburg	TTF FLASH	Main linac	DESY	1997	TESLA Collaboration, DESY
ILC Test Accelerator	ILCTA-NML	Main Linac	FNAL	2009	Fermilab
Beam Delivery Test Facility	ATF-2	Beam Delivery	KEK	2008	ATF Collaboration
End Station A (program terminated 2008)	ILC-SLAC ESA	Machine – Detector Interface	SLAC	2006	SLAC

R&D Test Facilities Deliverables

Test Facility	Deliverable	Date
Optics and stabilisation demonstrations:		
ATF	Generation of 1 pm-rad low emittance beam	2009
ATF-2	Demonstration of compact Final Focus optics (design demagnification, resulting in a nominal 35 nm beam size at focal point).	2010
	Demonstration of prototype SC and PM final doublet magnets	2012
	Stabilisation of 35 nm beam over various time scales.	2012
Linac high-gradient operation and system demonstrations:		
TTF/FLASH	Full 9 mA, 1 GeV, high-repetition rate operation	2009
STF & ILCTA-NML	Cavity-string test within one cryomodule (S1 and S1-global)	2010
	Cryomodule-string test with one RF Unit with beam (S2)	2012
Electron cloud mitigation studies:		
CESR-TA	Re-configuration (re-build) of CESR as low-emittance e-cloud test facility. First measurements of e-cloud build-up using instrumented sections in dipoles and drifts sections (large emittance).	2008
	Achieve lower emittance beams. Measurements of e-cloud build up in wiggler chambers.	2009
	Characterisation of e-cloud build-up and instability thresholds as a function of low vertical emittance (≤20 pm)	2010

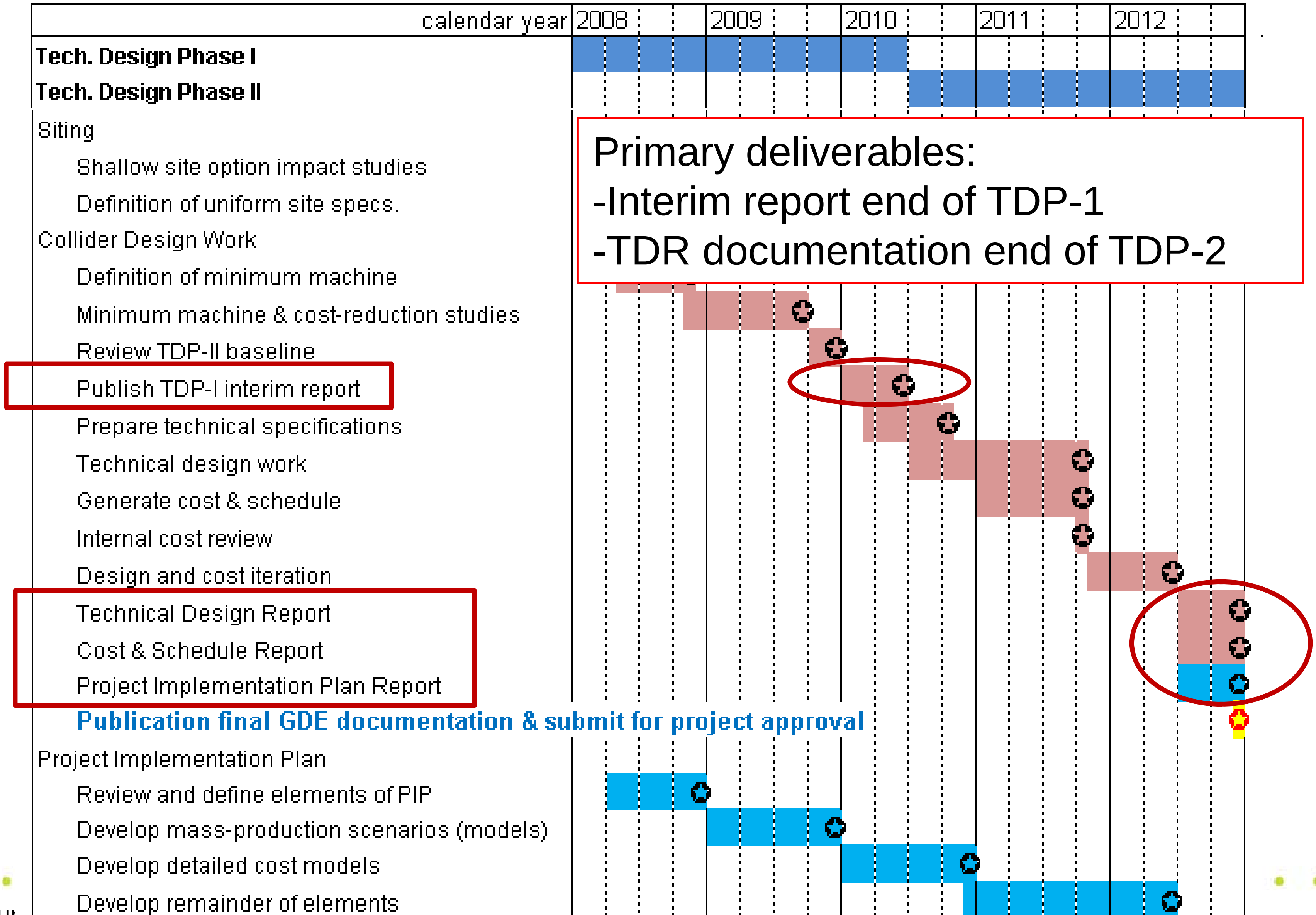
Our Plan with goals and dates



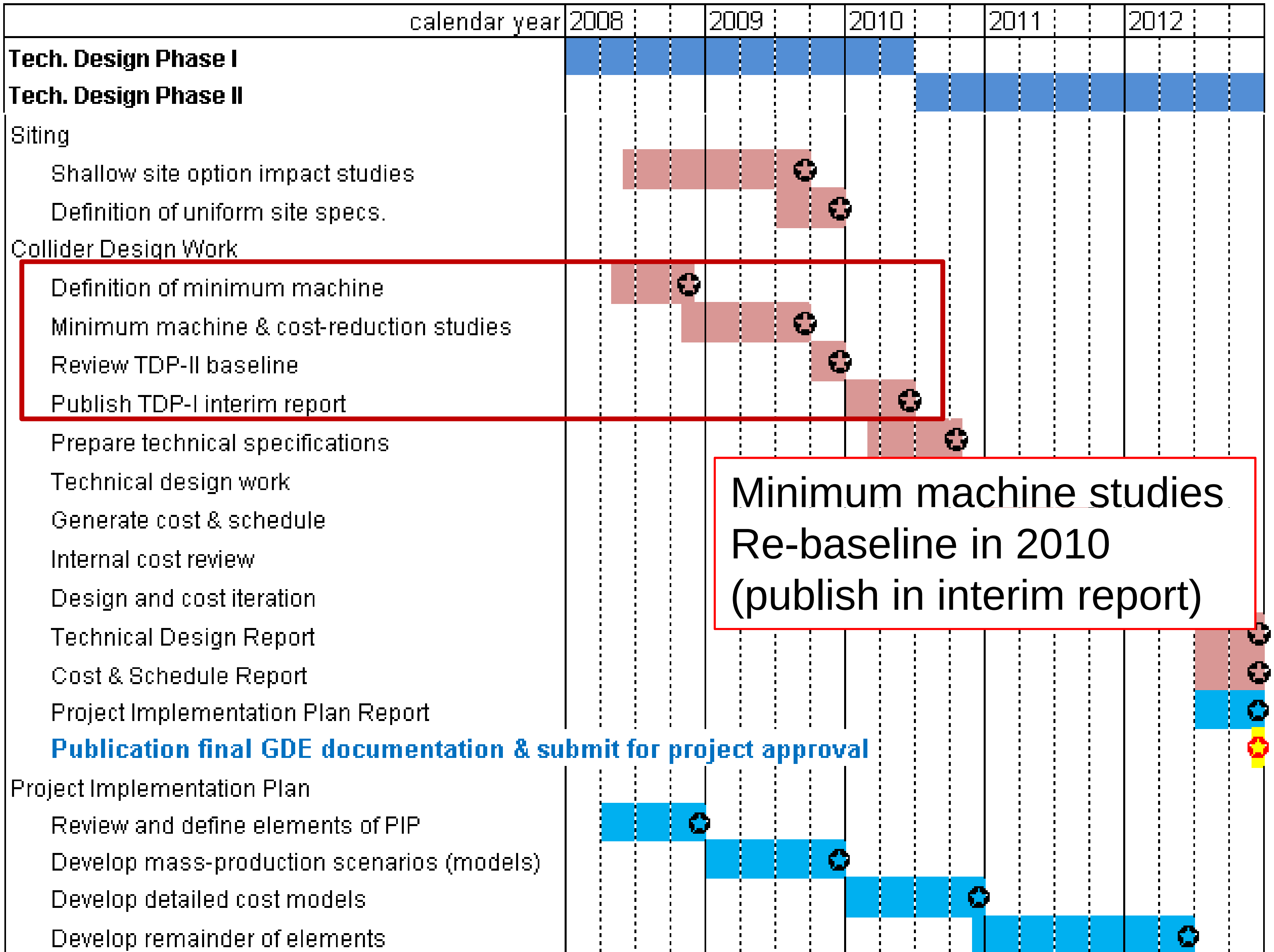
- Basic time-scale
  - Phase 1: July 2010
    - Paris meeting already scheduled
  - Phase 2: end of CY 2012
    - Not previously well-defined
    - Fits with current SCRF planning (S2 for example)

