What's RDR

K. Yokoya

KEK

For RDR Management Board

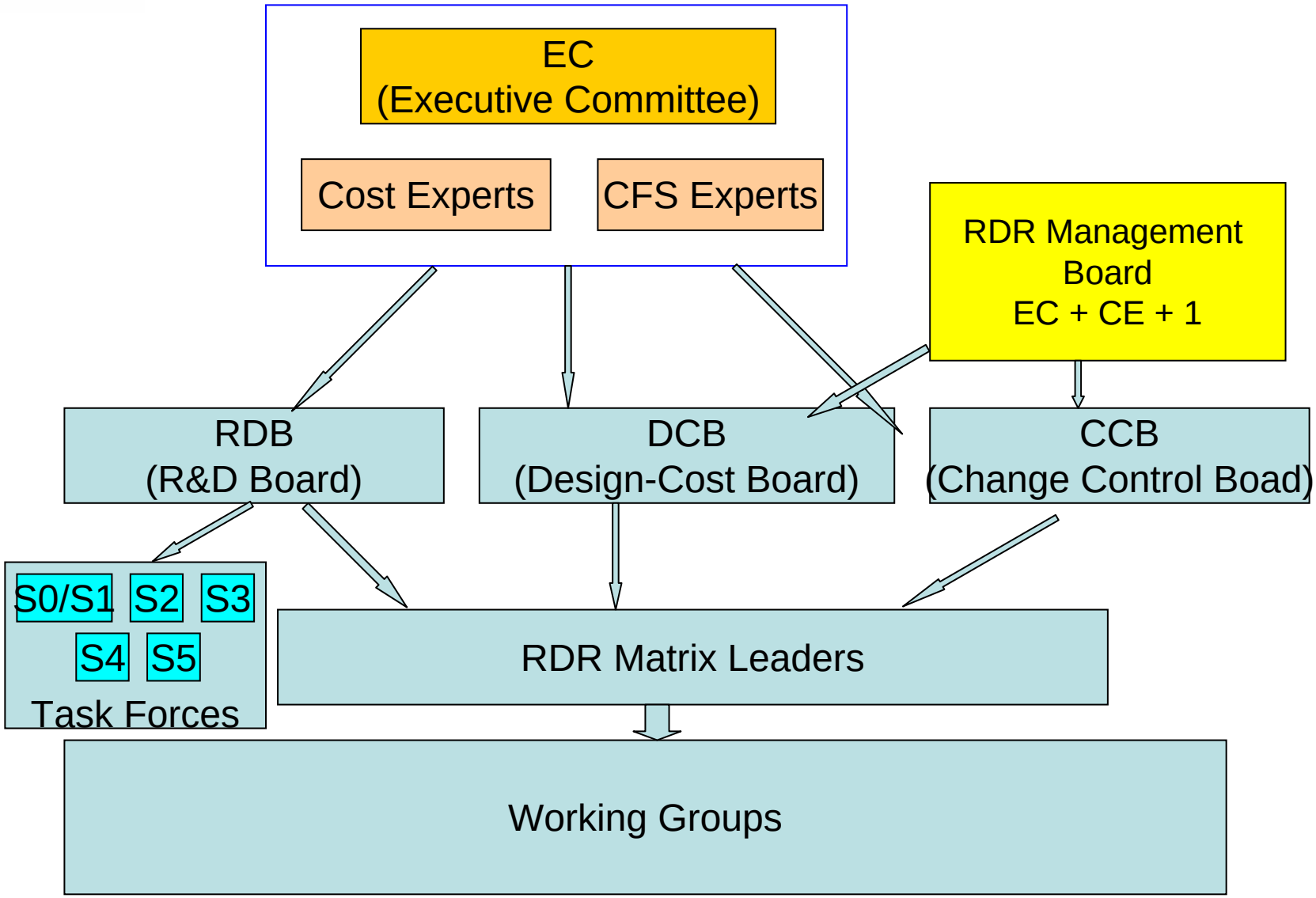
ILC Milestones

- 2004 Aug. ICFA Decision of SC Technology (ICHEP at Beijing)
- 2005 Aug. Formation of GDE (Snowmass Workshop)
- 2005 Dec. BCD (Baseline Configulation Document) completed (Frascati Workshop)
- 2007 Feb. Draft of RDR (Reference Design Report) with Cost to be open to public (Beijing GDE Workshop)

  We came to this point today,

  Then,
- EDR (Engineering Design Report), Site Selection, Approval, Construction...

GDE Structure



RDR Management Board

- Consists of GDE Director, 3 cost engineers, 3 accelerator design leaders and 1 integration scientist (plus 3 Regional Directors)
- Jobs
  - **Coordinate design and costing work for RDR: i.e., making schedule, initiate design changes, organize review meetings, giving inputs to the editor team, etc.**
- Report to the EC
- Every week teleconference,
  every month face-to-face meeting
- Ends its role when RDR is finalized

Change Control Board

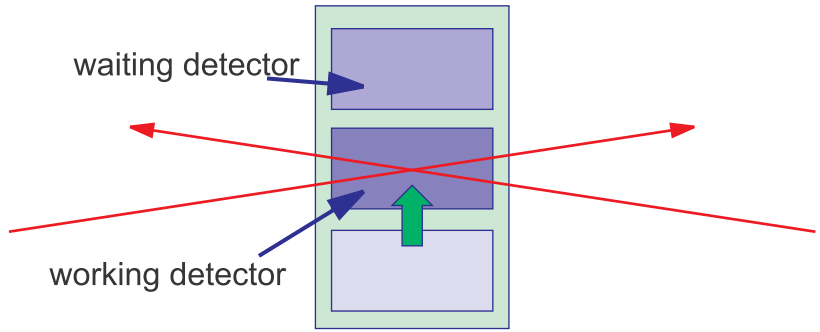
- Consists of 9 people for 3 regions (Asia, Americas, Europe)
- Jobs: control the design changes written in the BCD (Baseline Configuration Document)
- Receive CCR (Change Control Request)
- Initiate discussion among all GDE members and WWS people
- Decide small changes by itself
- Pass recommendation to EC for large changes (> ~100M$)

Steps in the Last 1 Year

- Bangalore GDE Meeting Mar.9-14
  - **Design temporarily frozen**
  - **Established costing methodology**
  - **Cost estimation started**
  - **ILCSC-MAC1 Apr. @FNAL**
- Vancouver GDE Meeting Jul.19-22
  - **1st stage cost sum**
  - **Identified cost driver**
  - **Cost reduction work started (target: 30%)**
    Restart of changing design
  - **ILCSC-MAC2 Sep.@KEK**
- Valencia GDE Meeting Nov.6-10
  - **2nd stage sum**
  - **Internal review Dec. @SLAC)**
  - **ILCSC-MAC3 Jan. @Daresbury)**

Design Changes Since Vancouver

- 2IP (2mard+20mrad)
  → 2IP (14mrad+14mrad)
  → 1IP (14mrad + push-pull)
- 3DRs (1e-, 2e+), 2 tunnels
  → 2DR (1e-,1e+), 2 tunnels
  → 2DR (1e-,1e+), 1 tunnel
- Central injector complex
- Reduce number of shafts and sizes of caverns
- And numerous small ones
  - **Larger RF unit (reduce power sources)**
  - **Muon wall 9m+18m → 5m**
  - **Reduce positron target redundancy**
  - **Reduce RF unit overhead**
  - **Surface detector assembly**
  - **Tunnel diameter 5m → 4.5m**



What's RDR

- Conceptual design
- With first-stage cost estimation
- Engineering details not yet contained

But what is published today is not RDR but Draft of RDR

- Not yet the final official version
- There are still many numerical inconsistencies
- There can be small changes in the next couple of months.
- But their cost impact will not be large.

