ILC - Upgrades

Nick Walker – 100th ILC@DESY meeting

18.10.2013

What's in store…

- **What's in the "baseline" document (TDR)**
  - The baseline 500 GeV machine (L = 1.8x1034)
  - Luminosity upgrade
  - TeV upgrade

- **Staged construction**
  - starting at 250 GeV CM

- **Beyond the TDR**
  - Increased repetition rate operation (power)

ILC Published Parameters

Centre-of-mass independent:

			Luminosity Upgrade
Collision rate	Hz	5	5
Number of bunches		1312	2625
Bunch population	$\times 10^{10}$	2	
Bunch separation	ns	554	366
Pulse current	mA	5.8	8.8
Beam pulse length	μs	730	960
RMS bunch length	mm	0.3	
Horizontal emittance	μm	10	
Vertical emittance	nm	35	
Electron polarisation	%	80	
Positron polarisation	%	30	

http://ilc-edmsdirect.desy.de/ilc-edmsdirect/item.jsp?edmsid=D00000000925325

ILC Published Parameters

Centre-of-mass dependent:

Centre-of-mass energy	**GeV**	**200**	**230**	**250**	**350**	**500**
Electron RMS energy spread	%	0.21	0.19	0.19	0.16	0.12
Positron RMS energy spread	%	0.19	0.16	0.15	0.10	0.07
IP horizontal beta function	mm	16	16	12	15	11
IP vertical beta function	mm	0.48	0.48	0.48	0.48	0.48
IP RMS horizontal beam size	nm	904	843	700	662	474
IP RMS veritcal beam size	nm	9.3	8.6	8.3	7.0	5.9
Vertical disruption parameter		20.4	20.4	23.5	21.1	24.6
Enhancement factor		1.83	1.83	1.91	1.84	1.95
Geometric luminosity	$\times 10^{34}$ cm^{-2}s^{-1}	0.25	0.29	0.36	0.45	0.75
Luminosity	**$\times 10^{34}$ cm^{-2}s^{-1}**	**0.50**	**0.59**	**0.75**	**0.93**	**1.8**
% luminosity in top 1% ΔE/E		92%	90%	84%	79%	63%
Average energy loss		1%	1%	1%	2%	4%
Pairs / BX	$\times 10^{3}$	41	50	70	89	139
Total pair energy / BX	TeV	24	34	51	108	344

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Luminosity Upgrade	**$\times 10^{34}$ cm^{-2}s^{-1}**	**1.00**	**1.18**	**1.50**	**1.86**	**3.6**
% luminosity in top 1% ΔE/E		92%	90%	84%	79%	63%
Average energy loss		1%	1%	1%	2%	4%
Pairs / BX	$\times 10^{3}$	41	50	70	89	139
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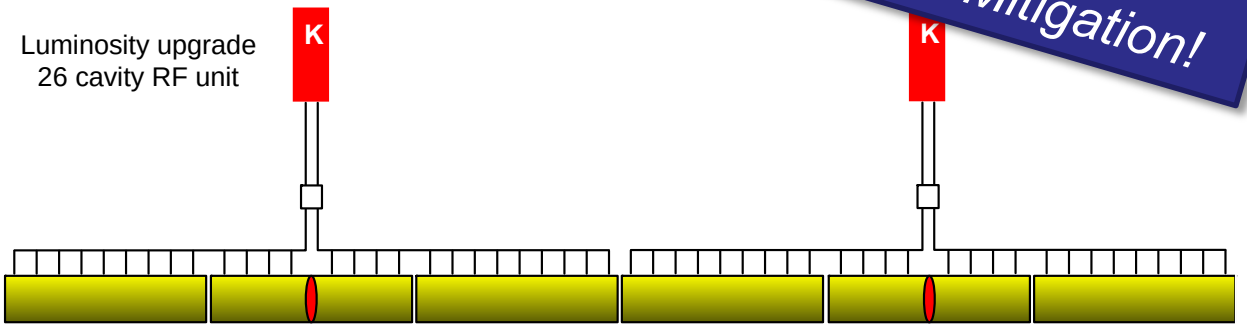
Luminosity Upgrade

Also seen as Risk Mitigation!

Adding klystrons (and modulators)

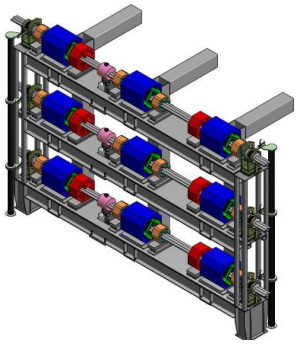


Damping Ring:

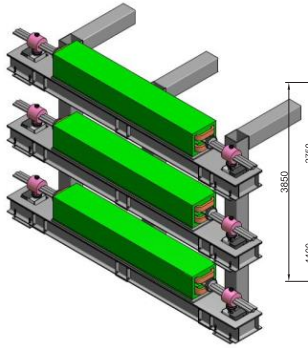
Positron ring (upgrade)

Electron ring (baseline)

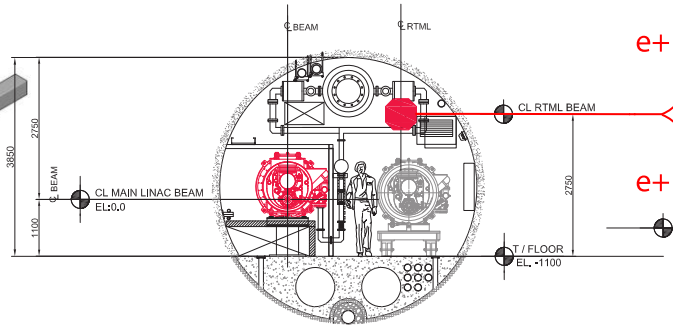
Positron ring (baseline)