- Encapsulates the PMs strategy and vision for the next four years
  - Critical R&D
  - Cost reduction / machine design
  - Project Implementation Plan

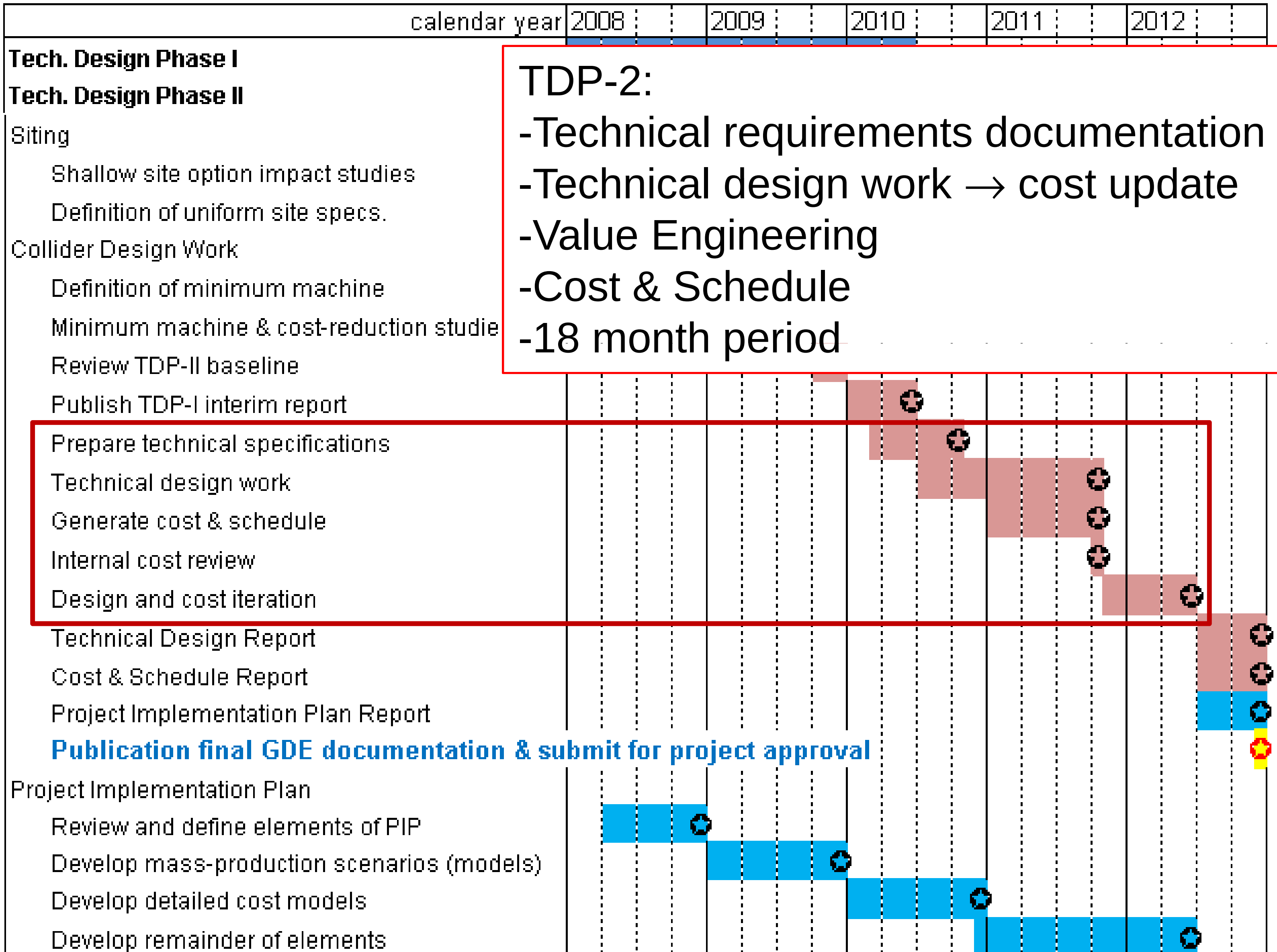
Design / Cost Reduction / PIP



Design / Cost Reduction / PIP

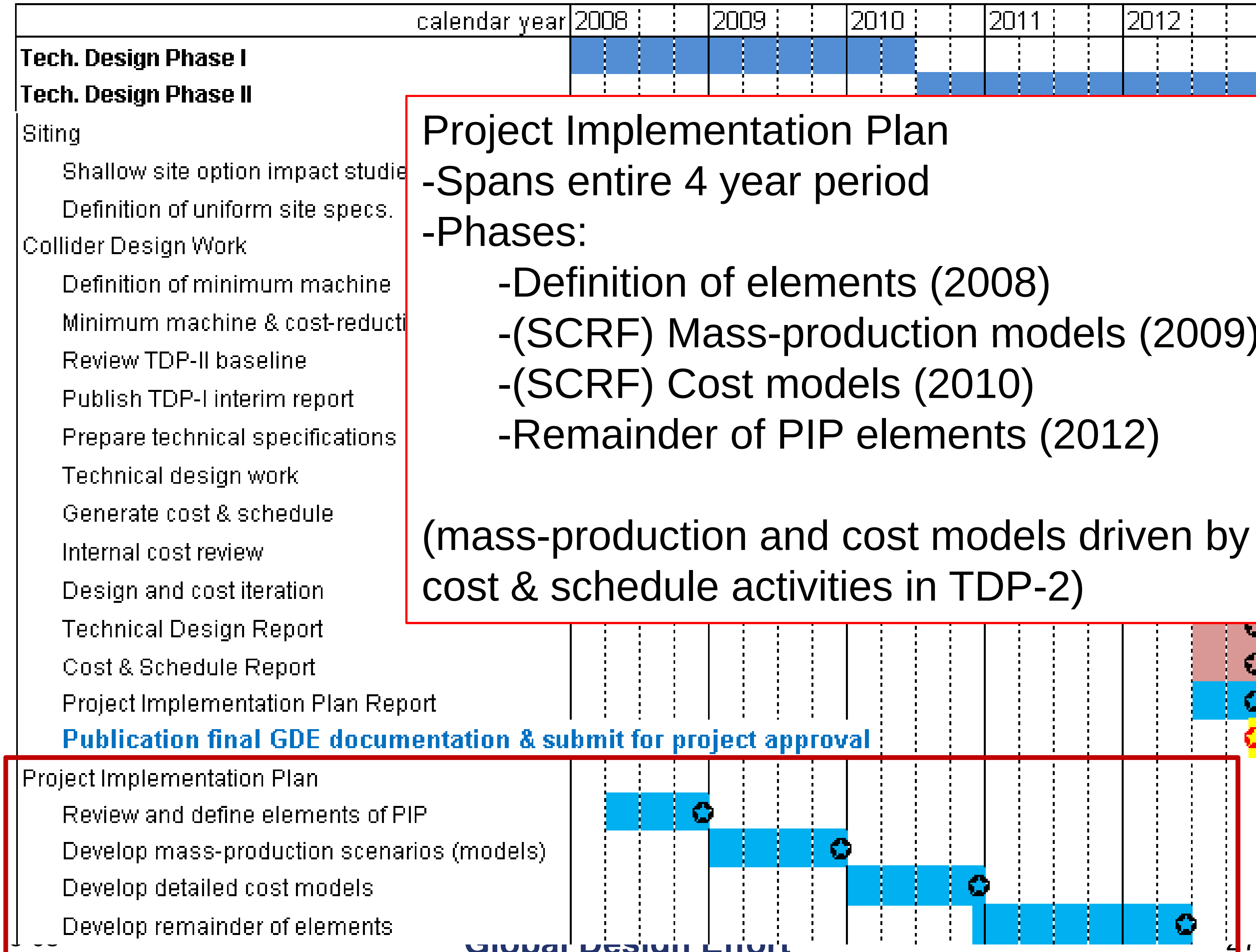


Design / Cost Reduction / PIP



TDP-2:
- -Technical requirements documentation
- -Technical design work → cost update