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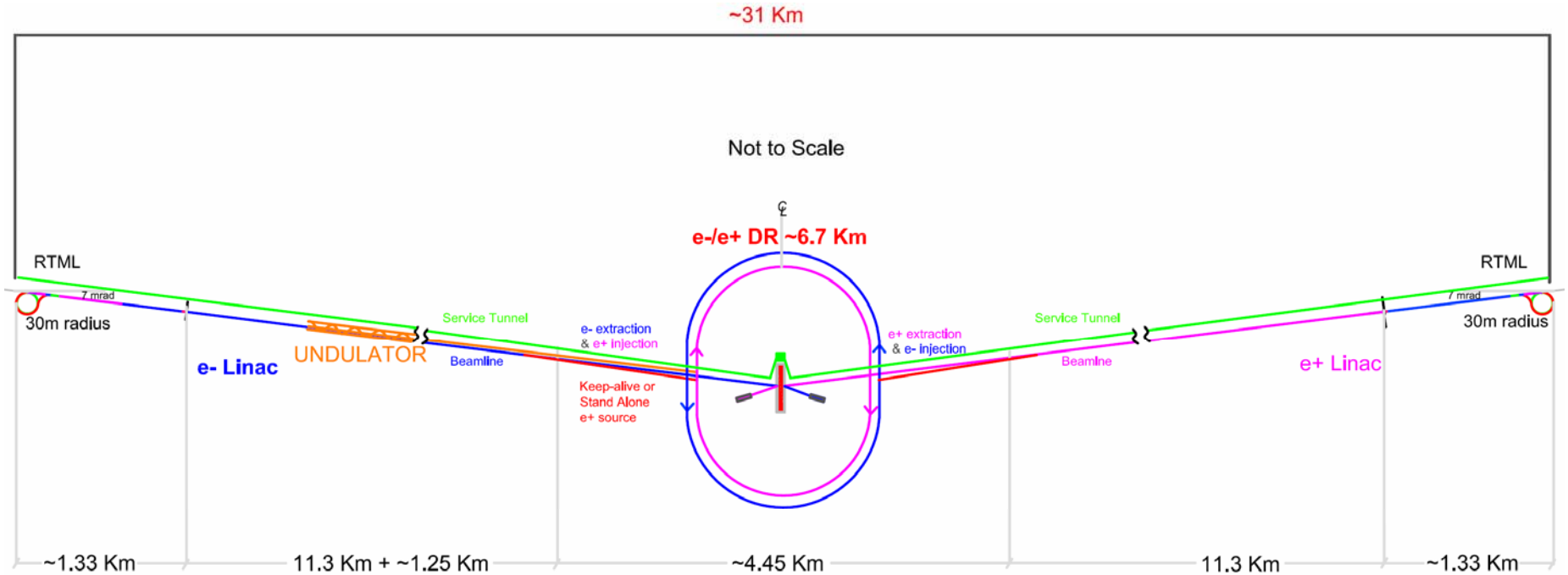
How Does ILC Look Like Now ?

1st Stage: 500 GeV



Schematic Layout of the 500 GeV Machine

Parameter Principle

- Define `Parameter Plane' instead of a single parameter set.
- We often encounter problems, unexpected or underestimated, in actual accelerators.
- Better to prepare for possible parameter changes during operation for machine flexibility.
- Thus, the several, representative parameter sets on the parameter plane are defined.
- They give essentially the same (paper) luminosity.
- Subsystems should be designed so as to satisfy all the sets at least in the design stage

Basic Global Parameters

Max. Center-of-mass energy	500	GeV
Peek Luminosity	~$2x10^{34}$	$1/cm^2s$
Beam Current	9.0	mA
Repetition rate	5	Hz
Average accelerating gradient	31.5	MV/m
Beam pulse length	0.95	ms
Total Site Length	31	km
Total AC Power Consumption	~230	MW

Beam Parameters for 500GeV cms

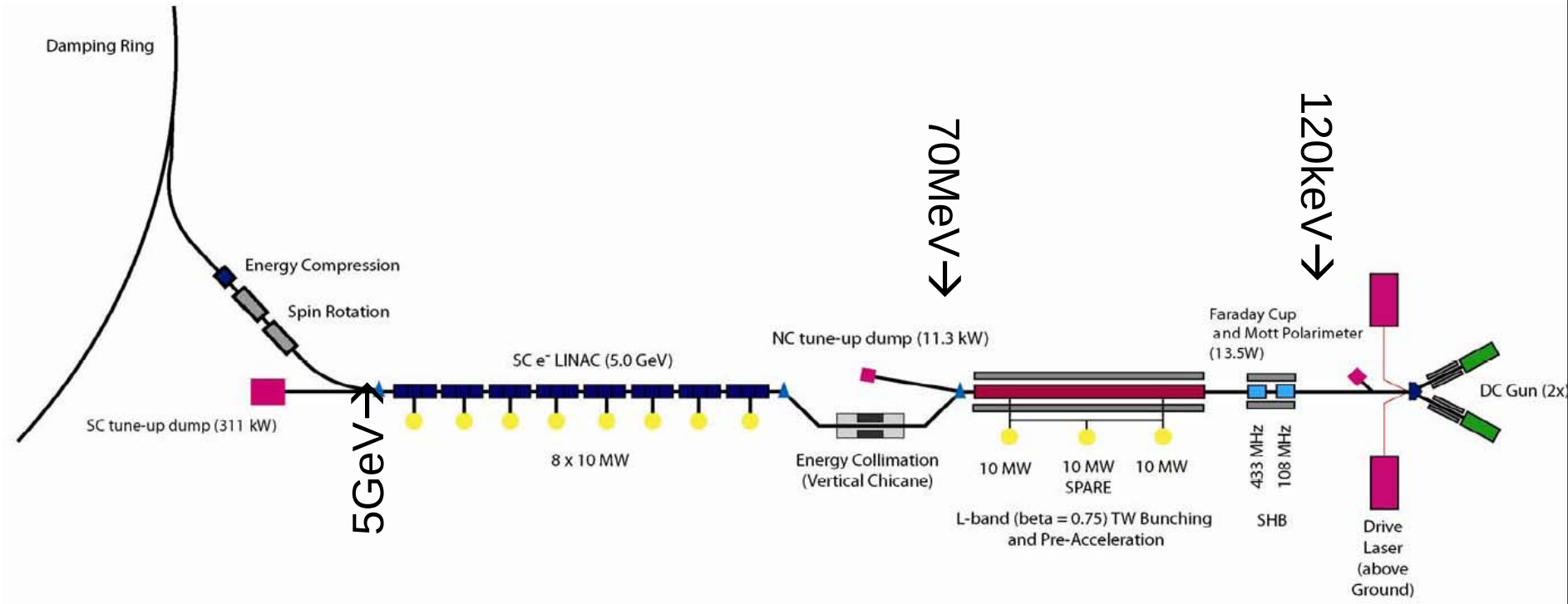
	Nominal	Low Q	Large Y	Low P	
Number of Particles	2	1	2	2	10^{10}
Number of bunches	2625	5120	2625	1320	
Bunch interval (buckets)	369(480)	189(246)	369(480)	480(624)	ns( )
Average current	9.0	9.0	9.0	6.8	mA
Norm.emittance at IP x/y	10/0.04	10/0.03	10/0.08	10(0.036)	μm
Beta at IP x/y	20/0.4	11/0.2	11/0.6	11/0.2	mm
Rms beamsize at IP x/y	639/5.7	474/3.5	474/9.9	474/3.8	nm
Rms bunch length	300	200	500	200	μm
Disruption param x/7	0.174/19.4	0.108/14.6	0.520/24.9	0.211/26.1	
Beamstrahlung param Υ	0.048	0.050	0.038	0.097	
Energy loss by beamstr.	2.4	1.7	2.7	5.5	%
# of photons of beamstr.	1.32	0.91	1.77	1.72	
Pinch enhancement	1.71	1.48	2.18	1.64	
Geometric luminosity	1.20	1.35	0.935	1.21	10^{34}
Luminosity	2.0	2.0	2.0	2.0	10^{34}

Range of Parameters

	min	-	nominal	-	max	
Number of particles	1	-	2	-	2	10^{10}
Number of bunches	1320	-	2625	-	5120	
Linac bunch interval	189	-	369	-	480	ns
DR bunch interval	3.08	-	6.15	-	12.3	ns
Bunch length	200	-	300	-	500	μm
Vertical emittance	0.03	-	0.04	-	0.08	μm
Beta at IP (x)	11	-	11	-	20	mm
Beta at IP (y)	0.2	-	0.4	-	0.6	mm

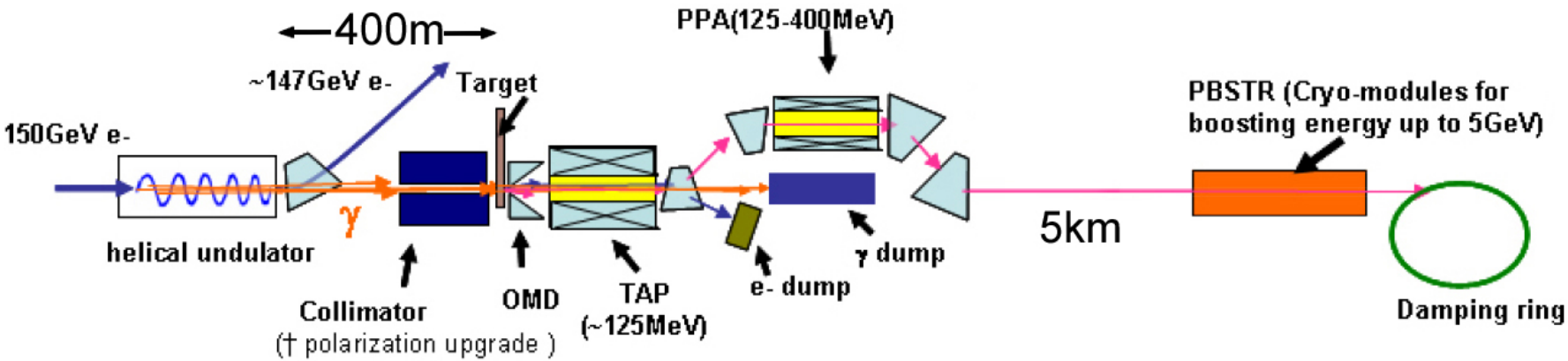
Electron Source

- Polarized gun (laser on surface) polarization >80%
- SHB
- NC TW L-band tapered (β=0.75→1) buncher
- SC linac to 5GeV