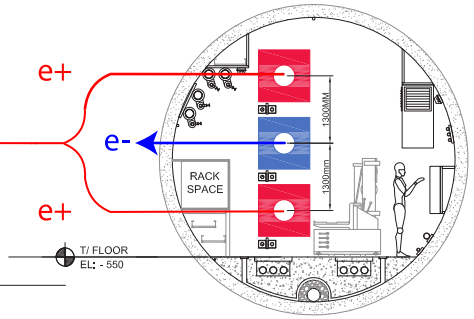
Arc quadrupole section



Dipole section



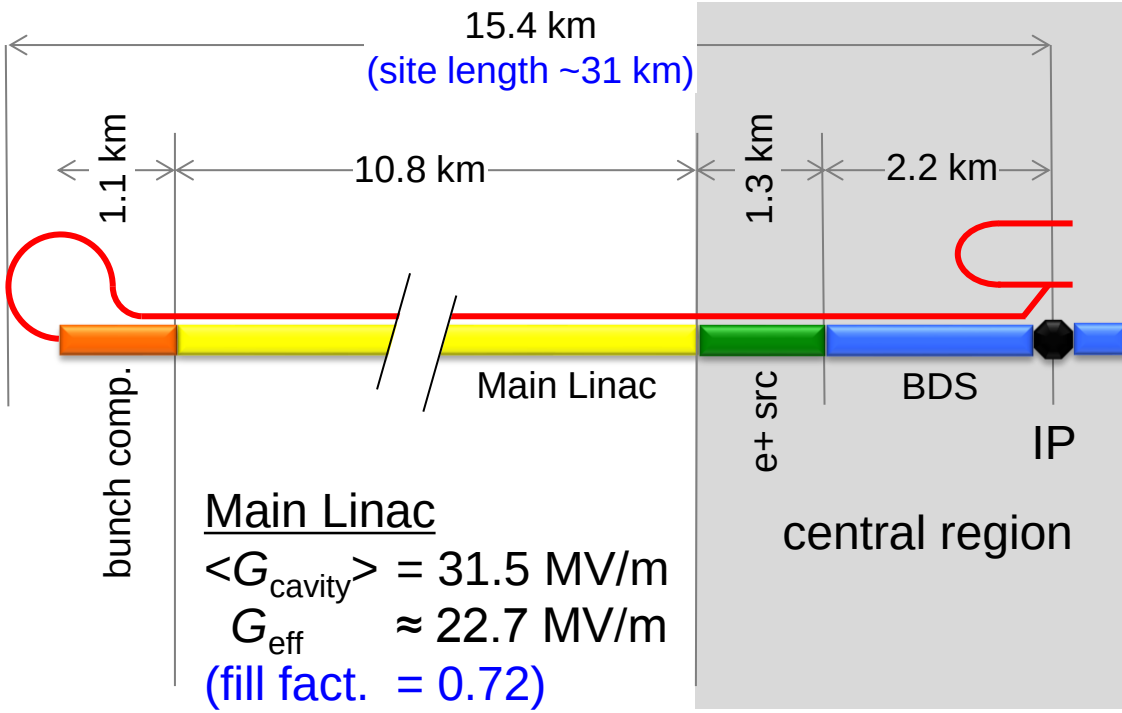
Main Linac Tunnel



Damping Ring Tunnel

Estimated cost based on TDR estimate: 490 MILCU and 1.6 MPHr

From 500 to 1000 GeV



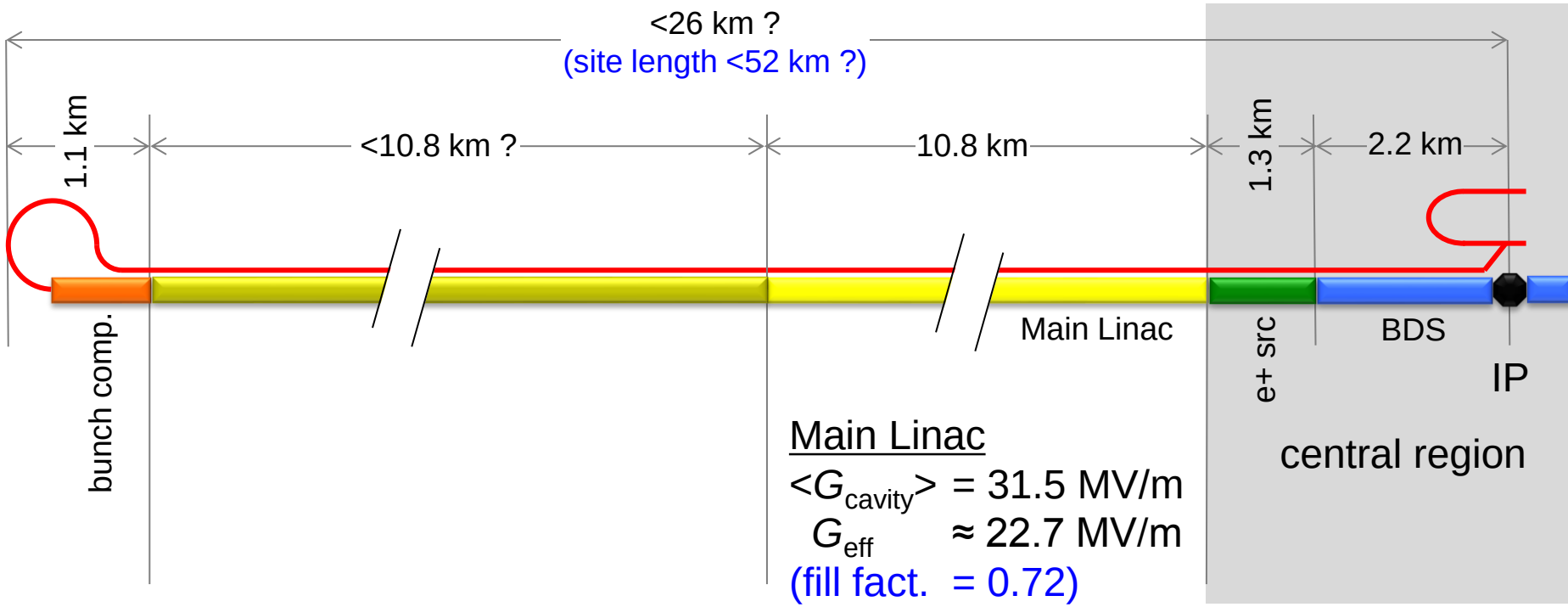
Main Linac

$\langle G_{cavity} \rangle$ = 31.5 MV/m

G_{eff} ≈ 22.7 MV/m

(fill fact. = 0.72)

From 500 to 1000 GeV



Main Linac

$\langle G_{cavity} \rangle$ = 31.5 MV/m

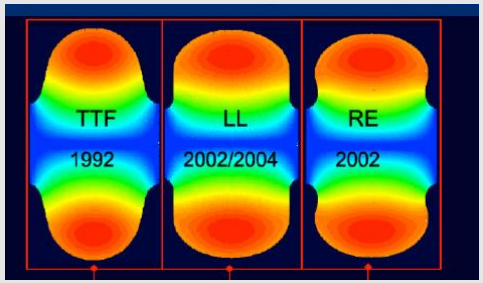
G_{eff} ≈ 22.7 MV/m

(fill fact. = 0.72)