- -Value Engineering
- -Cost & Schedule
- -18 month period

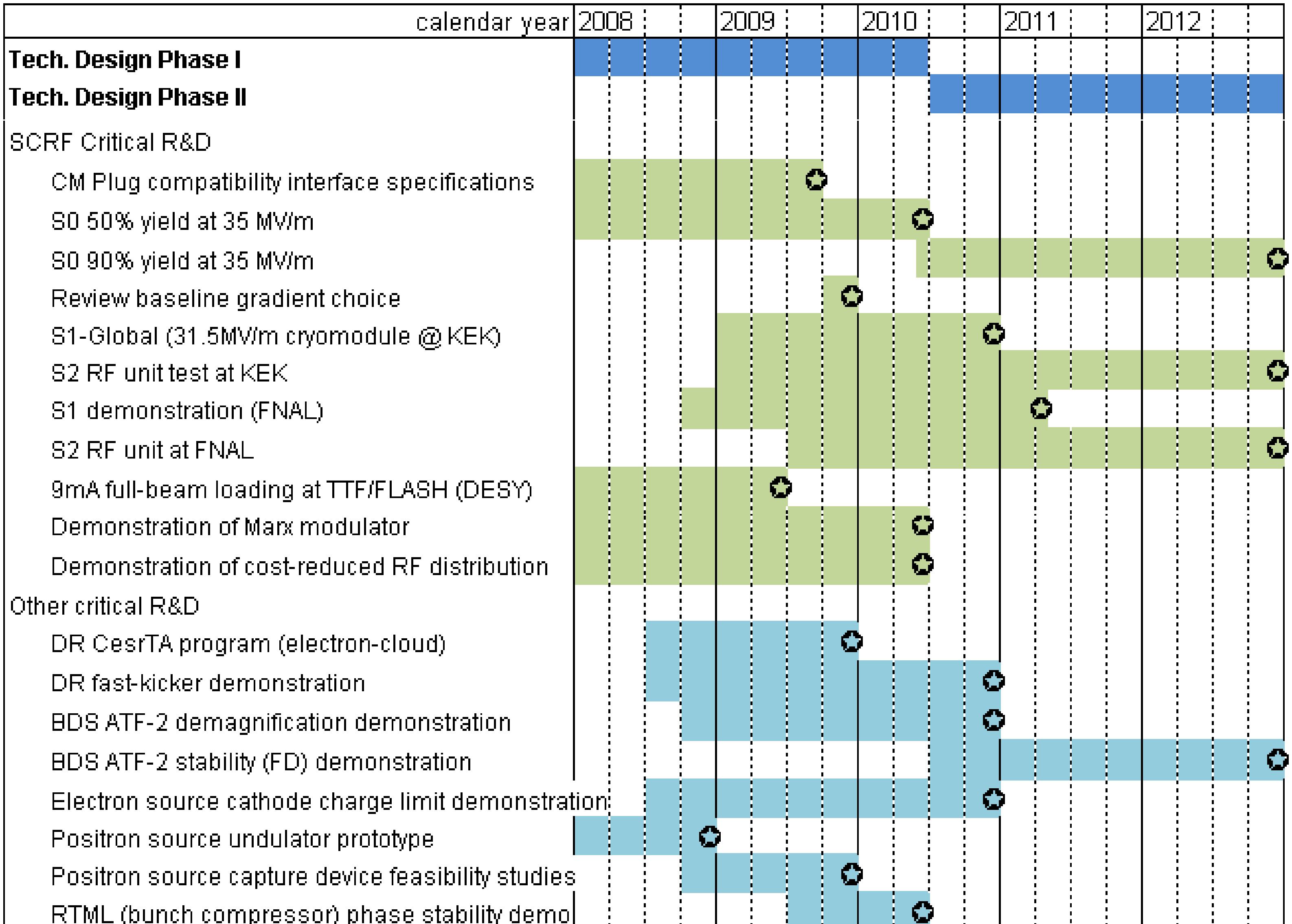
Design / Cost Reduction / PIP



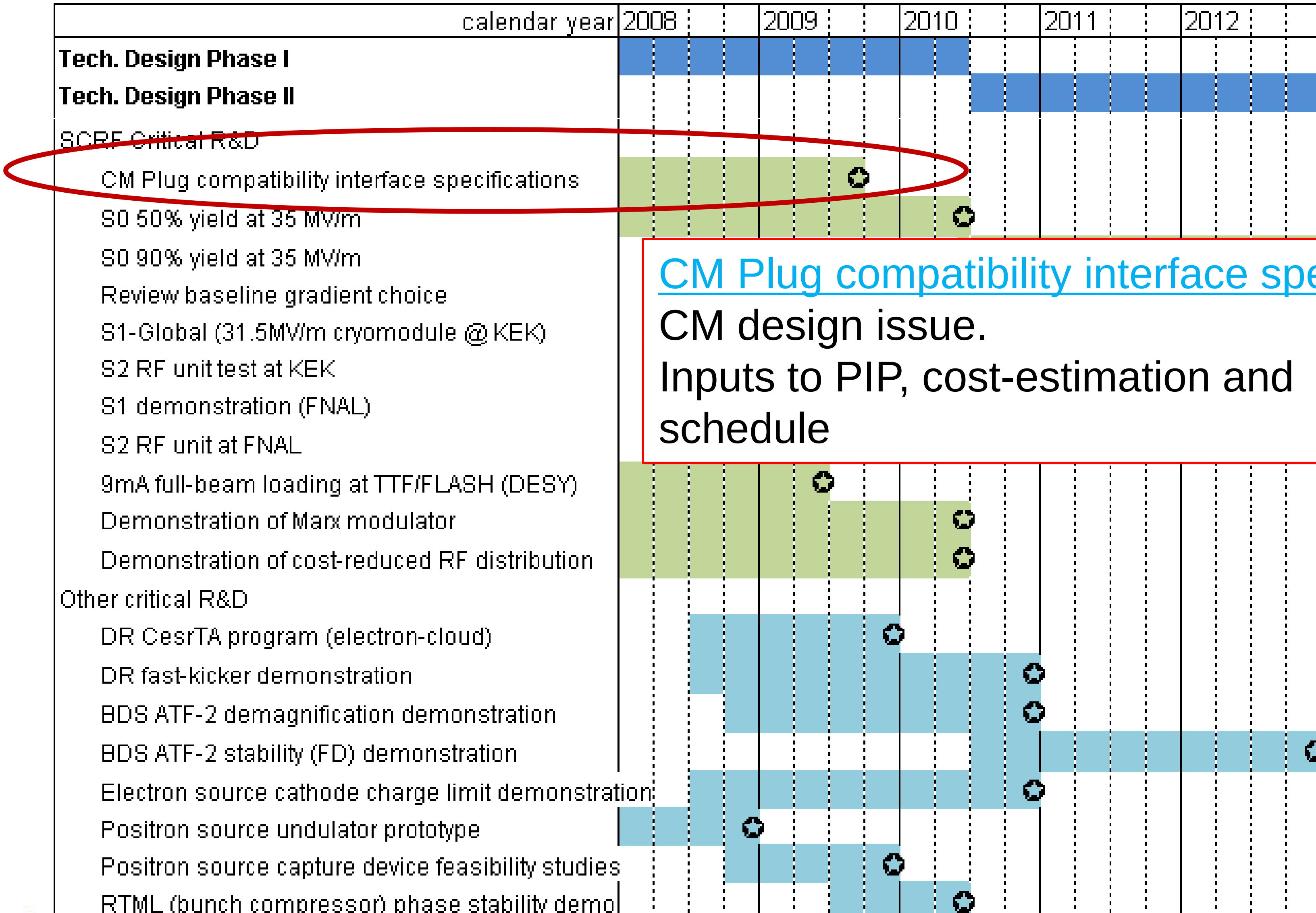
Project Implementation Plan
- -Spans entire 4 year period
- -Phases:
  - -Definition of elements (2008)
  - -(SCRF) Mass-production models (2009)
  - -(SCRF) Cost models (2010)
  - -Remainder of PIP elements (2012)