Positron Source

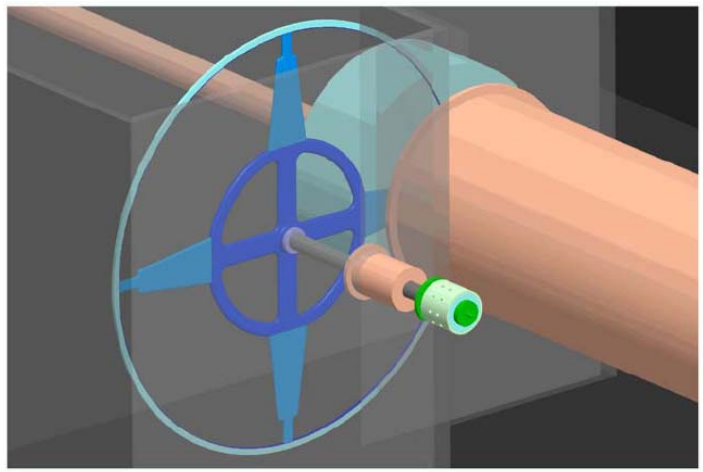
- Undulator scheme
  - **Electron beam at 150GeV**



  - **Undulator**
    - Helical, superconducting
    - length ~100m (~200m for polarized e+)
    - K=0.92, λ=1.15cm, (B=0.86T)
  - **Needs `keep-alive source'**
    - 10% intensity
    - Share 5GeV linac

R&D items

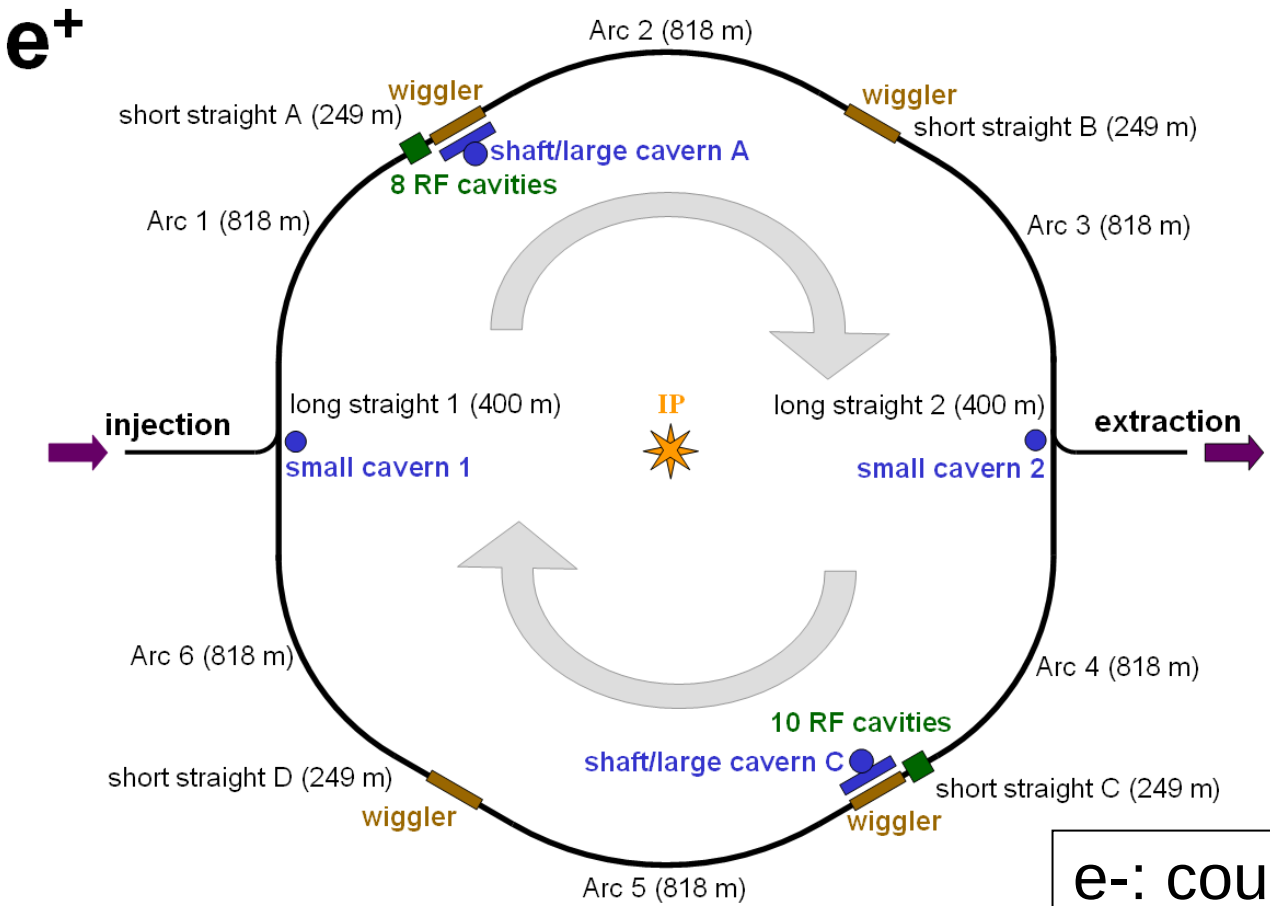
- **Undulator fabrication (SC, pitch 1cm, 0.86T)**
- **Target (titanium alloy, diam.1m, 1.4cm think, rotating at 100m/s)**
- **Target region design**



Damping Rings

- 1e- and 1e+ ring in the same tunnel
- Beam energy 5GeV
- Circumference 6.7km
- Requirements
  - **Bunch population 2×10^{10}**
  - **Number of bunches ~2600 (max ~5100)**
  - **Extracted beam**
    - Norm.emittance $\varepsilon\gamma x = 8\mu m$, $\varepsilon\gamma y = 0.02\mu m$
    - Bunch length 9mm
    - Energy spread 0.13%

