Cost Impacts of two e- ML cycles at sqrt(s) ≤ 250 GeV

purpose:
not to generate a new ILC estimate,
but to facilitate SB2009 decisions

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BAW-2, SLAC, January 21, 2010

last modification – 21jan2011 – 1130 PST

filename: PHG-BAW_Cost_Impact_10Hz.ppt

Outline of this presentation

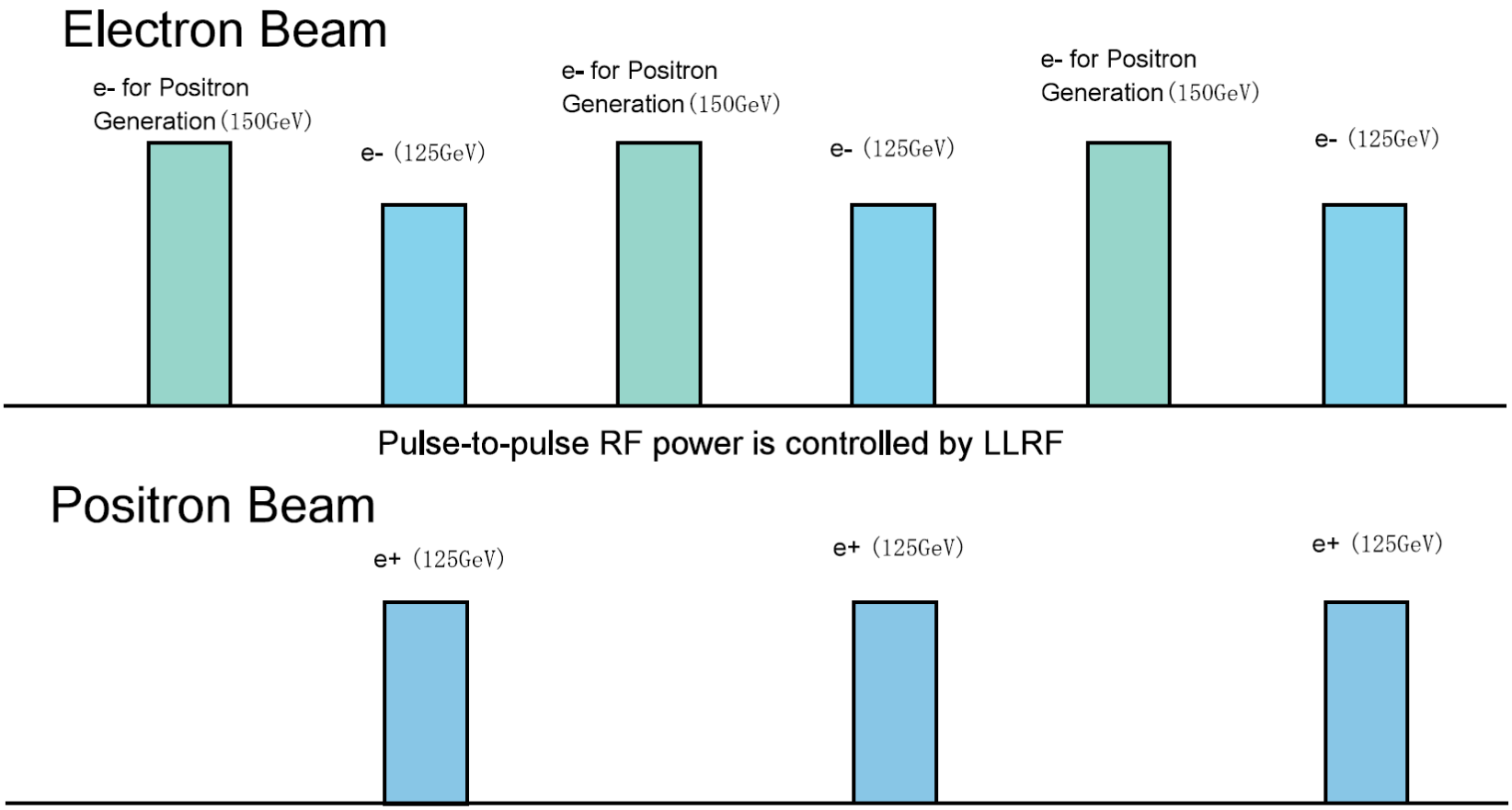
- call it: ***1 + 125x125*** normally: ***250x250***
- factorize: 1 + 125x125, then Centralized e+ Source
- pulse structure – starting point
- limitations in this analysis
- Impact Matrix, more details for e- ML & DRs (τ_{damp})
- Cost Impact Table for 1 + 125x125
- My hallucinations on Centralized e+ Source
- A little bit clearer picture
- Cost Impact Table for Centralized e+ Source
- Summary