(mass-production and cost models driven by cost & schedule activities in TDP-2)

Critical R&D


calendar year
2008
2009
2010
2011
2012
Tech. Design Phase I
Tech. Design Phase II
SCRF Critical R&D
CM Plug compatibility interface specifications
S0 50% yield at 35 MV/m
S0 90% yield at 35 MV/m
Review baseline gradient choice
S1-Global (31.5MV/m cryomodule @ KEK)
S2 RF unit test at KEK
S1 demonstration (FNAL)
S2 RF unit at FNAL
9mA full-beam loading at TTF/FLASH (DESY)
Demonstration of Marx modulator
Demonstration of cost-reduced RF distribution
Other critical R&D
DR CesrTA program (electron-cloud)
DR fast-kicker demonstration
BDS ATF-2 demagnification demonstration
BDS ATF-2 stability (FD) demonstration
Electron source cathode charge limit demonstration
Positron source undulator prototype
Positron source capture device feasibility studies
RTML (bunch compressor) phase stability demo

Critical R&D

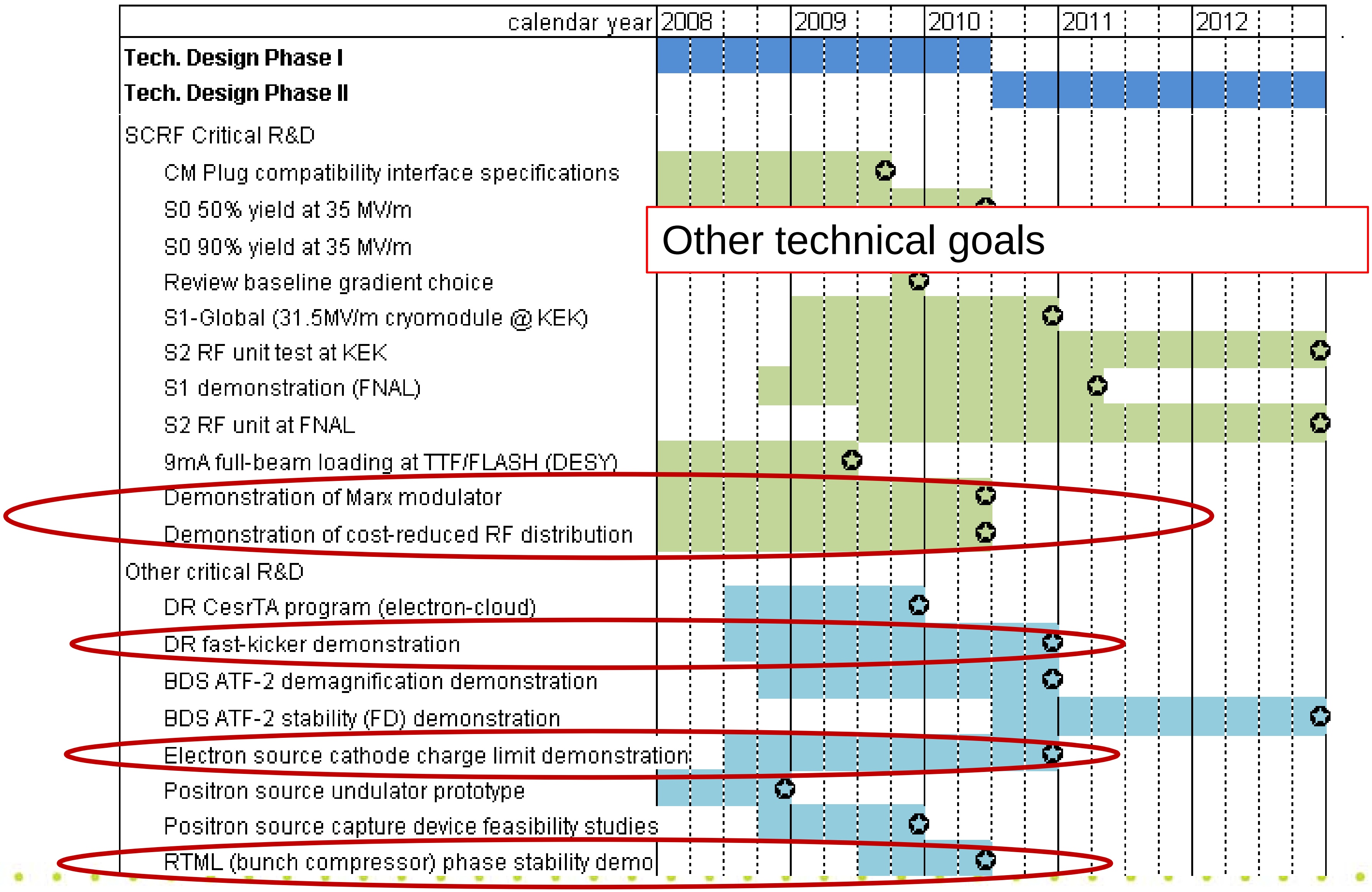


CM Plug compatibility interface specs.

CM design issue.

Inputs to PIP, cost-estimation and schedule

Critical R&D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BDS ATF-2 stability (FD) demonstration
Electron source cathode charge limit demonstration
Positron source undulator prototype
Positron source capture device feasibility studies
RTML (bunch compressor) phase stability demo
Other technical goals