Schematic Layout

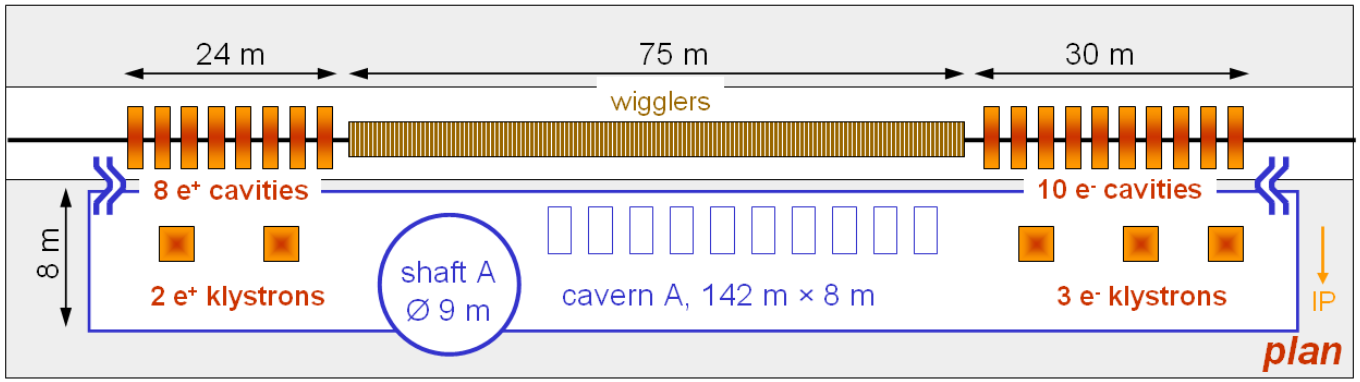


e-: counter-clockwise

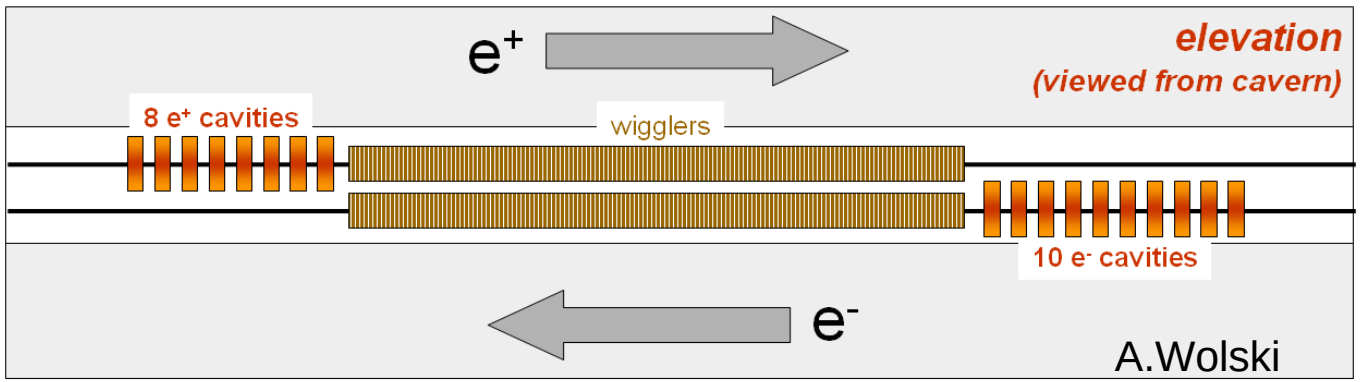
2 vertical shafts

A. Wolski

Wiggler-RF Region



Plan View



Side View

e+ RF does not overlap with e- RF

Tunnel diameter 5m

DR Remaining Issues

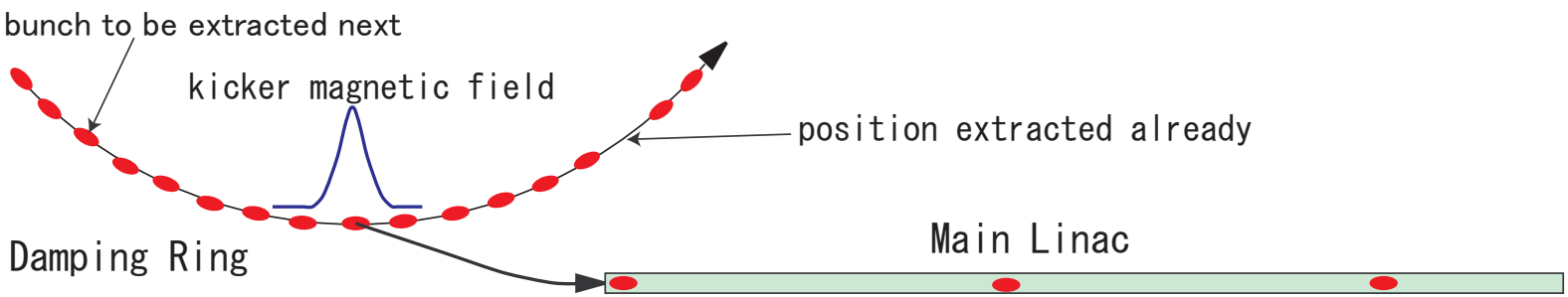
- Injection/extraction kickers
- Instabilities
  - **Electron-cloud, Fast Ion, microwave, …**
- Dynamic aperture
- Tuning for low emittance
- 650MHz RF system

Task Force S3 has been established for DR R&D

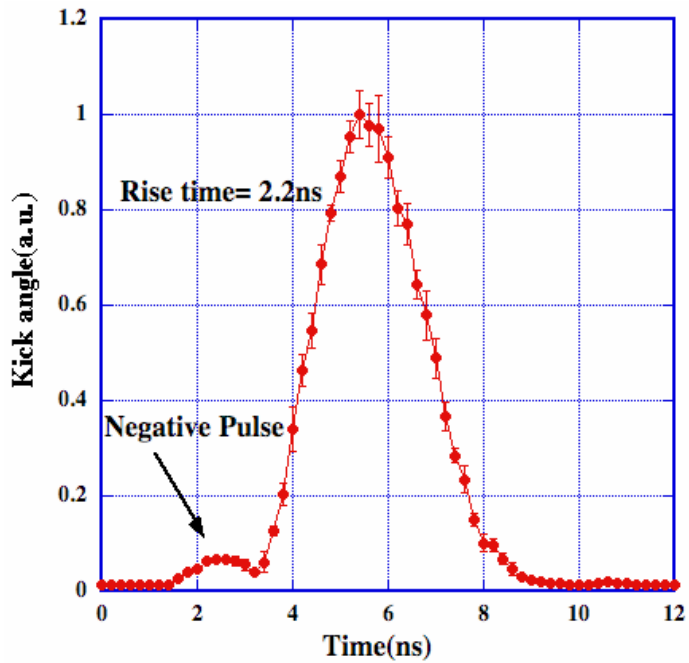
- Defining work packages
- Available machines
  - KEK-ATF
  - CESR, HERA, KEKB

Kicker System

- Must extract bunches one-by-one

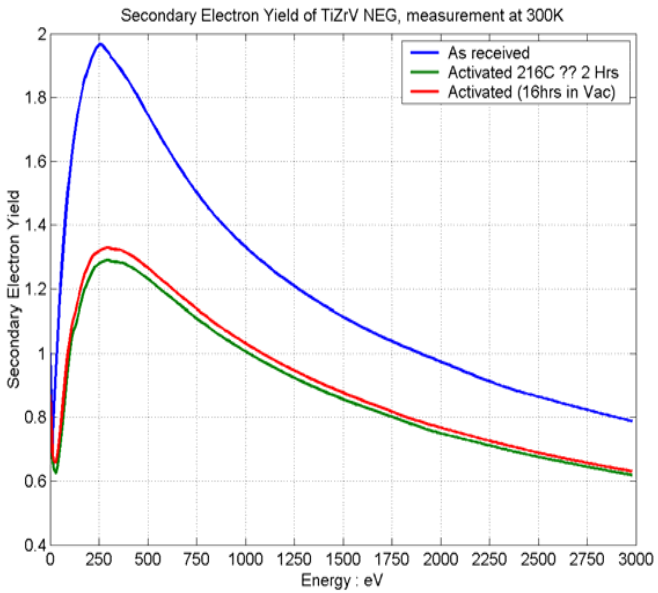


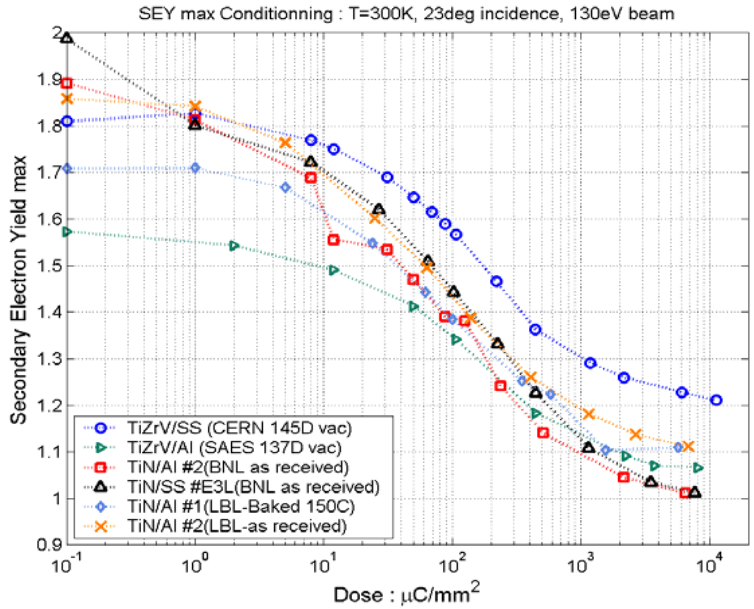
- Specification
  - rise, fall time < 3ns
  - rep.rate 5.5MHz
  - pulse length 1ms
  - stability < 0.1%
    (can be relaxed by feedforward)
- Fast kicker needed
  - A system with fast pulser and stripline developed at KEK. Unit test done.



Electron Cloud

- Secondary electrons attracted by positron beam causes an instability
- Max of SEY (Secondary Electron Yield) should be < 1.1
- Possible cures
  - **Coating with NEG**
  - **Solenoids in free field region**
  - **Grooves on the chamber wall**
  - **Clearing electrode**