Snowmass 2005 baseline recommendation for TeV upgrade:

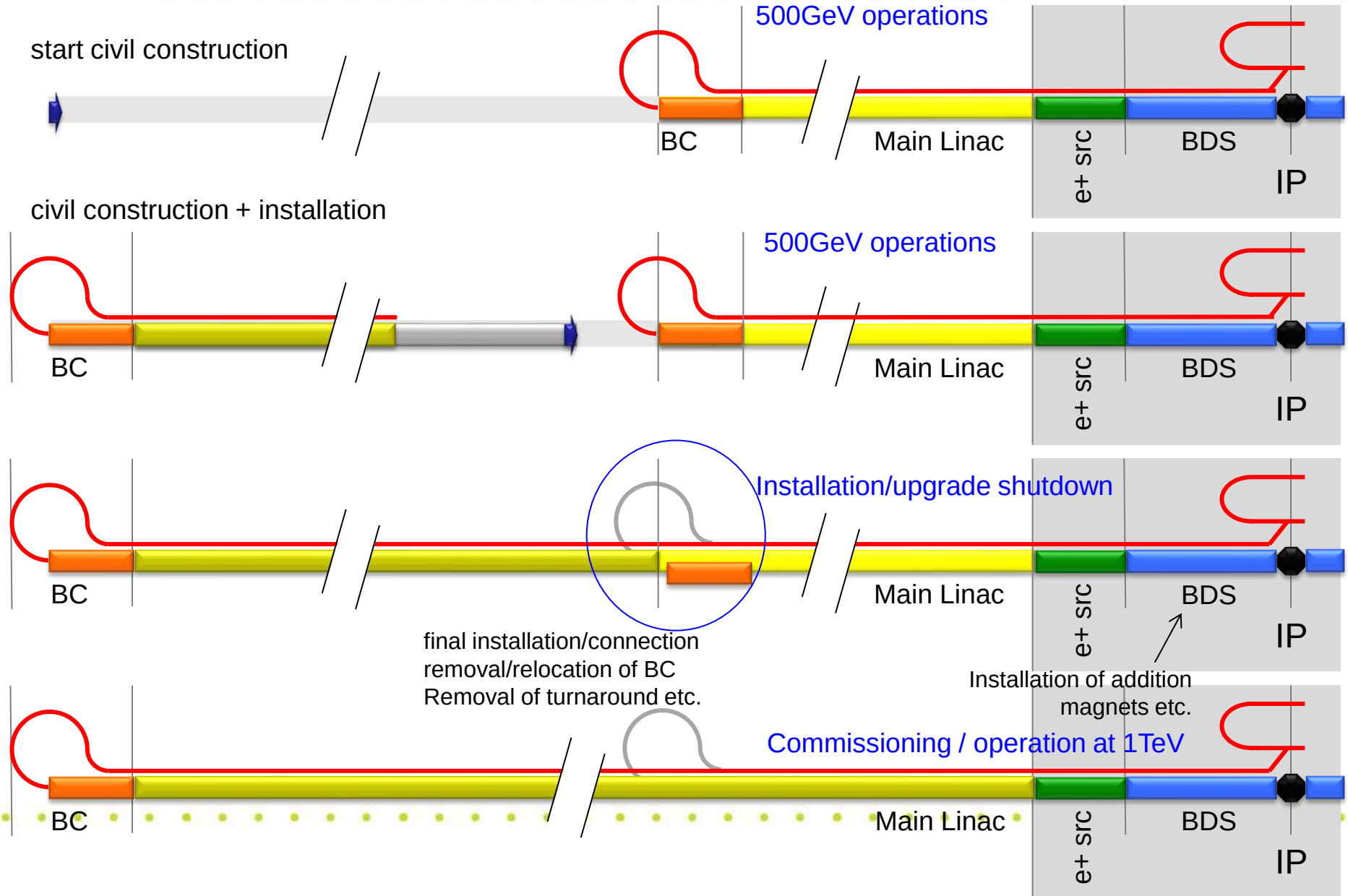
G_{cavity} = 36 MV/m ⇒ 9.6 km

(VT ≥ 40 MV/m)



Based on use of low-loss or re-entrant cavity shapes

Construction Scenario(s)



TeV Parameters (2 sets)

Beam energy	GeV	500	
Collision rate	Hz	4	
Number of bunches		2450	
Bunch population	$\times 10^{10}$	1.74	
Bunch separation	ns	366	
Pulse current	mA	7.6	
RMS bunch length	mm	0.25	0.225
Electron RMS energy spread		0.08	0.09
Positron RMS energy spread		0.04	0.05
Electron polarisation	%	80	
Positron polarisation	%	30	
Horizontal emittance	mm	10	
Vertical emittance	nm	30	
IP horizontal beta function	mm	22.6	11.0
IP vertical beta function	mm	0.25	
IP RMS horizontal beam size	nm	481	335
IP RMS veritcal beam size	nm	2.8	
Luminosity	$\times 10^{34}$ cm^{-2}s^{-1}	**3.6**	**4.9**
Fraction of luminosity in top 1%		0.6	0.4
Average energy loss		0.06	0.11
Number of pairs per bunch crossing	$\times 10^{3}$	200	383
Total pair energy per bunch crossing	TeV	1338	3441

P_{AC} constrained ≤300 MW

shorter bunch length
(within BC range)