150 + 125*125 @ 5 Hz

- Today's question: how much ***more*** will it cost to provide this extra capability?
- I'll concentrate on ML and DR for this presentation
  and then add cost impact of moving
  Positron Source to 250 GeV in e- ML
- e- DR must produce 2 pulses every 200 msec,
  which is 10 Hz
- e+ DR must produce 1 pulse every 200 msec, which is 5 Hz. It has a 50% RF duty factor, which will increase its PEAK RF power required by
  ~15% - S. Belomesnykh, Geneve, Oct 2010

Pulse Structure

Nice illustration that I'll "borrow" from Shigeki!



limitations

I will ***not*** consider impacts of this
150 + ≤ 125x125 pulsing at ***full #*** of bunches
– per Nick Walker's BAW-2 instructions

Although there has been much discussion of "optimizing" the length of the undulator and choice of either quarter-wave transformer or flux concentration as collection stage of the positron source, I will assume a ***single*** choice will apply to the cases under consideration and therefore there is ***no cost differential***.

Cost Impact Matrix for 150 + ≤ 125x125 relative to 250x250 @ reduced # bunches

150 plus 125*125	Tech. Comps.	RF Power	Cryo Power	Civil Tunnels	Civil Cavern*	Civil Buildings	Electrial Power	Thermal Cooling	Notes * includes alcoves & tunnel widenings
e- source	√	√	√		?		√	√	must provide 10 Hz pulses
e+ source	√				√		√	√	none, no extra load on γ target/dump
e- DR	√	√	√				√	√	provides 150 and ≤ 125 GeV pulses
e+ DR	√	√	√				√	√	needs more peak RF power for 50% df
e- RTML		√	√				√	√	must double pulse BC-1
e+ RTML									no impact
e- ML (&BC2)	√	√	√			KCS	√	√	must provide 125 and ≤ 125 GeV pulses
e+ ML (&BC2)									no impact
e- BDS				√	√			√	MPS & spent 150 GeV e- beam to dump
e+ BDS									no impact
Exp Hall									no impact
Common							√		only Master Substation

- Major costs are for ***e- Main Linac*** & ***both Damping Rings***, so we will concentrate only on these systems
- Different civil construction (enclosures) for e+ Source
- e- Source, e- RTML (BC-1) and e- BDS (dump only) have small increased power ~ small extra costs

Chris A – minor impact on RF

- More details and discussion in backup slides

RF & wigglers for DRs
conventional components are the same

lattice	SB2009	SB2009	SB2009
	LowP 5 Hz	LowP 10 Hz	LowP 10 Hz
beams	e+/e- ea	e+ Ring	e- Ring
reference-page	4-11,30	4-28,30	ref 4 p 30
Circumference (m)	3238	3238	3238
# bunches per DR	1305	1305	1305
damping time ms	24	13	18
RF Voltage MV/DR	7.5	13.4	10.4
# RF cavities/DR	6	9	9
# klystrons/DR	2	3	3
Wiggler B (Tesla)	1.6	2.4	2.4
Wiggler period (m)	0.4	0.28	0.28
Wiggler lgt ea (m)	2.45	1.72	1.72
Wiggler lgt/DR (m)	78	75	75
# wigglers/DR	32	44	44