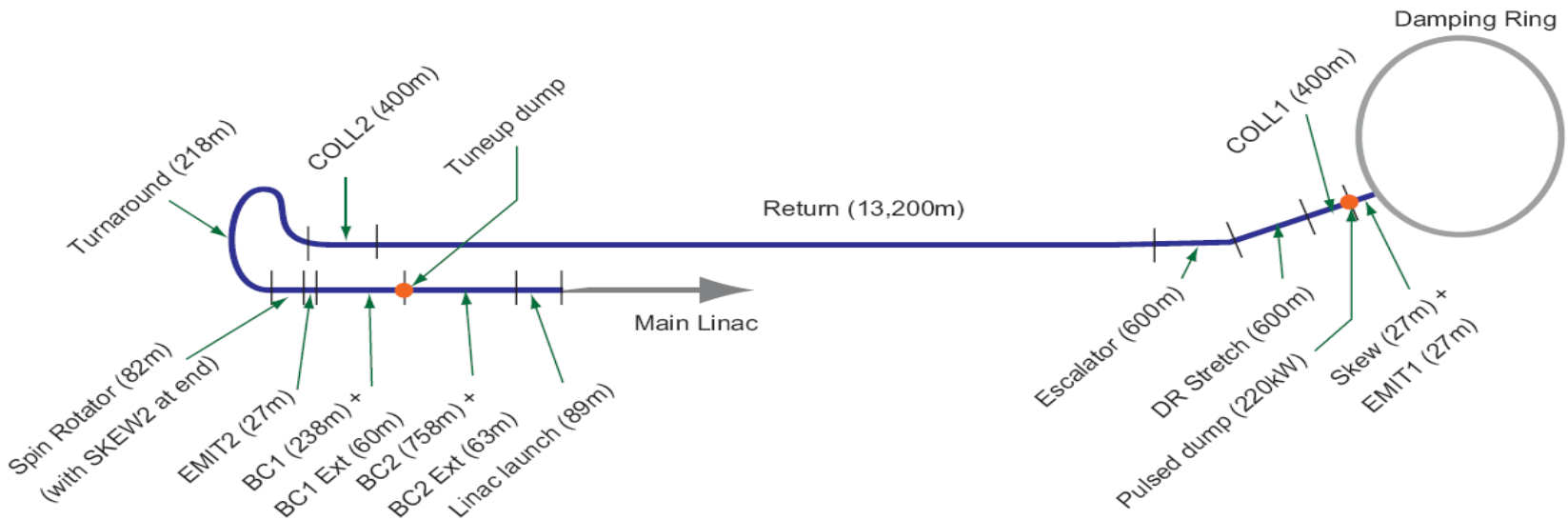


Fast Ion Instability

- Ions created from ionization by electrons are attracted by electrons and cause instability
- Cures
  - **Low vacuum pressure ~1nTor**
  - **Bunch-by-bunch feedback system**
  - **Gaps between bunch trains**

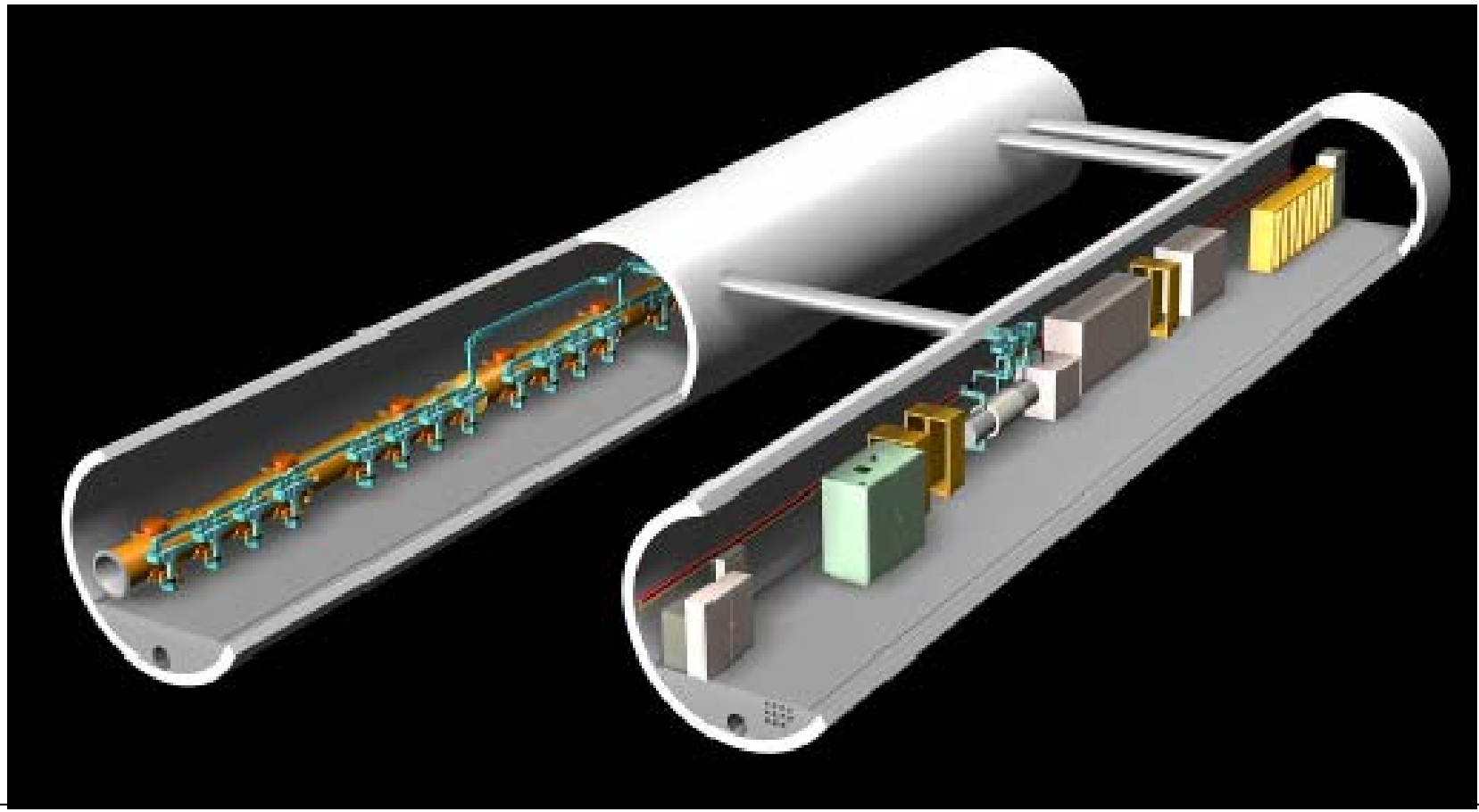
RTML (Ring To Main Linac)

- ~14 km long transport
- Turn-around
- Spin Rotator
- Bunch compressor (2 stages)
  9mm→300μm (nominal param)
  9mm →200μm possible (Low Q param)
- Diagnostics and collimators



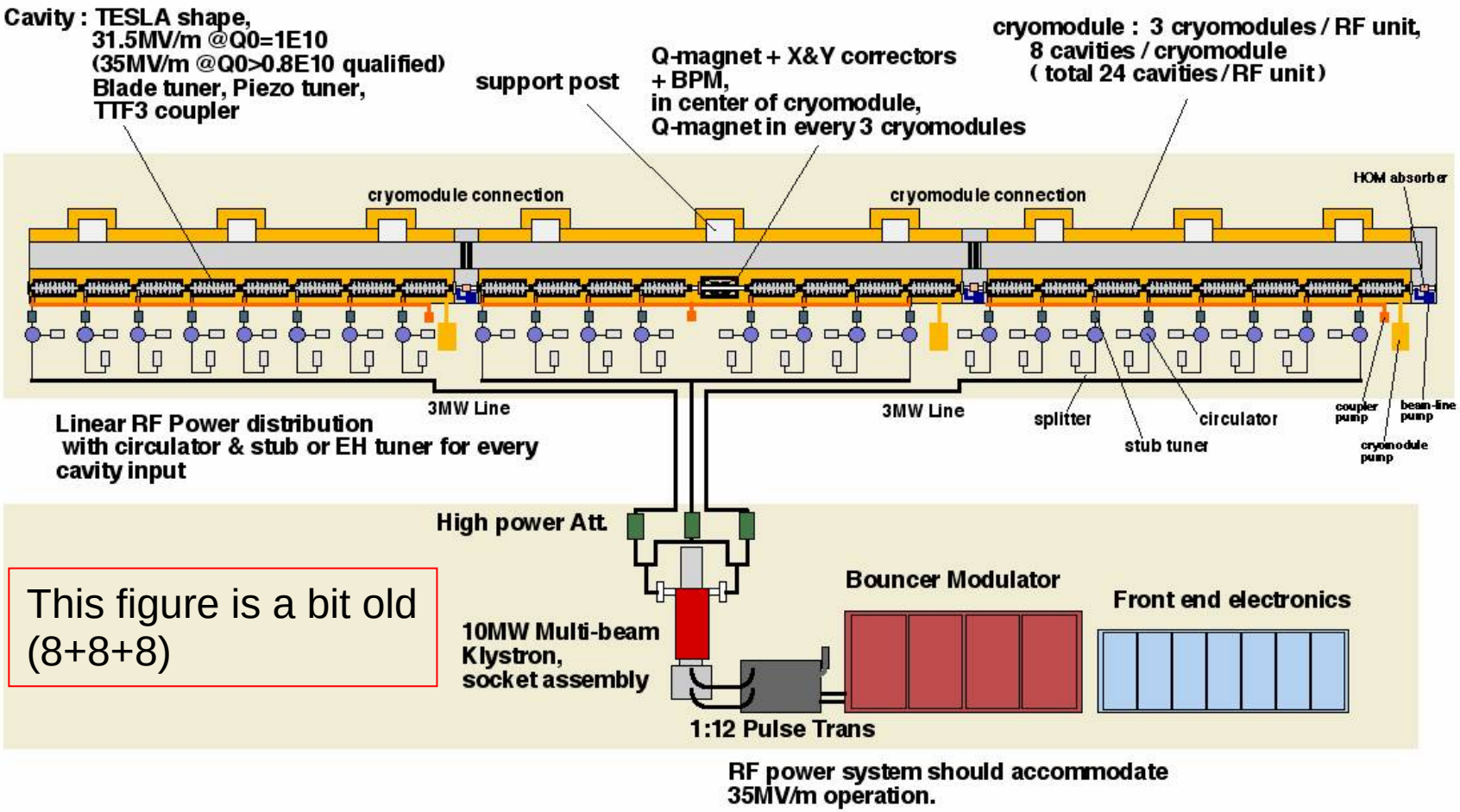
Main Linac

- Length ~11km x 2 (Average gradient 31.5MV/m)
- 2 tunnels (diameter 4.5m)