horizontal focusing main difference

low and high beamstrahlung

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Higgs Factory

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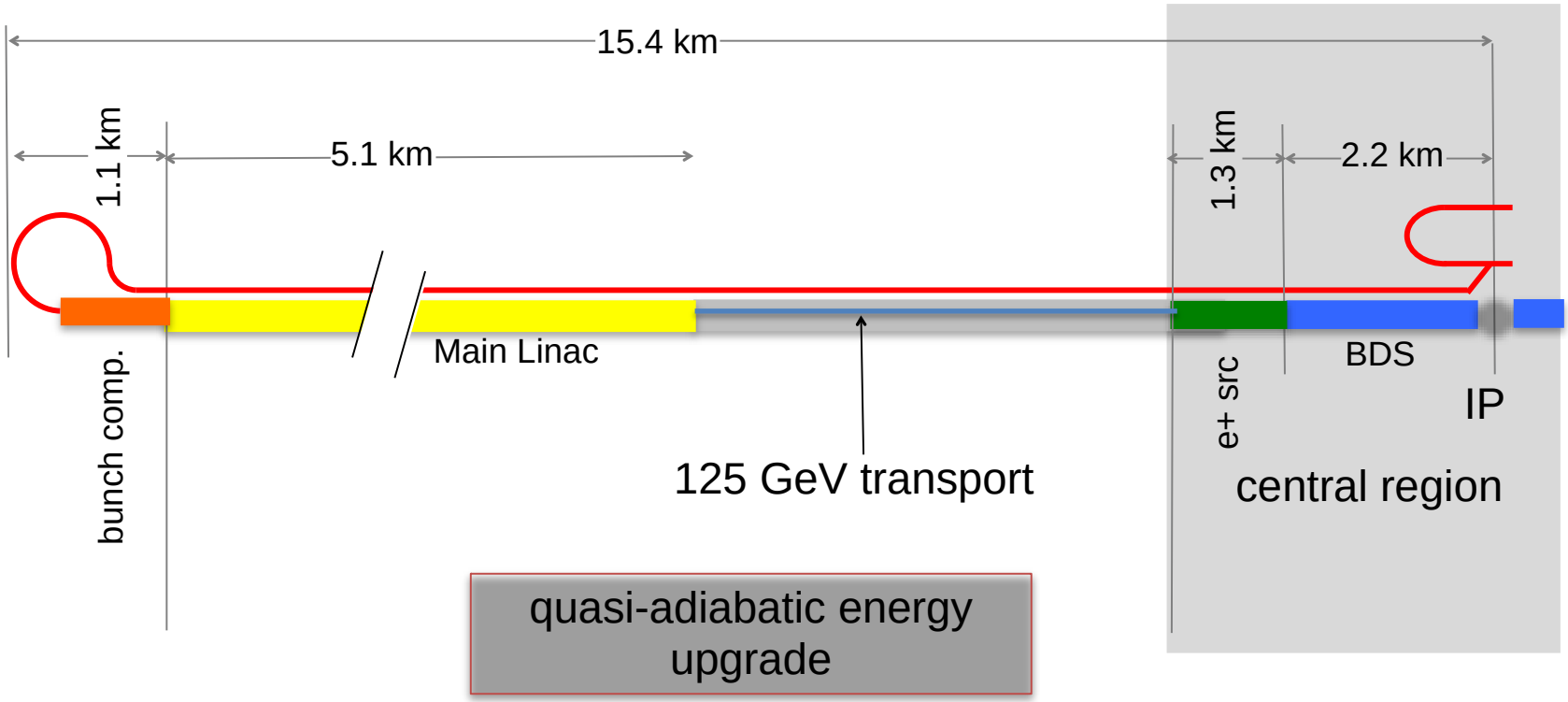
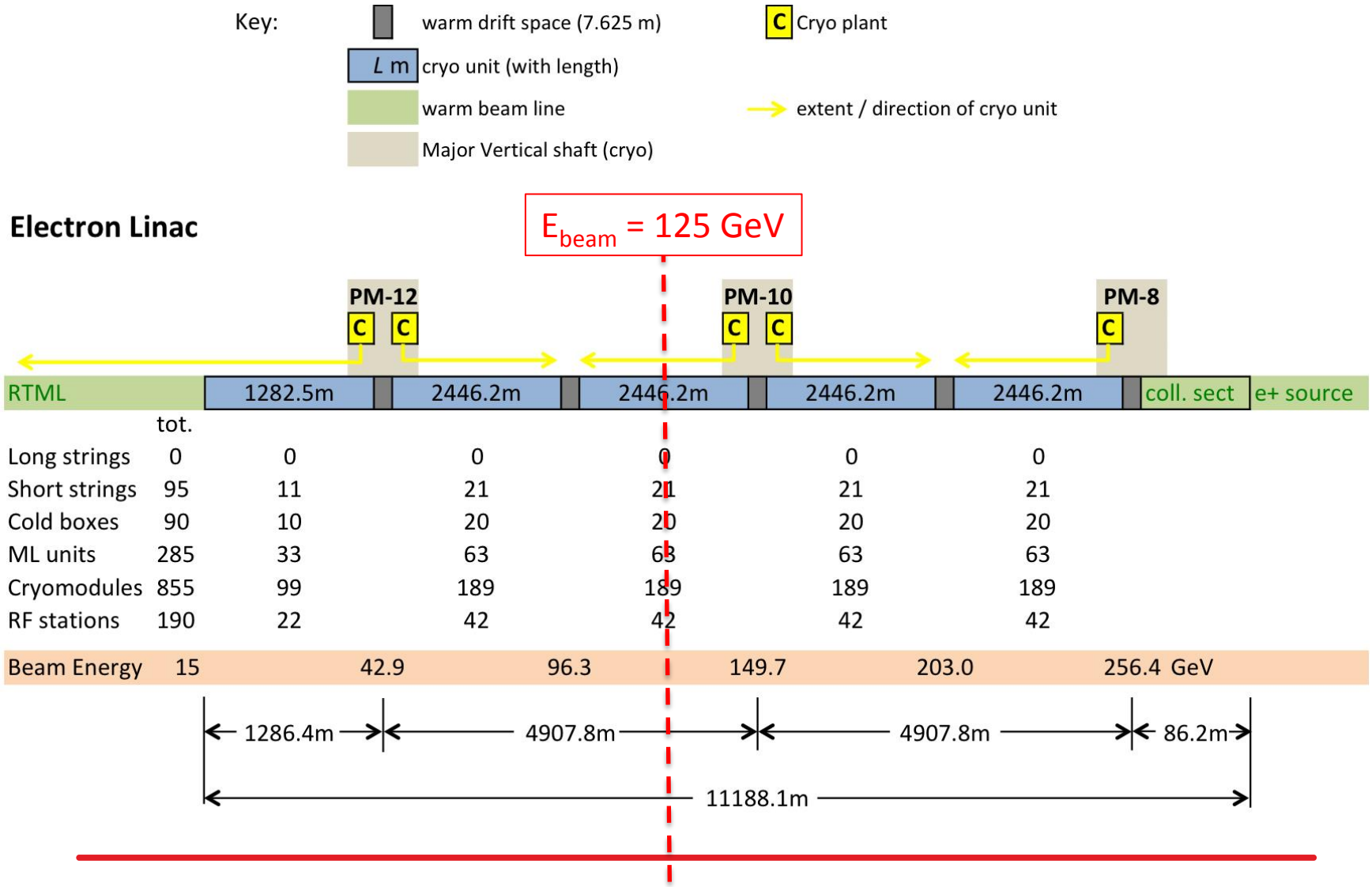
Staged construction: 250 GeV