tab: DR-info

different wigglers
assume same cost - MP

SR photon absorbers in wigglers

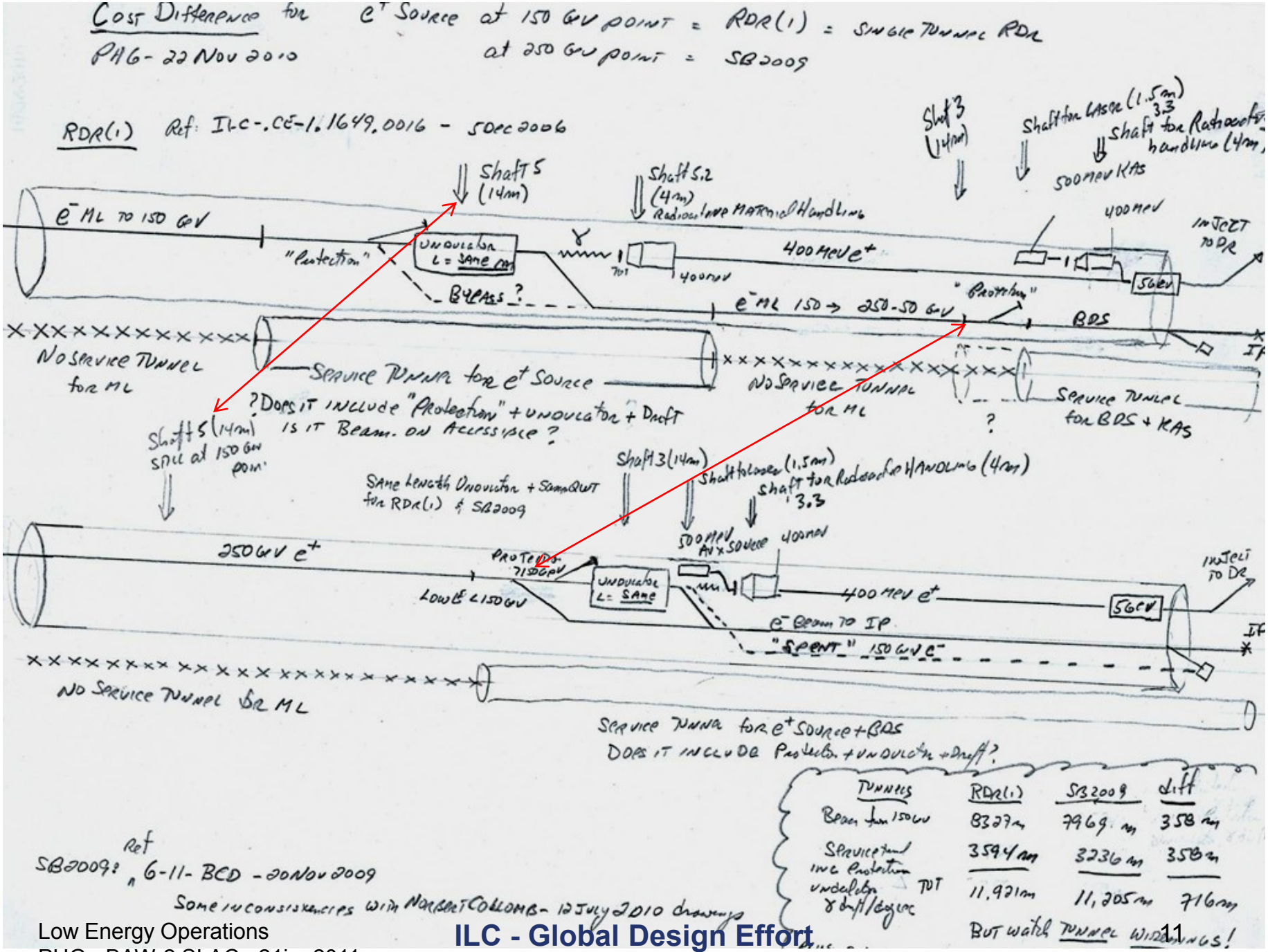
- cost estimates were not included in RDR or in any of the SB2009 and BAW-2 analyses
- Hope that they cancel in the differential cost sense…

Cost Differentials for ML & DR

1312 bunches	250x250		150+125*125		Cost diff M ILCU	Notes
	Quantity	Cost M ILCU	Quantity	Cost M ILCU		
Main Linac - KCS						
modulators & PS for e- ML	499/2	76.9	499/2	77.0	0.2	ChrisJ estimate (+0.2%) & ChrisA note
cryogenics plants e- ML	5*4.12 MW		5*3.35 MW		0	lower, so no impact
cryogenics plants e+ ML	5*4.12 MW		5*2.65 MW		0	lower, so no impact
RF power	66 MW		59 MW		0	no impact, PHG => Emil 12jan2011
other electrical power	54 MW		54 MW		0	same, no impact
thermal cooling	64 MW		57 MW		0	lower, so no impact
Damping Rings - 2 rings - 3.2 km						
technical components		276.3		298.4	22.1	see detailed RF & wiggler change list
cryogenic plant e- DR	1.18 KW 4.5K	3.5	1.64 KW 4.5 K	4.3	0.8	100% df + 2*50% duty factor
cryogenic plant e+ DR	1.18 KW 4.5K	3.5	1.55 KW 4.5 K	4.1	0.6	100% duty factor & 50% duty factor
cryo accessories e- DR		3.1		3.1	0	same, no impact
cryo accessories e+ DR		3.1		3.1	0	same, no impact
cryo distribution e- DR		4.2		4.2	0	same since # end boxes the same
cryo distribution e+ DR		4.2		4.2	0	same since # end boxes the same
CFS: Civil		107.3		107.3	0	same, no impact
CFS: Electrical Power	12.8 MW	16.3	16.8 MW	17.4	1.1	CFS did this better than PHG's P^{α}
CFS: Thermal Cooling	8.5 MW	24.1	12.4 MW	28.2	4.1	CFS did this better than PHG's P^{β}
e- Src - Modulators & PS					1.2	need to double pulse, same E
e- Src - Electrical & Cooling					3.2	PHG guess/scale for RF & Cryo
e- Cryogenics capacity					2.9	2X dynamic cryogenics load
e- RTML Modulators & PS					0.2	need to double pulse BC-1 at 5 GeV
e- RTML Electrical & Cooling					0.2	PHG guess/scale for RF & Cryo
e- RTML Cryogenics capacity					0.4	2X dynamic cryogenics load