Linac Unit

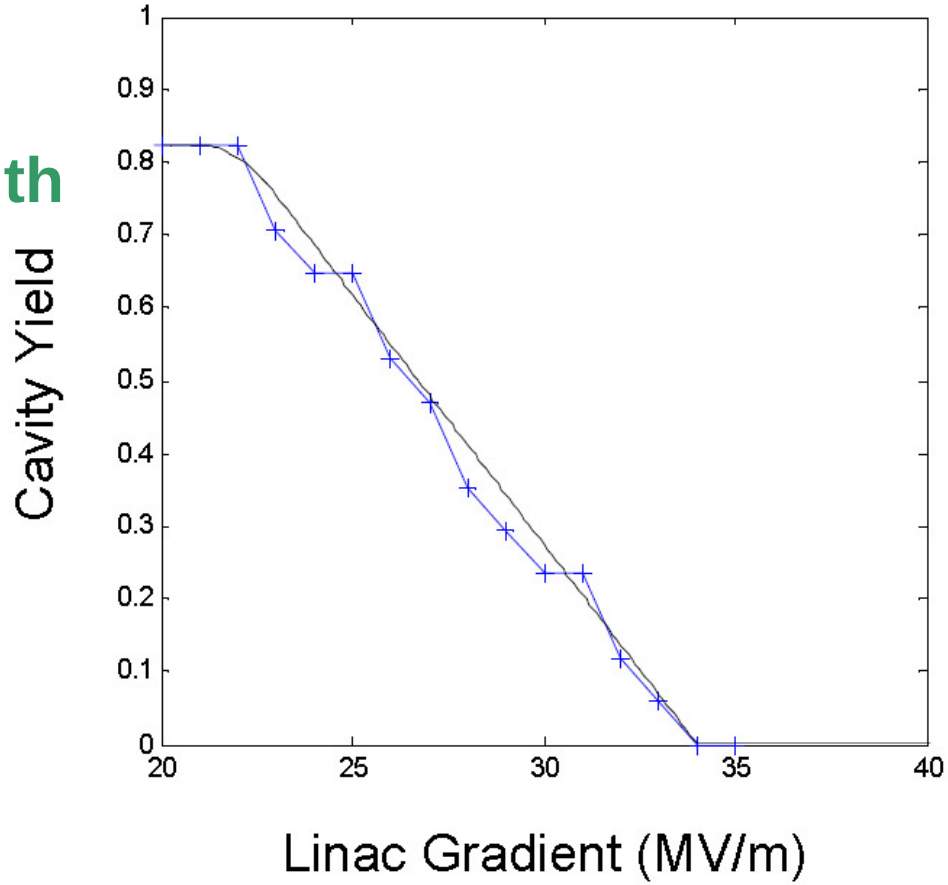
- Bouncer type modulator
- Multibeam klystron (10MW, 1.6ms)



This figure is a bit old (8+8+8)

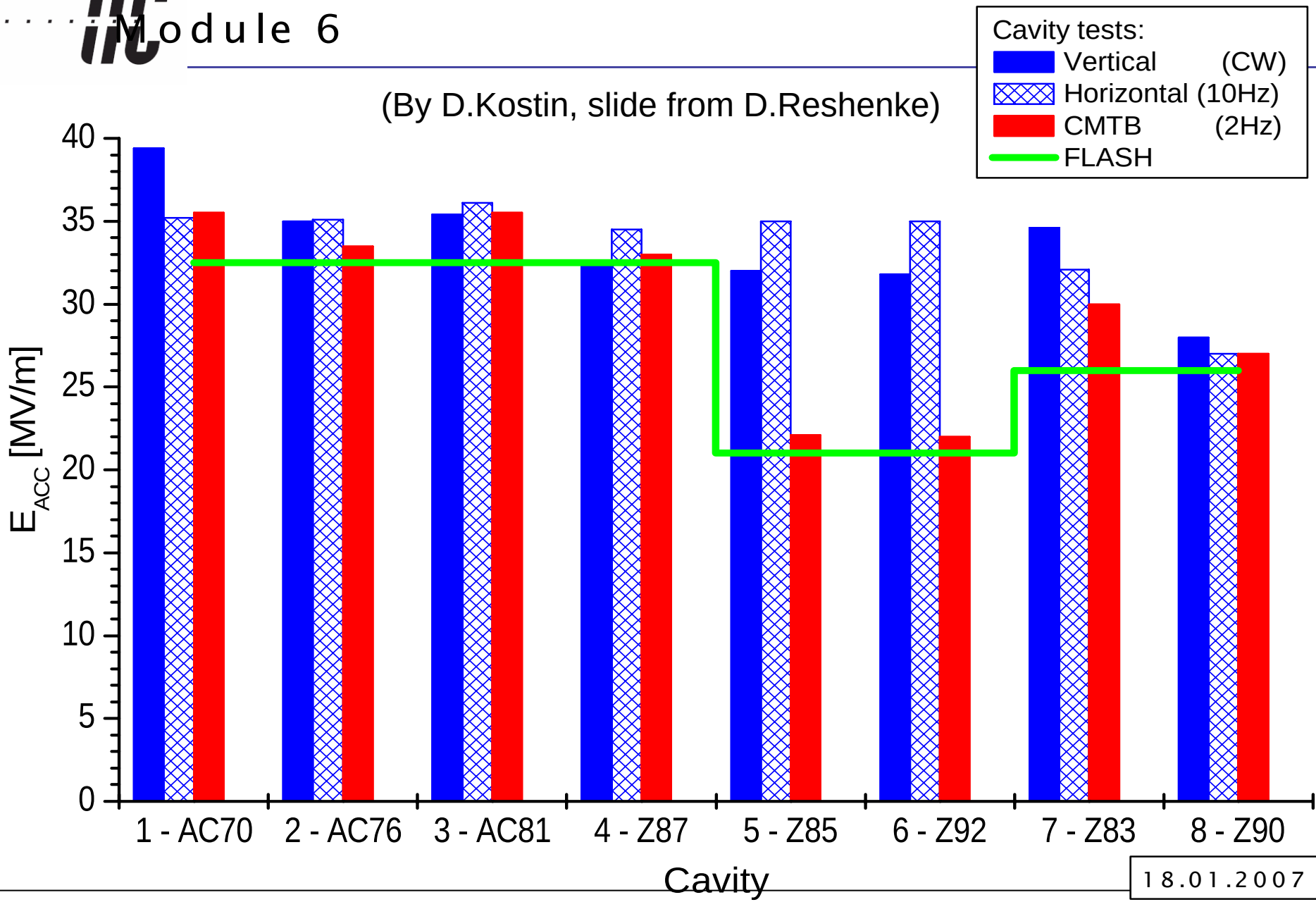
Cavities

- Baseline Choice
  - **Accept only those with >35MV/m Qo>8e9 in vertical test**
  - **Average gradient for operation 31.5MV/m**
  - **TESLA type**
  - **Electro-polishing**
- Yield for >35MV/m is still too low



Statistics of 17 ZANON cavities

(By D.Kostin, slide from D.Reshenke)



Alternative

- LL-type cavity
  - **Lower max.B field at same Acc.gradient**
  - **Potentially higher gradient > 40MV/m**
  - **Under development at KEK**
  - **Single-cell test successful (max. over 50MV/m)**
  - **But 9-cell cavities are still poor (max. 29MV/m)**