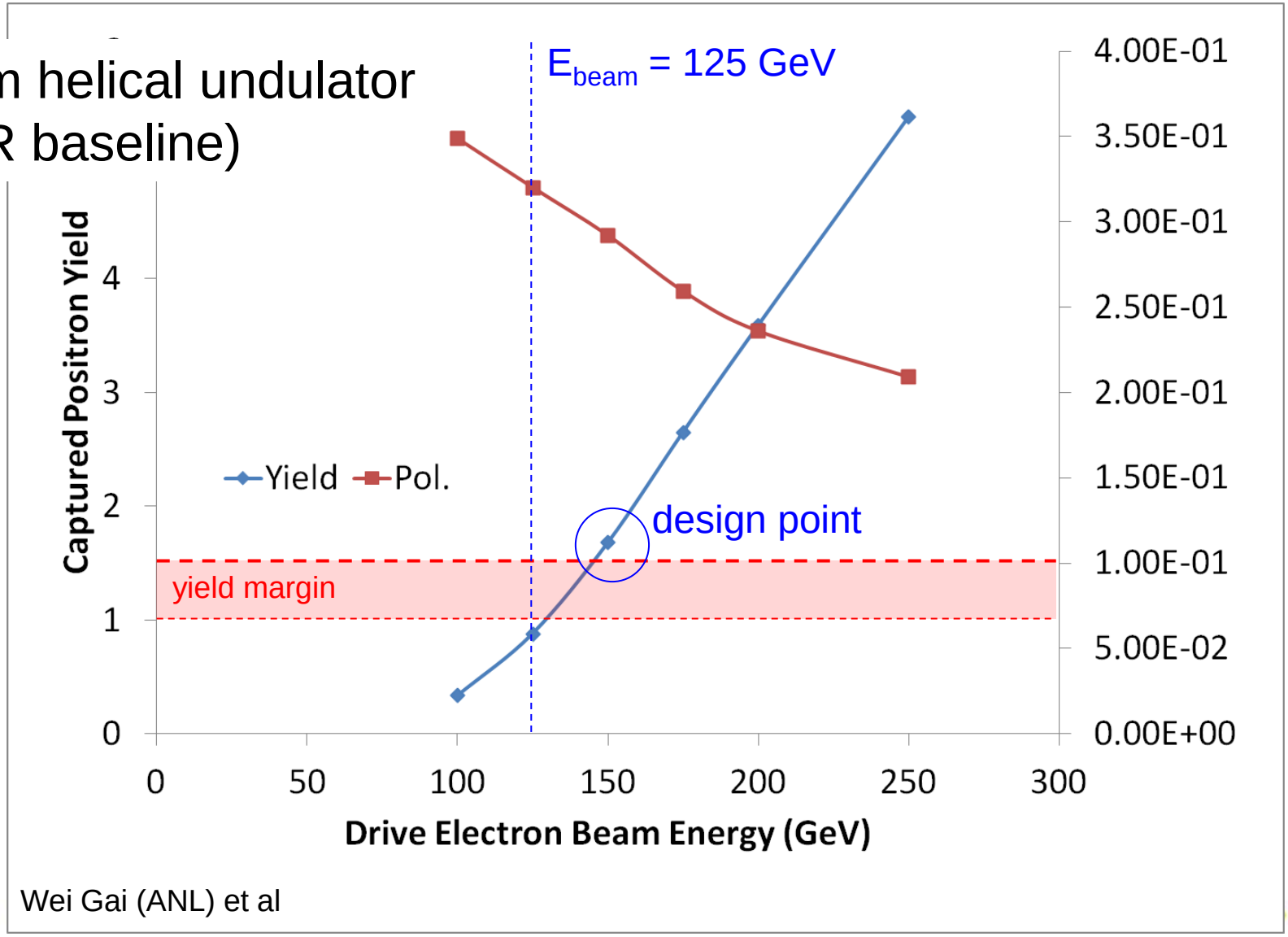
- Complete civil construction for 500 GeV machine
- Install ~1/2 linacs for fist stage operation (and long transport line)
- Capital savings ~25%
- Adiabatic energy upgrade (lower rate cryomodule production)

Favoured by Japan


Key:
warm drift space (7.625 m)
C Cryo plant
L m cryo unit (with length)
warm beam line
extent / direction of cryo unit
Major Vertical shaft (cryo)
Electron Linac
E beam = 125 GeV
PM-12
PM-10
PM-8
C
RTML
1282.5m
2446.2m
2446.2m
2446.2m
2446.2m
coll. sect
e+ source
tot.
Long strings 0 0 0 0 0 0
Short strings 95 11 21 21 21 21
Cold boxes 90 10 20 20 20 20
ML units 285 33 63 63 63 63
Cryomodules 855 99 189 189 189 189
RF stations 190 22 42 42 42 42
Beam Energy 15 42.9 96.3 149.7 203.0 256.4 GeV
1286.4m
4907.8m
4907.8m
86.2m
11188.1m

Making Positrons @ 250 GeV CM

147m helical undulator
(TDR baseline)



Wei Gai (ANL) et al

TDR: 10-Hz Mode (e+ production)