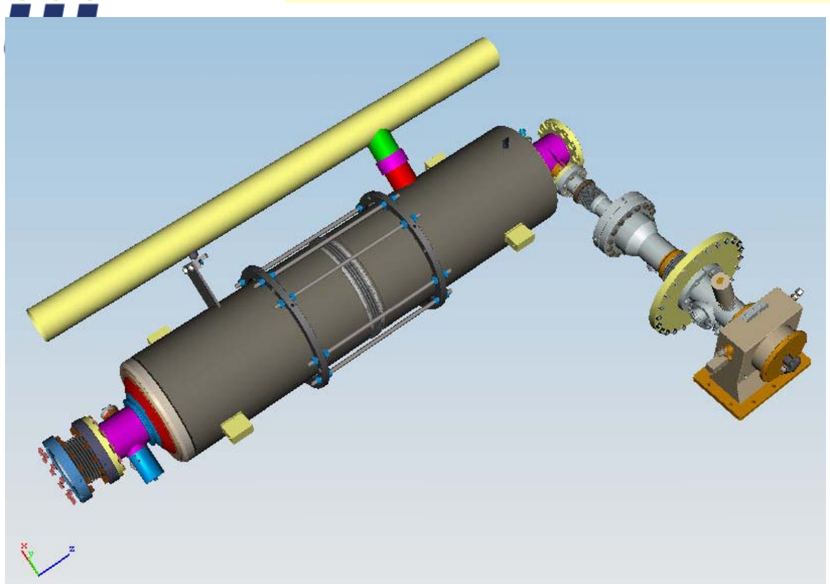
SCRF Major Goals

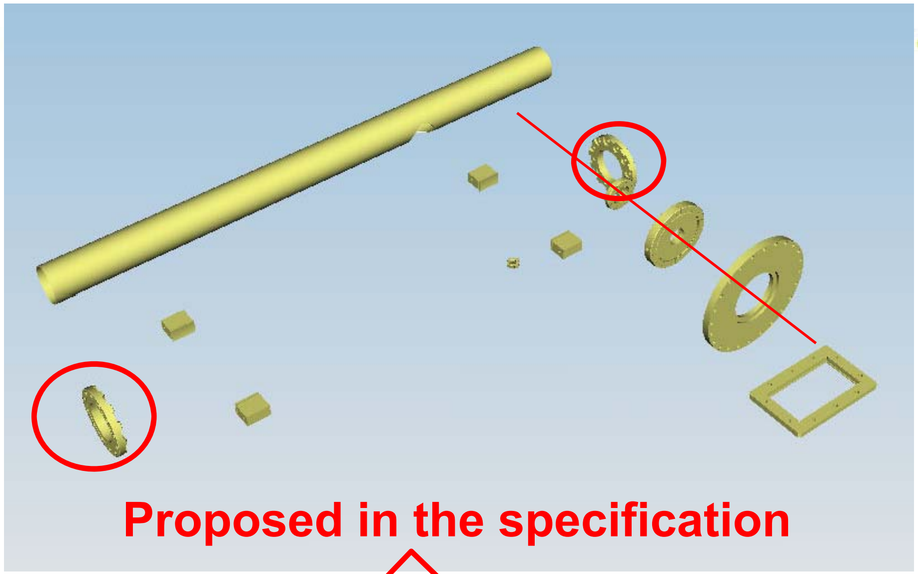
High-gradient cavity performance at 35 MV/m according to the specified chemical process with a yield of 50% in TDP1, and with a production yield of 90% in TDP2	2010 2012
Nominal Cryomodule design to be optimized: - plug-compatible design including tune-ability and maintainability - thermal balance and cryogenics operation - beam dynamics (addressing issues such as orientation and alignment)	2009
Cavity-string performance in one cryomodule with the average gradient 31.5 MV based on a global effort (S1 and S1-global)	2010
An ILC accelerator unit, consisting of three cryomodules powered by one RF unit, with achieving the average gradient 31.5 MV/m (S2)	2012

Global R&D Plan
Consensus in SCRF-TA

Calender Year		2008	2009	2010	2011	2012
EDR	**TDP1**				**TDP-II**	
S0: **Cavity Gradient (MV/m)**	**30**	**35** (> 50%)				**35** (>90%)
KEK-STF-0.5a: 1 Tesla-like/LL						
KEK-STF1: 4 cavities						
S1-Global (AS-US-EU) **1 CM (4+2+2 cavities)**			CM ($4_{AS}+2_{US}+2_{EU}$) <31.5 MV/m>			
S1(2) -ILC-NML- Fermilab **CM1- 4 with beam**			**CM2 CM3 CM4**			
S2:STF2/KEK: **1 RF-unit with beam**			**Fabrication in industries**		**STF2 (3 CMs) Assemble & test**	

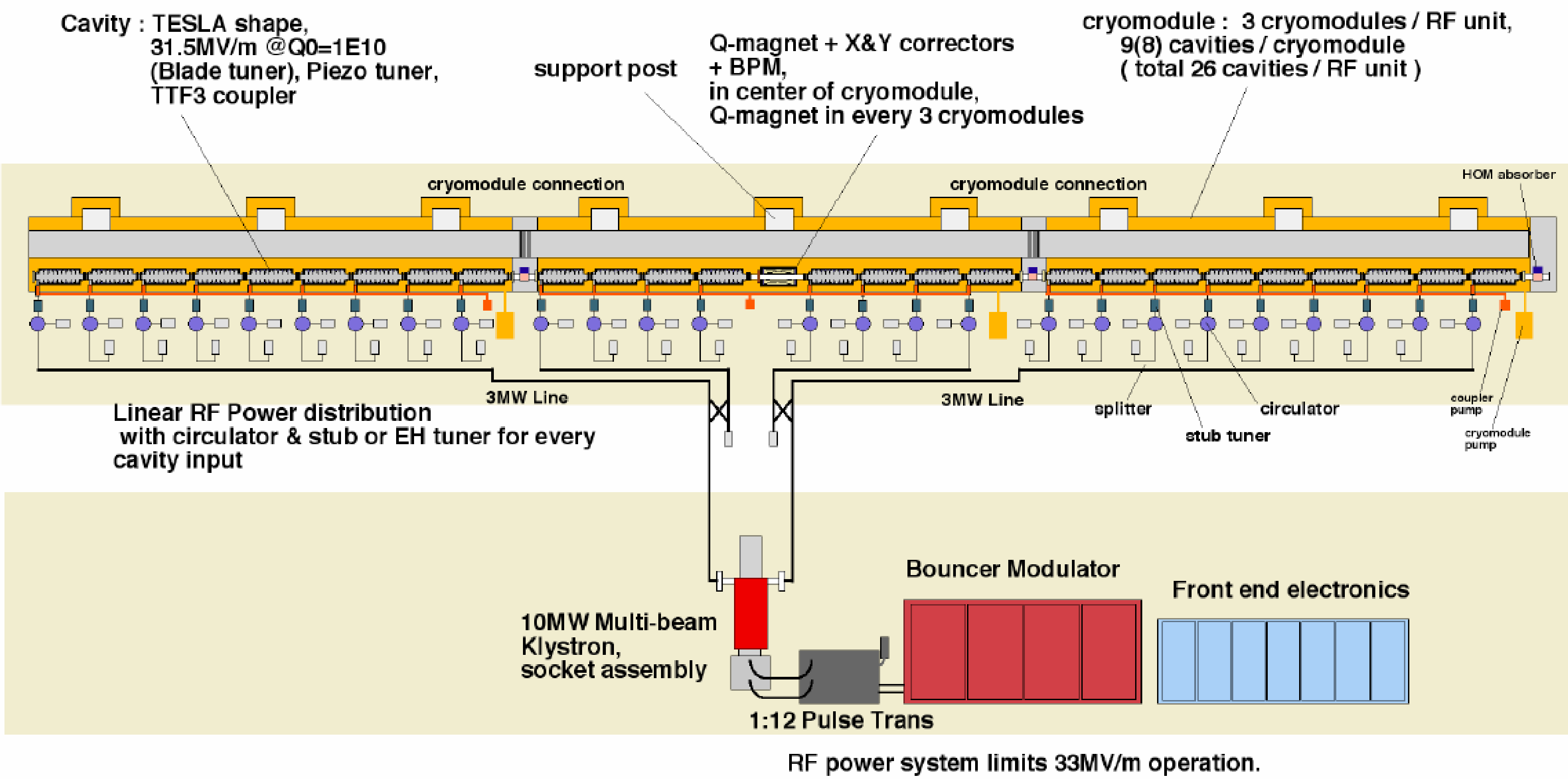
Plug Compatible Assembly





Helium Vessel Body		KEK-STF-BL	KEK-STF-LL	FNAL-T4CM	DESY-XFEL
Helium Jacket	Material	Ti	SUS	Ti	Ti
	Slot length, mm	1337	1337	1326.7	(1382:Type3)
	Distance between beam pipe flanges, m	1258.6	1254.5	1247.4	1283.4
	Distance between bellows flanges, mm	78.4	85.2	80.49 (cold)	
	Outer diameter, mm	242	236	240	240
Beam Pipe Flange	Material	NbTi	Ti	NbTi	NbTi
	Outer diameter, mm	130	140	140	140
	Inner diameter, mm	84	80	82.8	82.8
	Thickness, mm	14	17.5	17.5	17.5
	PCD, bolts	ϕ115, 16−ϕ9	ϕ120, 16−ϕ9	12, M8 SS studs	12, M8 SS studs
	Sealing	Helicoflex	M-O seal	Al Hex Seals	Hexagonal Al ring
	Distances between the connection				
	surface and input coupler axis	62, −1196.6	58.1, −1213.9	60.6, −1186.8	60.6, −1222.8