- Nb material:
  Single crystal, Large grain

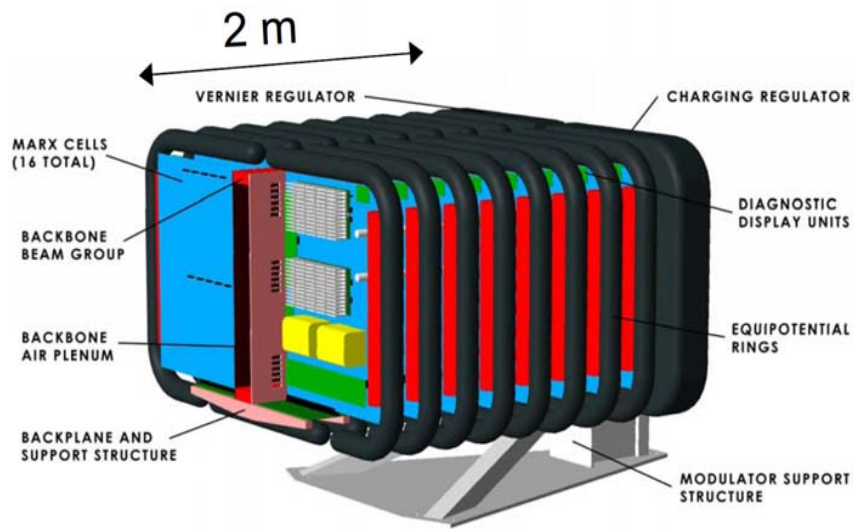
S0 Program

- Task Force S0 created a report for the R&D program to establish 35 MV/m (vert.test)
  - **Tight-loop process**
    repeated surface treatment with small number of cavities including exchange of cavities among Asia-US-Europe in 2007
  - **Production-like process**
    many cavities with the same recipe
- Time line
  - **decide cavity type by ~mid 2008**
  - **Establish high yield by ~mid 2009**
- Task Force S1 for establishing 31.5MV/m (average gradient)

Modulator

- Bouncer-type modulator
  - **Design at FNAL**
  - **Has been working for 10 years**
  - **More cost-efficient design under way**
- Alternative:

  Marx Modulator
  - **Under development at SLAC**
  - **12kV Marx cell x 16**
  - **IGBT switch**
  - **Saving of ~180M$**
  - **SLAC prototype produced 70kV with 6 cells**



MARX MODULATOR - MECHANICAL DETAIL

Klystron

Requirements:

- 10MW
- 1.6ms
- life >40000hrs?

Thales

CPI

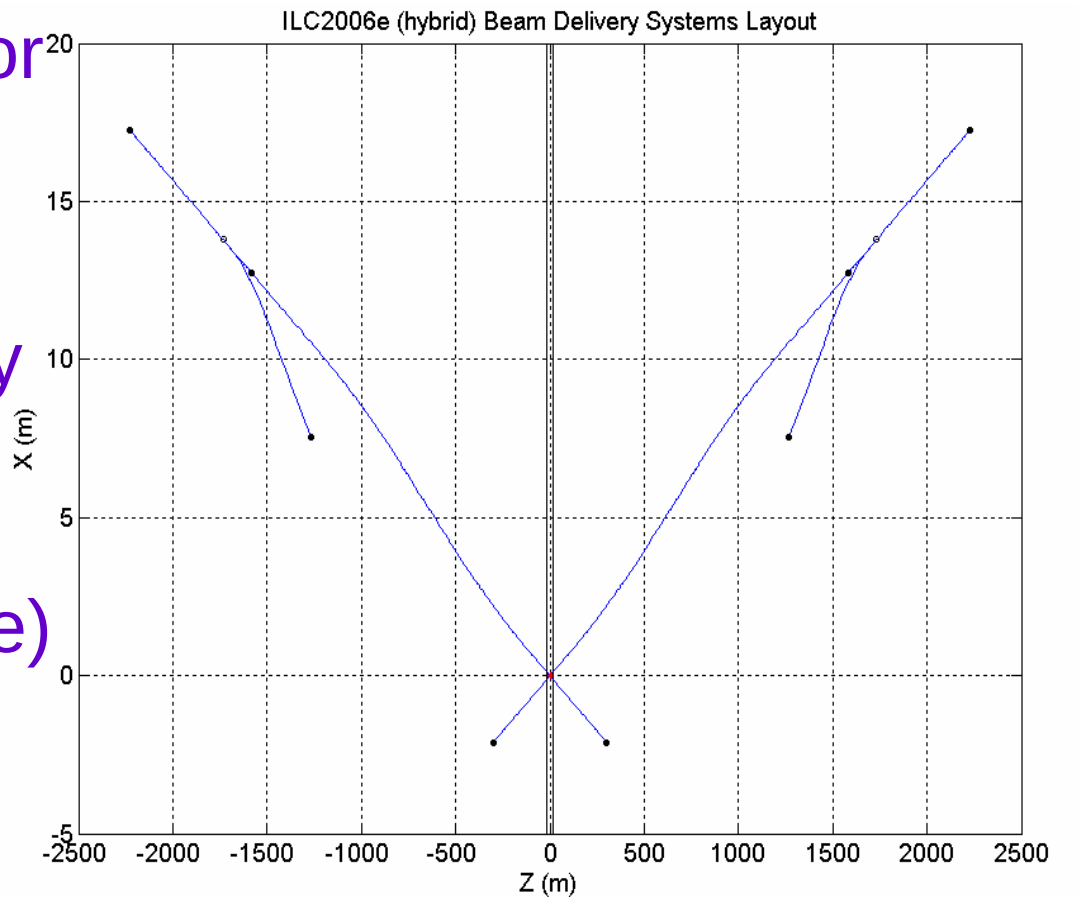
Toshiba

- **Toshiba klystron being tested at DESY at full spec for > 700hrs.**
  ➔ Nearly established except for the life

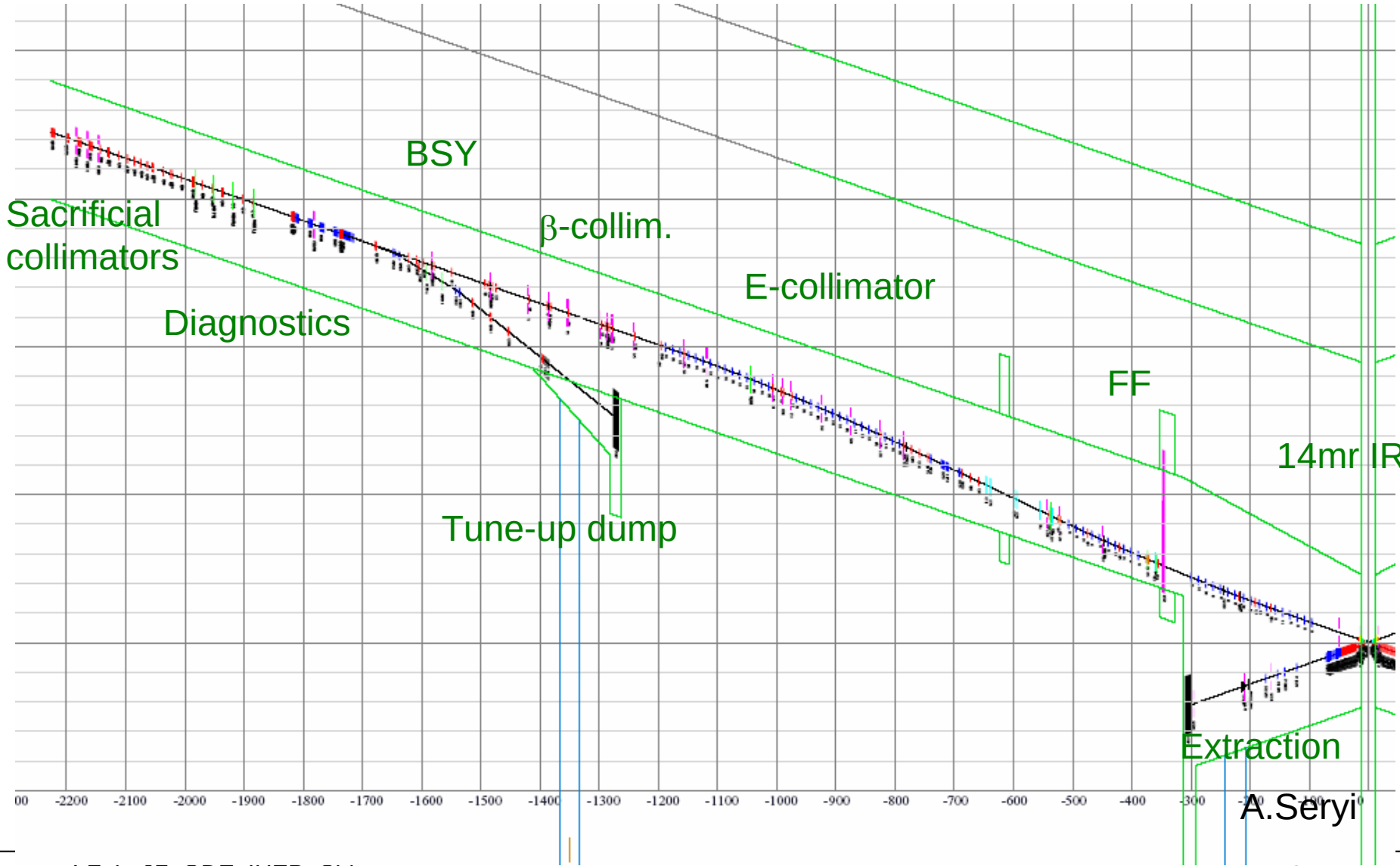
- **Horizontally mounted klystron needed for small tunnel diameter. (Bidding for Euro-XFEL)**

BDS (Beam Delivery System)