- **For TDR, we are required to have solutions down to Z-pole (~45 GeV beam)**

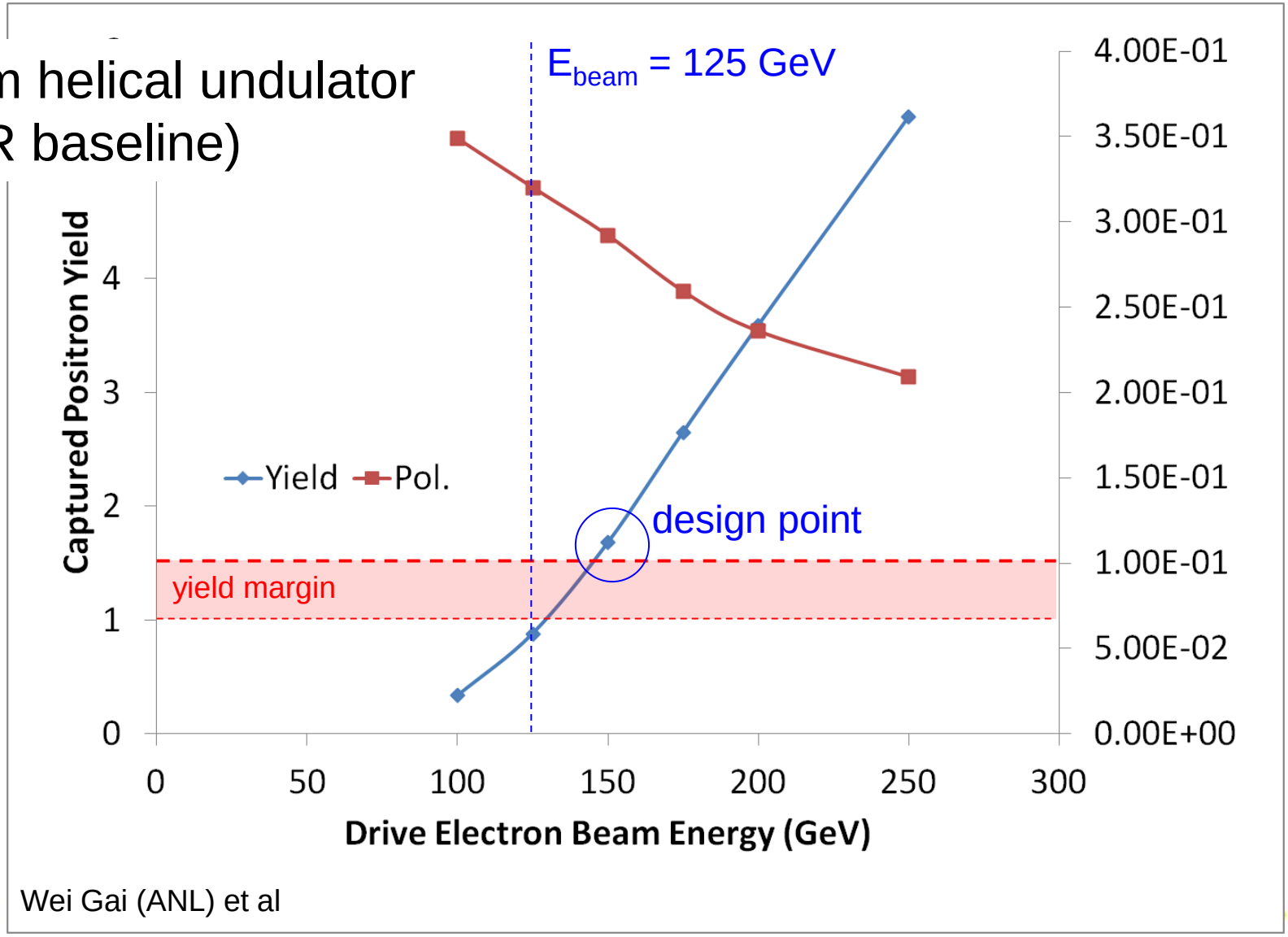
- **ILC TDR assumes 10-Hz mode where**
  - e- linac is pulsed at 10 Hz
  - **first pulse** @ 150 GeV to **make positrons**
  - **second pulse** @ $E_{cm}/2$ to **make luminosity**

collision rate still 5Hz

- **Issues**
  - DR damping time halved (extra cost and MW)
  - Beam dynamics in Main Linac (looks OK)
  - Additional beam lines and pulsed magnet systems
  - Additional AC power for elec linac 10-Hz mode
    - **But for 500 GeV design, additional power already available**
    - Not insignificant cost increase for a dedicated LHF

Positron Yield

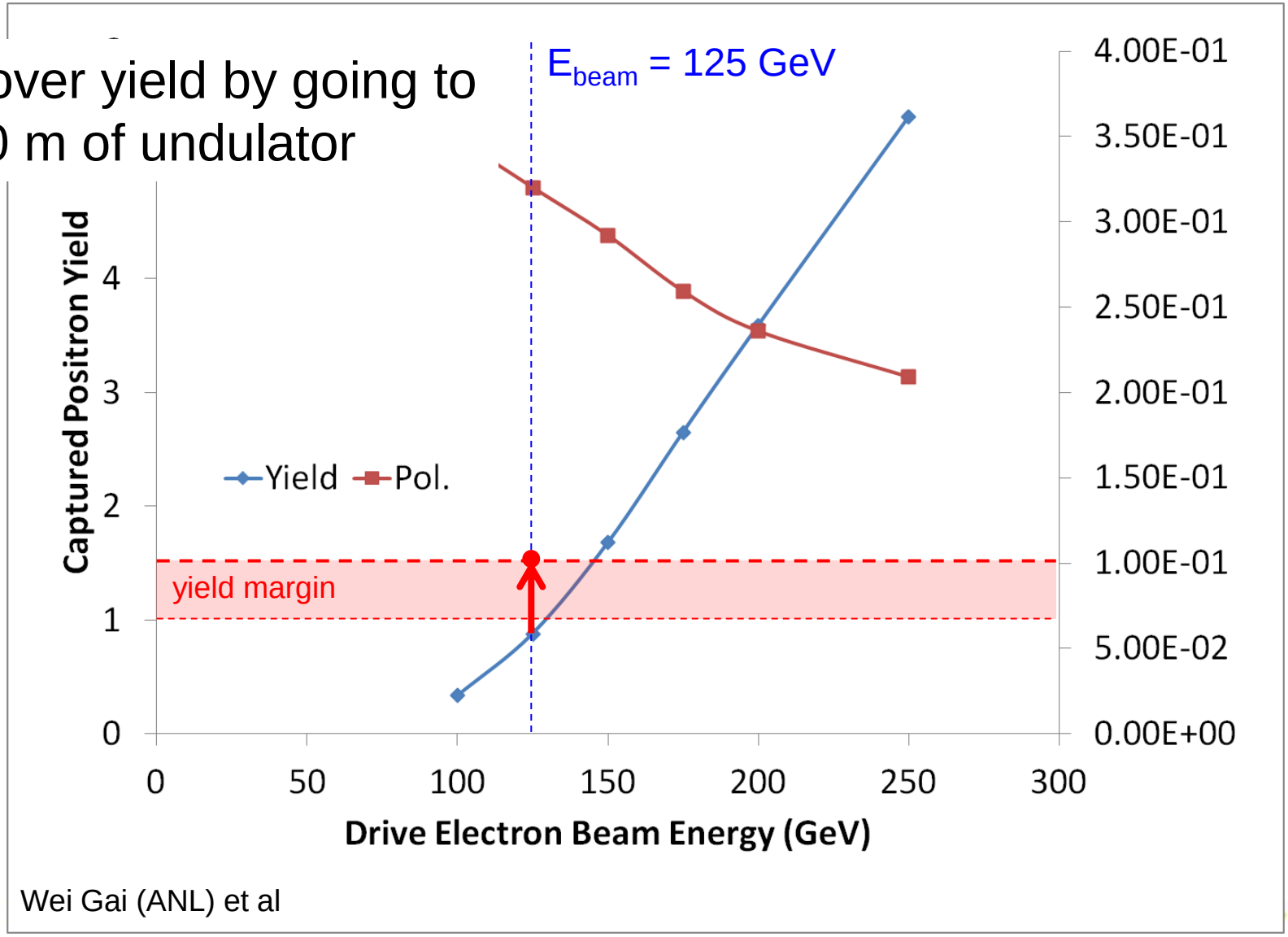
147m helical undulator
(TDR baseline)