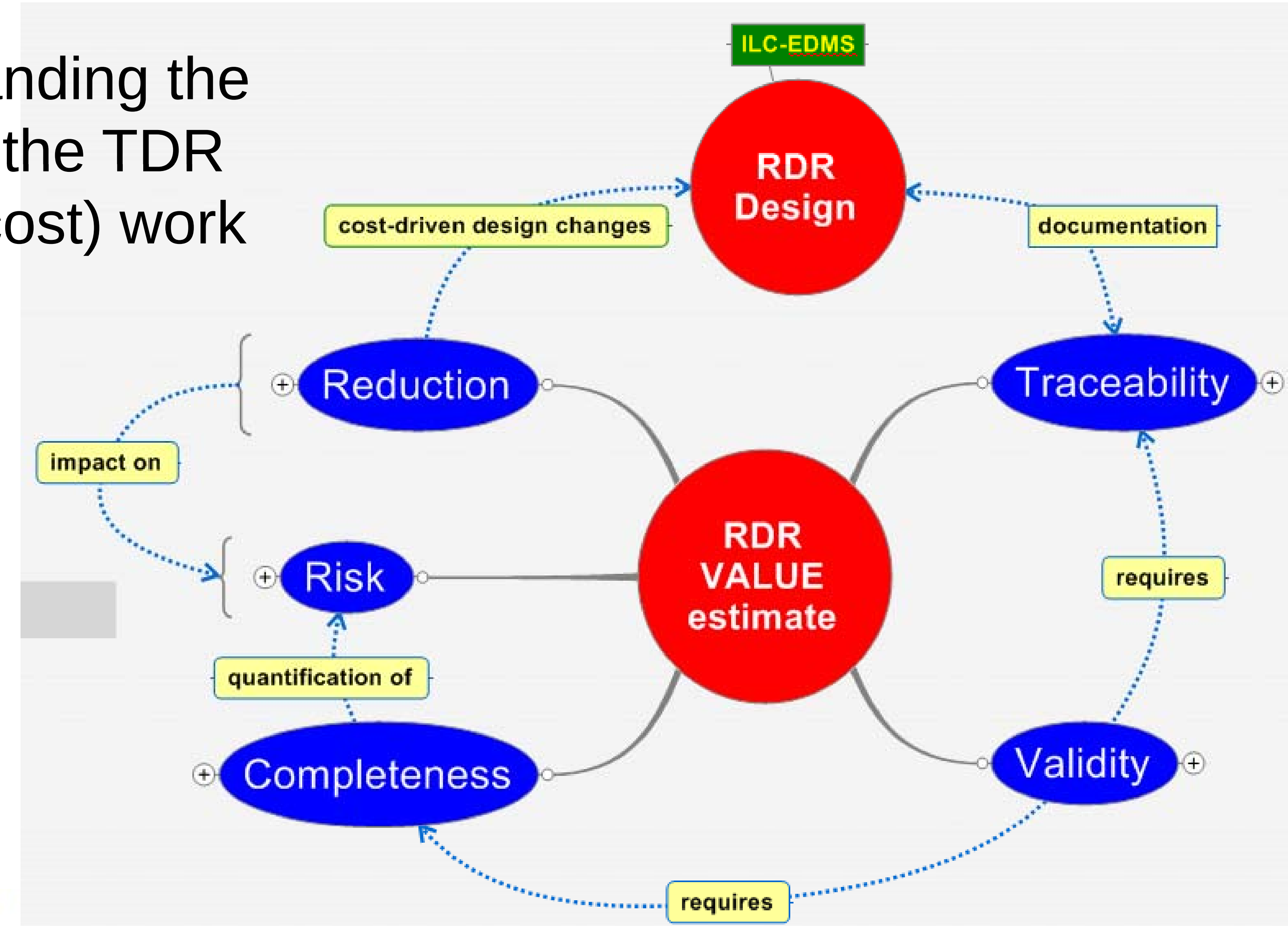
ILC Main Linac RF unit



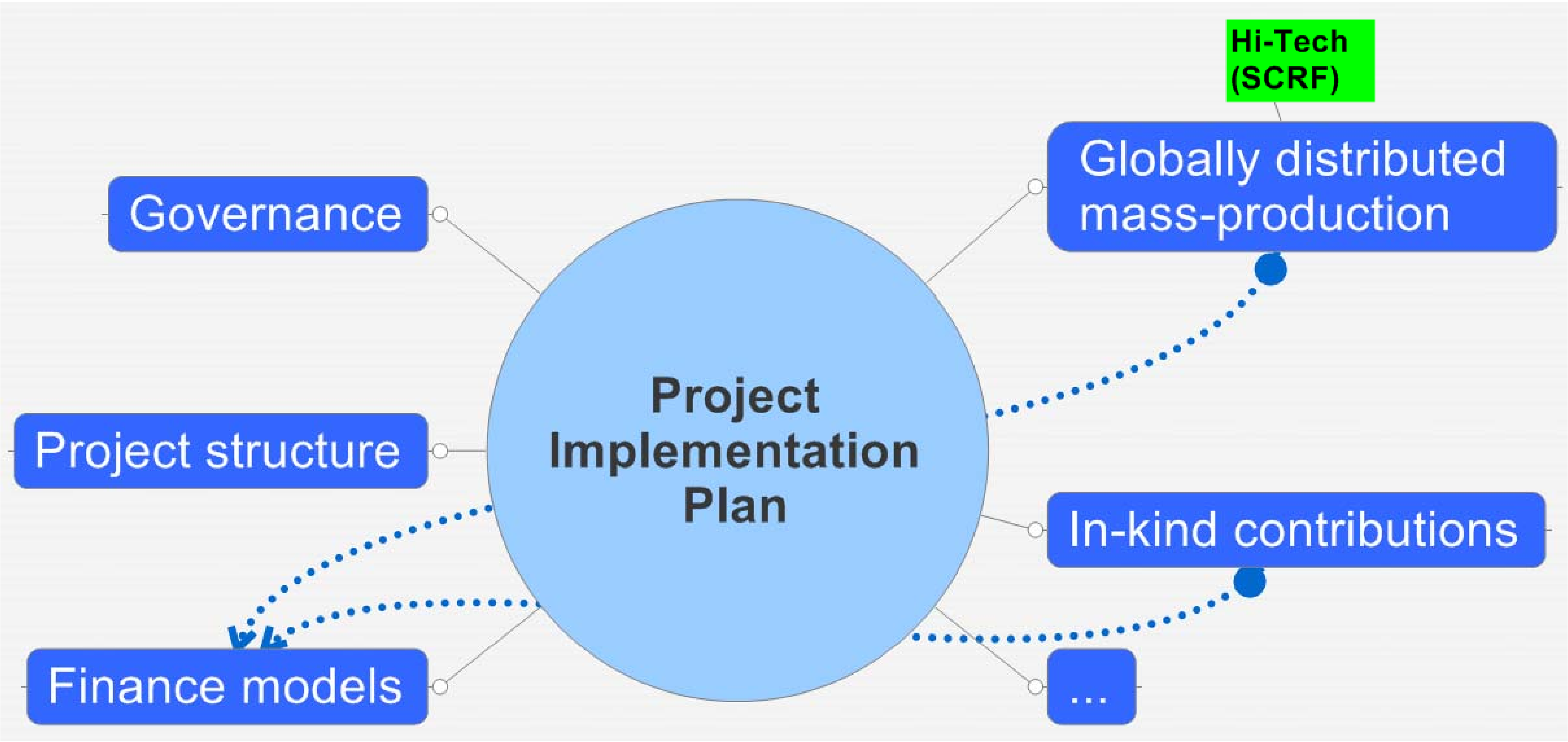
RDR configuration

Cost Consciousness and Reduction

Understanding the scope of the TDR (design/cost) work



Project Implementation Plan



Conventional Facilities Plan

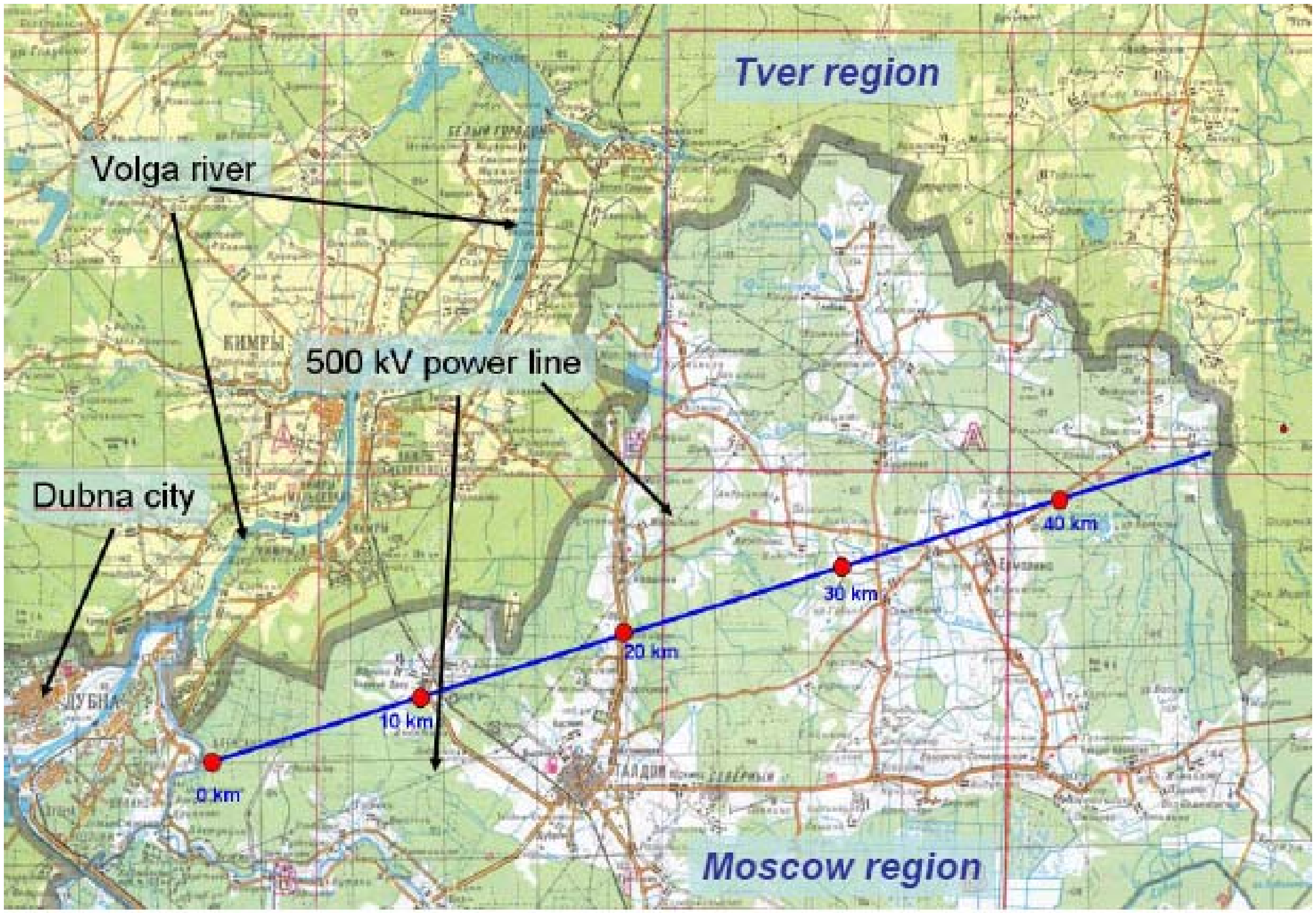
- RDR based on “sample sites”
  - **Accounts for about 1/3 of costs**
  - **Much specific information, but not cost minimized**
- TD Phase proposed to produce “uniform” site study
  - **Work together on siting to apply “value engineering” to minimize costs**
  - **Investigate shallow sites, single tunnel, etc.**
  - **Define uniform site**
- Develop Siting strategy
  - **Desired features, requirements, cost and other information for potential hosts**
  - **What is asked from hosts?**

Uniform Design Approach

- Examine CFS Requirements for ILC Reference Design
- Develop Models for Cost Scaling to Various Alternative Sites and CFS Configurations, in Particular Shallow Sites and Single-Tunnel Options
- Examine the Conventional Facilities of the Machines with Particular Attention to the Cost Drivers (Process Cooling Water etc.), and Understand the Impact with Respect to the Choice of Site Configuration
- Evaluate Alternative Layouts to minimize cost and to understand the cost/ performance trade-offs