- Single IR and push-pull detector
- Total length 4.45km
- 1TeV upgrade by inserting some components (no geometry change)



BDS with single IR

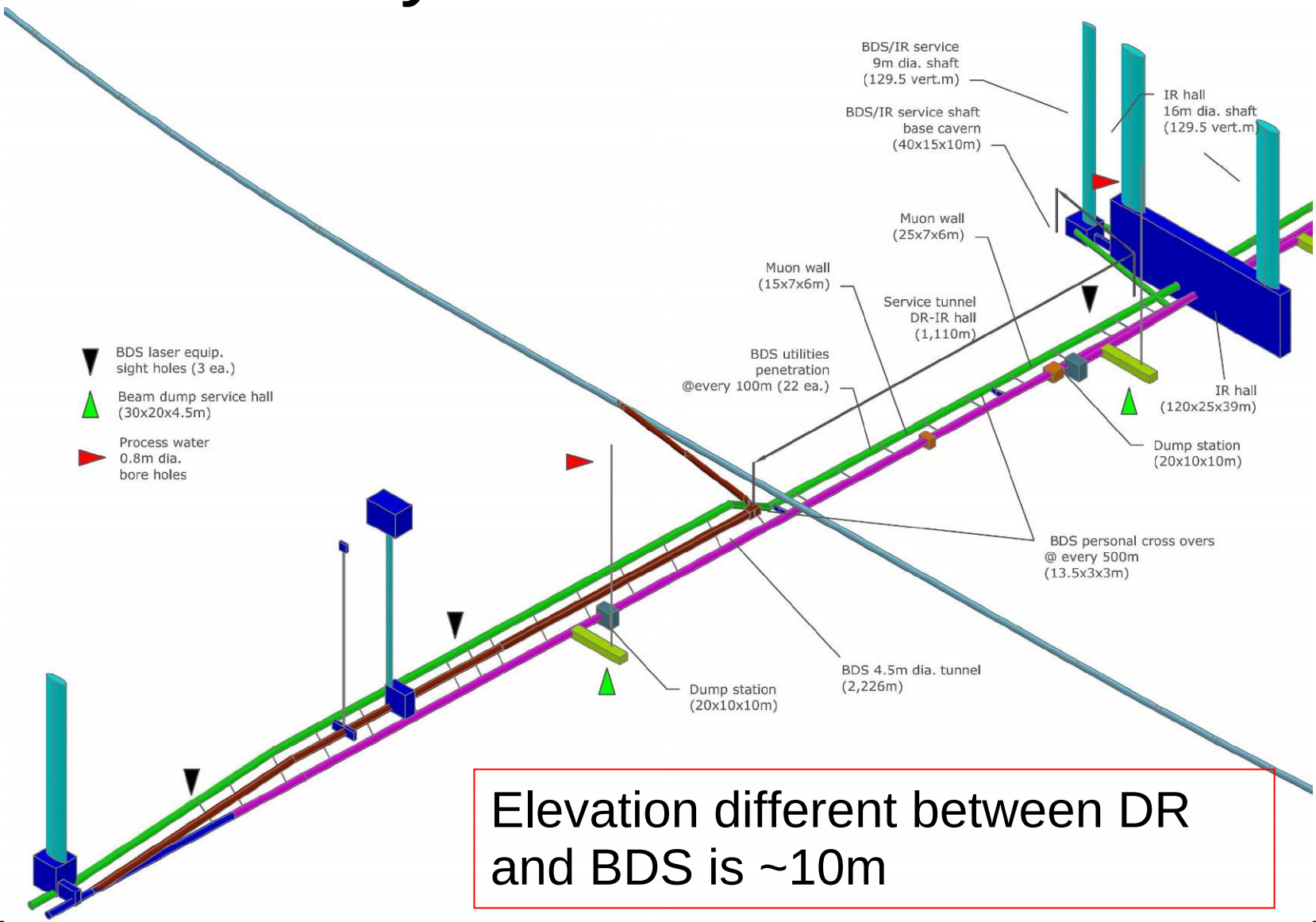


A.Seryi

Single IR with Push-Pull Detectors

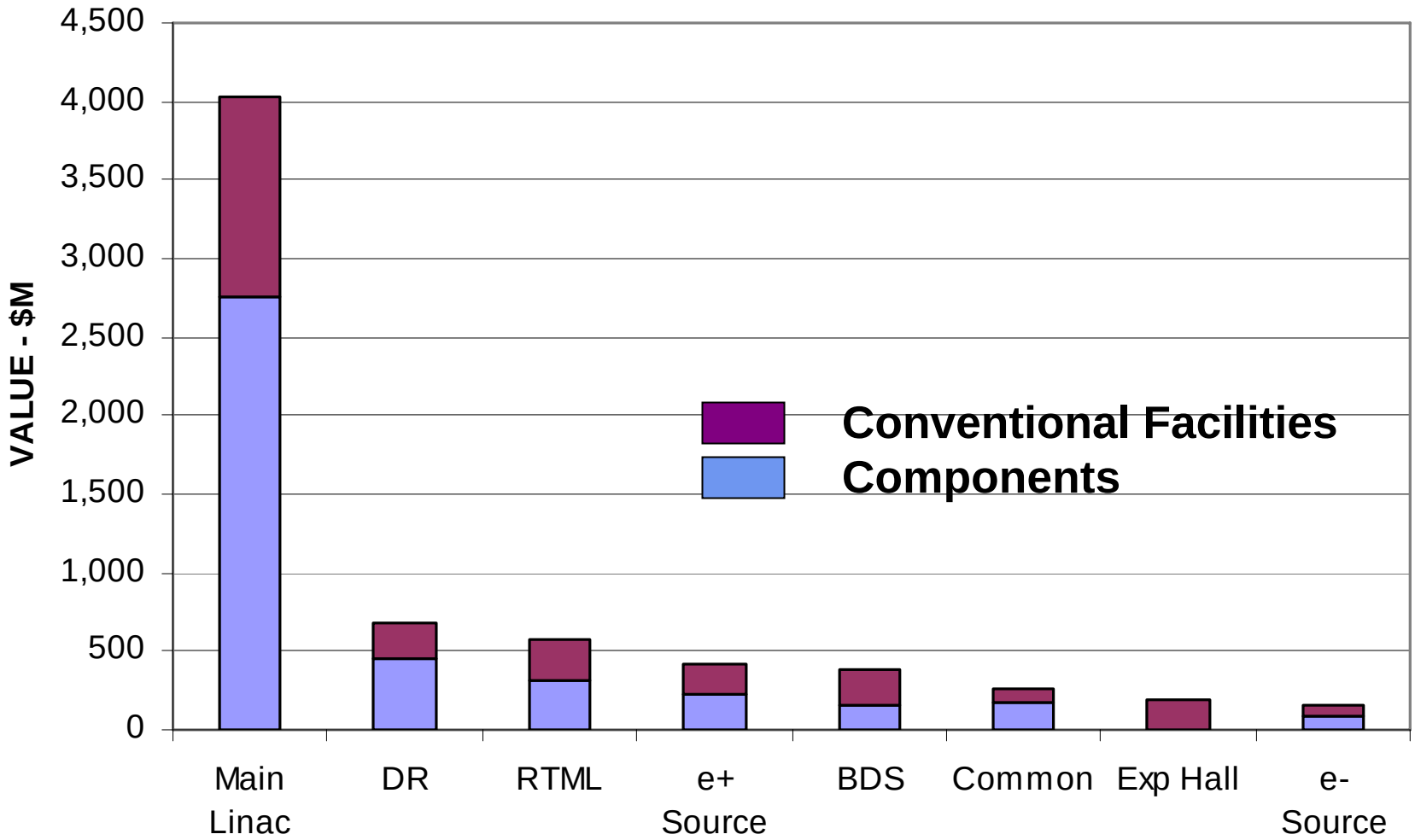
- Large cost savings compared with 2 IR
  - **~200M$ compared with 2IR with crossing angles 14+14mrad**
- Push-pull detectors
  - **Task force from WWS and GDE formed**
  - **Quick conclusion is**
    - No show-stoppers
    - But need careful design and R&D works
    - 2IR should be left as an `Alternative'

Layout of BDS+DR



Elevation different between DR and BDS is ~10m

Value Distribution



What from now?

- Finalize RDR
  - **Check inconsistencies (still many!)**
  - **Possible final small changes**
  - **ILCSC-MAC review in ~April**
  - **Final form in summer**
- Organization of GDE for the next step
  - **Next milestone EDR (Engineering Design Report) around 2009.**
  - **Coordination of R&D essential**
  - **Engineering stage**
  - **To be decided in the next coule pf months**

Finally

- RDR Draft is going to be published
- This is the first major milestone reached by international collaboration
- First estimation of the cost will be open to public
- There still remains many R&D items, including, e.g., the establishment of the accelerating gradient 35/31.5 MV/m.
- GDE is going to coordinate the R&D
- The nest step is
  - **To finalize the RDR**
  - **And to start the work for EDR**