Wei Gai (ANL) et al

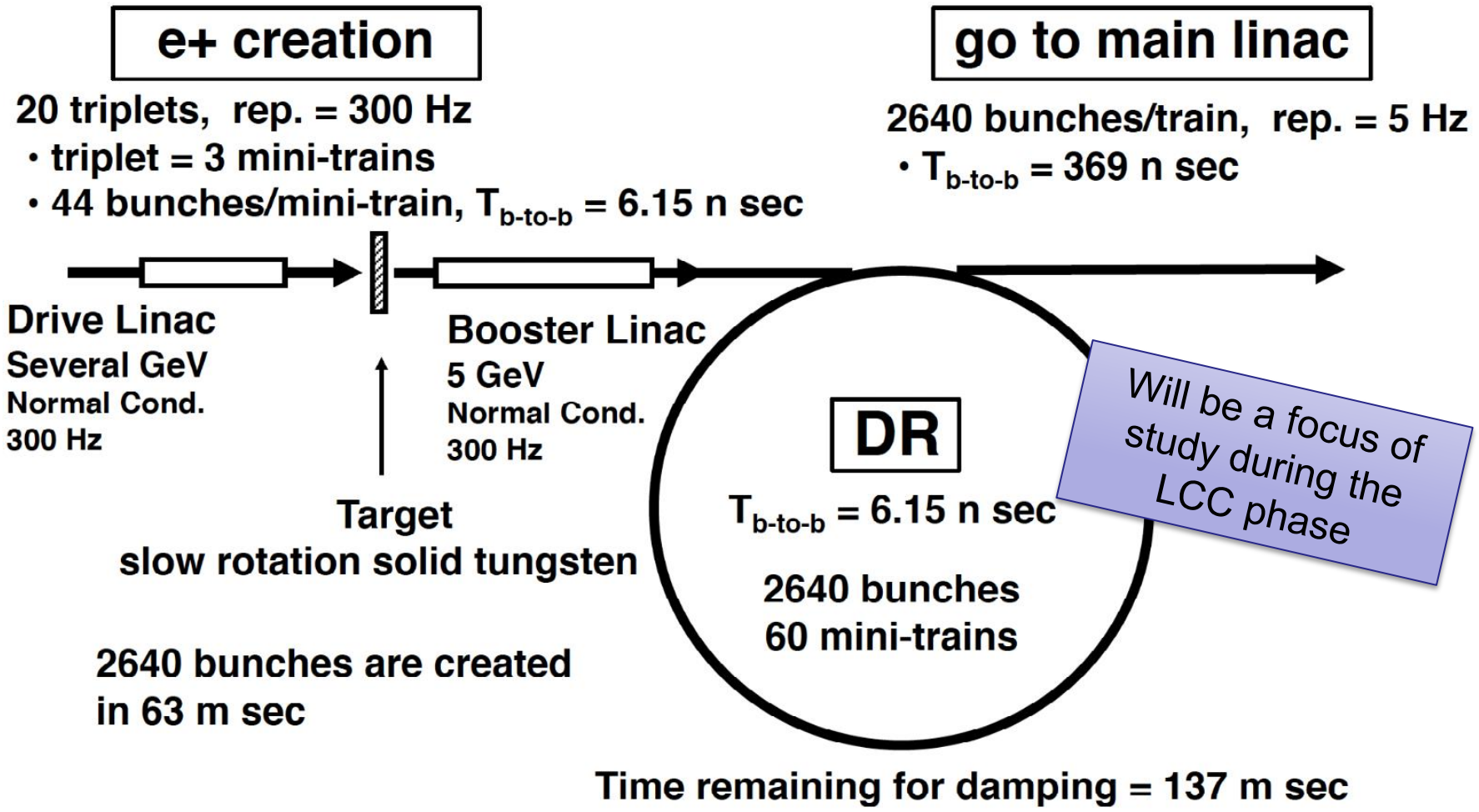
Positron Yield for a LHF

Recover yield by going to ~250 m of undulator



Wei Gai (ANL) et al

Alternative Electron-Driven Source

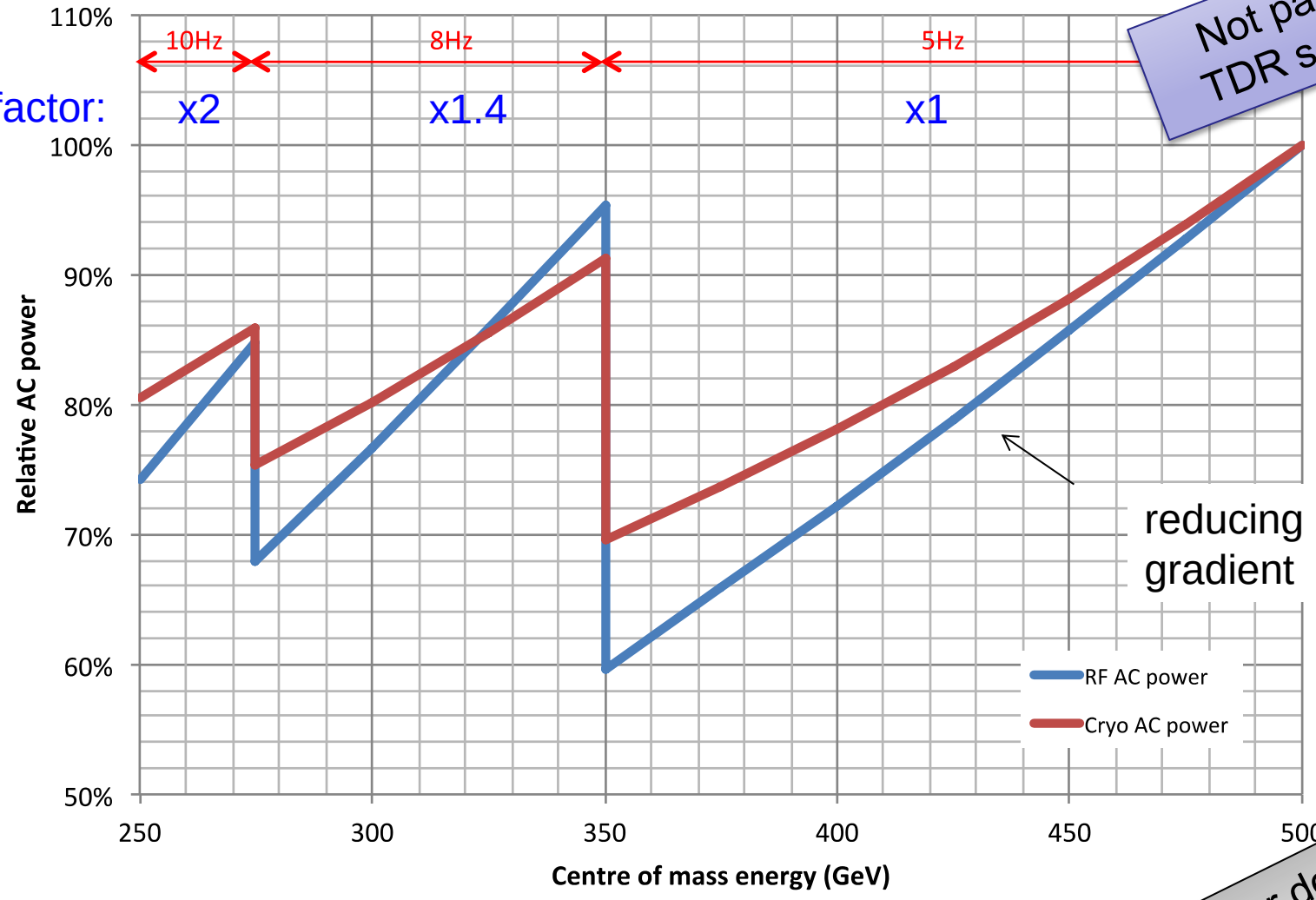


T. Omori *et al*, Nucl. Instrum. Meth. A **672** (2012) 52-56

Light Higgs Factory

- **Assume we do not need 10-Hz e+ production mode**
  - P_{AC} ~ 120 MW → ~100 MW (at least for undulator)
- **TDR still contains**
  - 10 Hz damping ring (100 ms store time)
  - 10 Hz e+e- source and injectors
- **Could we run 10 Hz collisions?**

Higher rep rate running



Not part of TDR scope!

issues for detectors?

Snowmass scenario: http://arxiv.org/abs/1308.3726