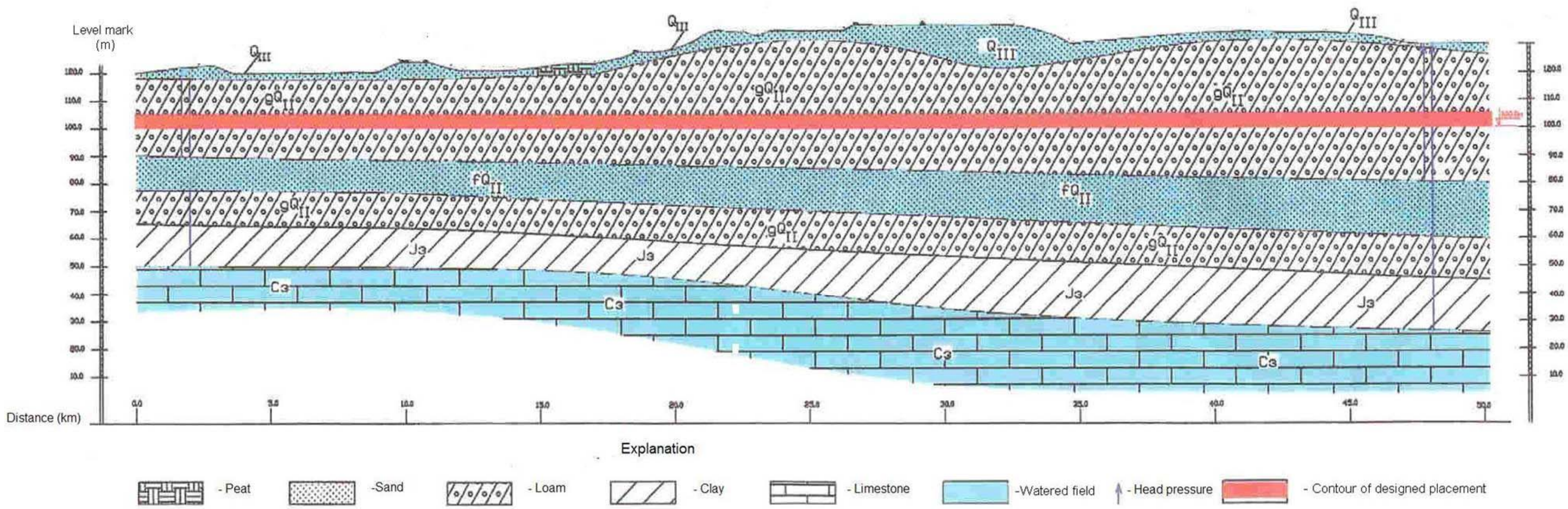
Russian Site

- ***Unique shallow site – thick loam layer near the surface.***



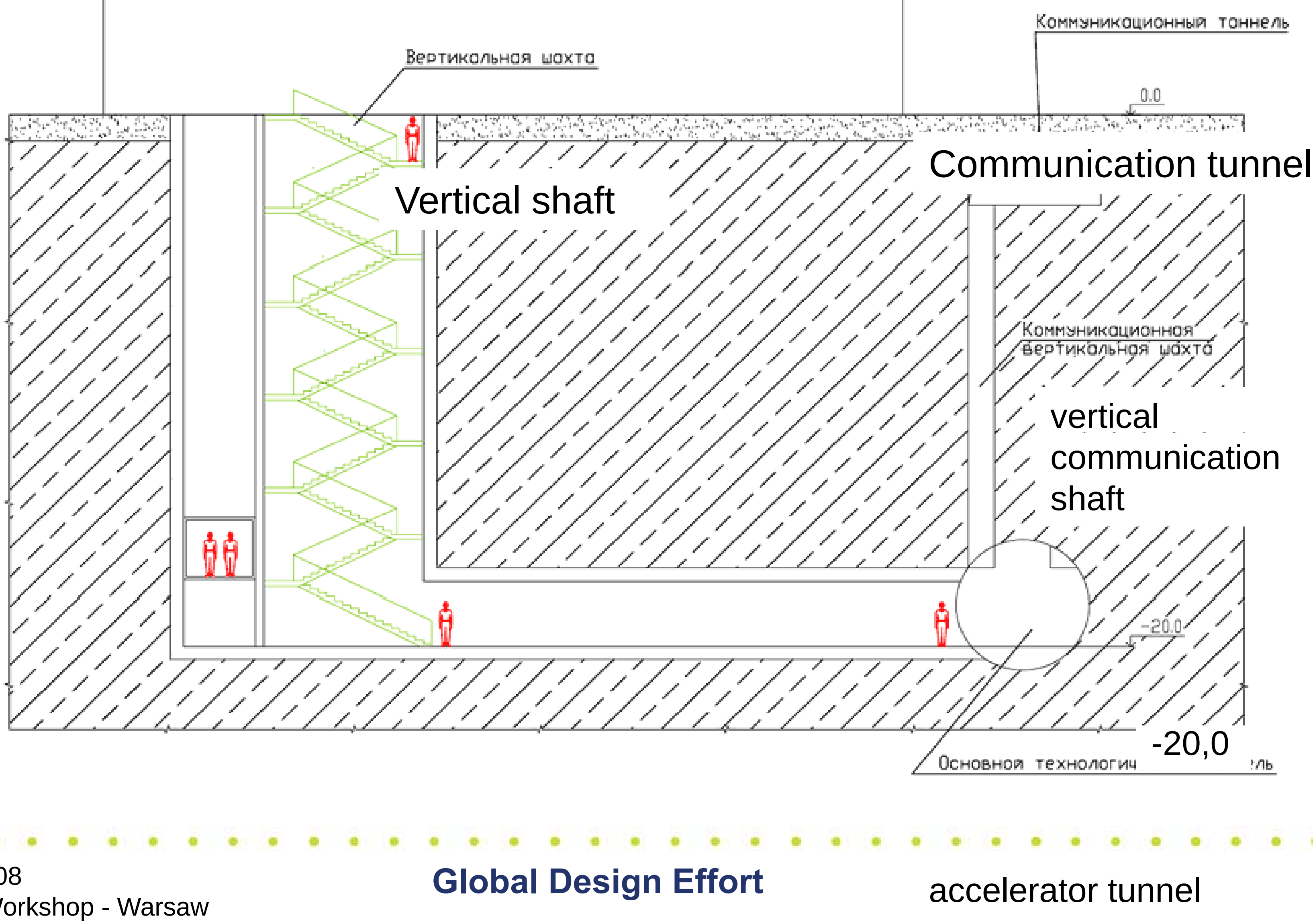
Russian Site

The ILC linear accelerator is proposed to be placed in the drift clay at the depth of 20 m with the idea that below the tunnel there should be impermeable soil preventing from the underlying groundwater inrush. It is possible to construct tunnels of the accelerating complex using tunnel shields with a simultaneous wall timbering by tubing or falsework concreting.



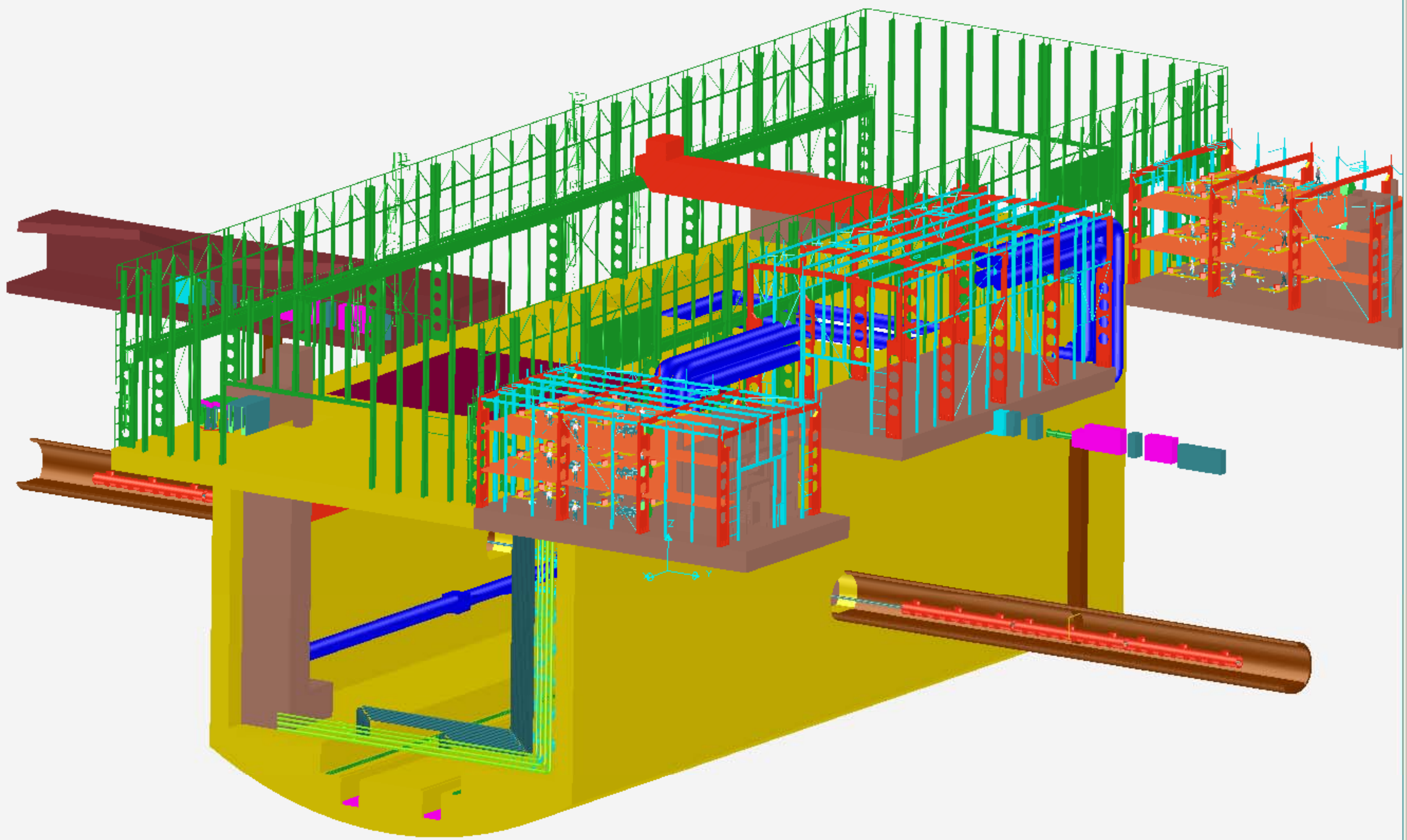
Russian Site

Cross section of beam tunnel 20m below surface



Russian Site

Possible layout for interaction region for a Shallow Site



Near Surface Solution represents approx 5% saving on total CFS costs for experimental hall

+ much less risk

Conclusions

- We have presented the elements of the GDE plan for the next phase, which we call the Technical Design Phase.
  - **A two stage ILC Technical Design Phase (TDP-1 2010 and TDP-2 2012 is proposed)**
- Overall Goals: Cost and risk reduction, complete the technical design and implementation plan on the time scale of LHC results
-
- *SCIENCE remains the key to ultimate success.*