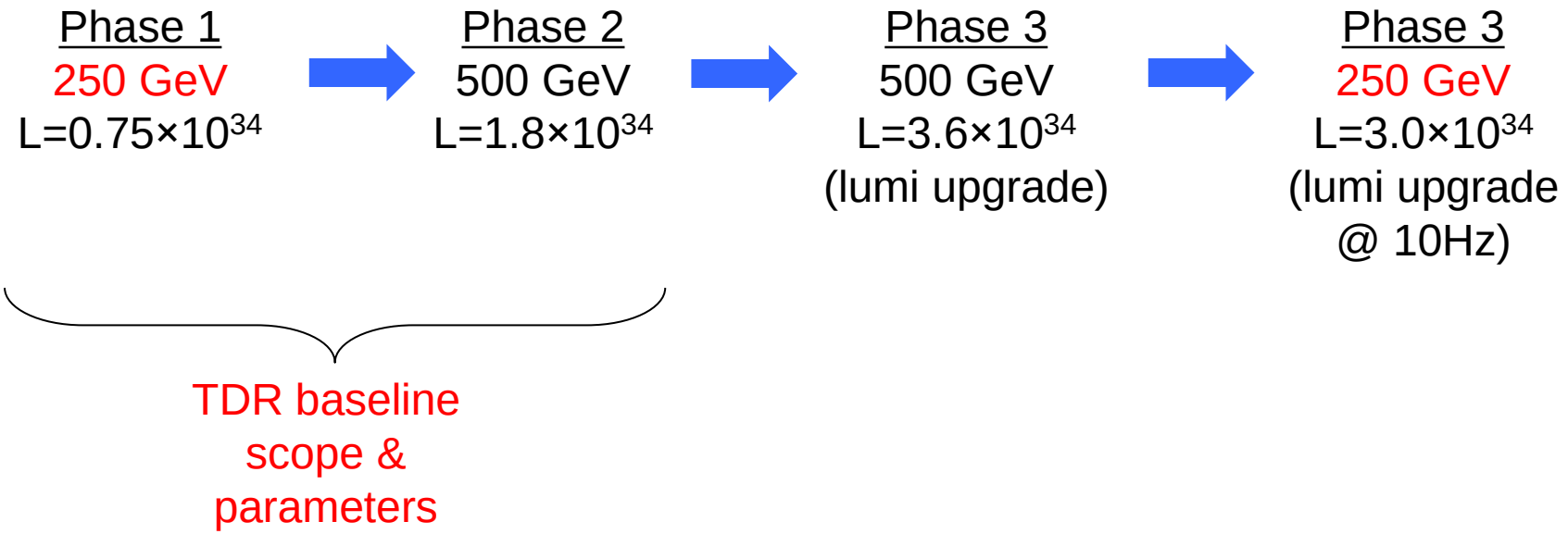
Issues for LHF 1st stage?

- **Shorter linacs run at full gradient (31.5 MV/m)**
- **10Hz operation would require additional AC power**
  - x2 RF AC power
  - x1.5 Cryo power
- **Requires feasibility study**
  - e.g. cryoplant capacity
  - cost!

Beyond TDR baseline!!
Something to talk about ☺

Snowmass Scenario

- **http://arxiv.org/abs/1308.3726**



Last Words

- **No technical show stoppers to higher luminosity**
  - God created SRF for high currents ☺
- **It's all about**
  - $$
  - Megawatts
  - Risk
- **Keep focused on the baseline physics case!**
  - Keep the upgrades in your pocket for refining arguments
  - (AND risk mitigation)