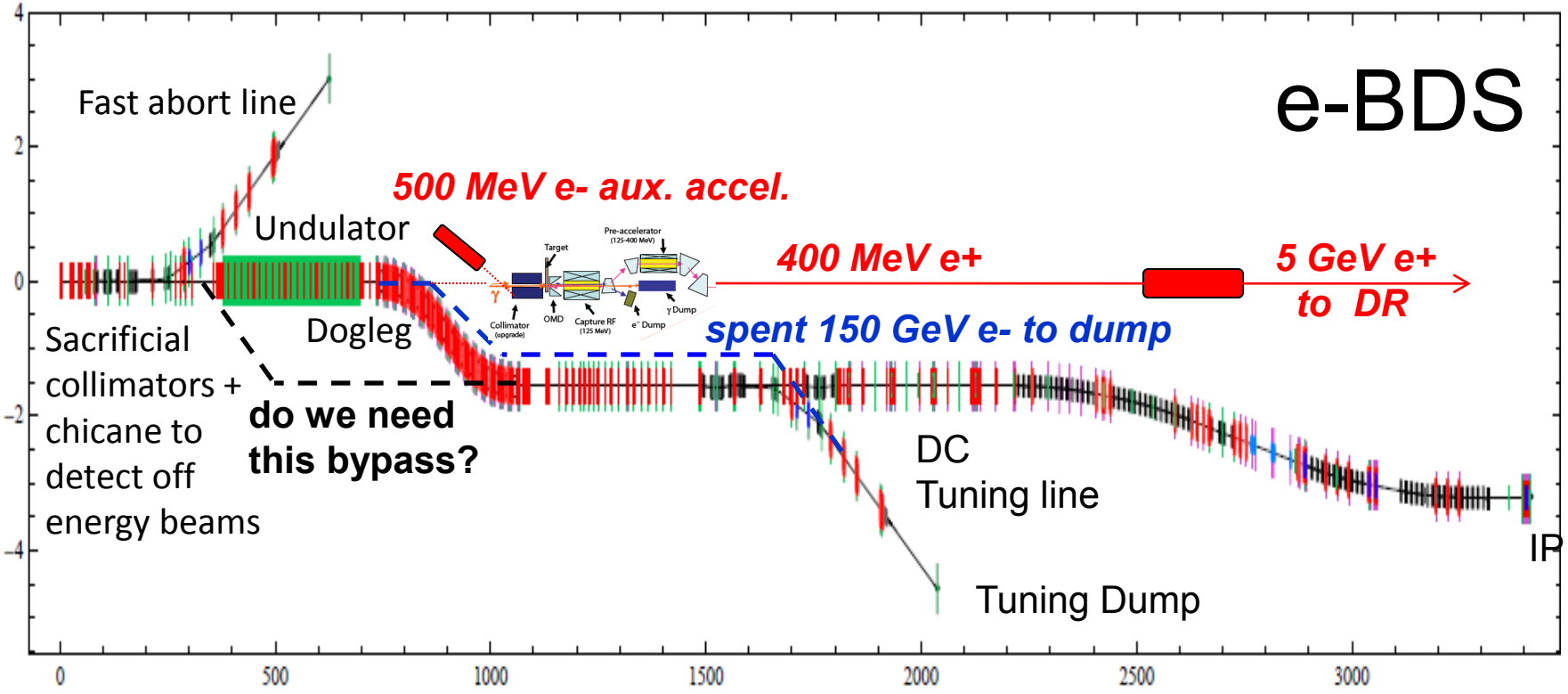
tab: 10 Hz summary

total increase = 37 M divide by 6,618 M ILCU = +0.56%


Cost Difference for e+ Source at 150 GeV point = RDR(1) = Single Tunnel RDR
PHG - 22 Nov 2010
at 250 GeV point = SB2009
RDR(1) Ref: ILC-.CE-1.1649.0016 - 5Dec2006
Shaft 5 (14m)
Shaft 5.2 (4m) Reduced Diameter Material Handling
Shaft 3 (14m)
Shaft for Laser (1.5m) 3.3
Shaft for Retrocooler handling (4m)
500 MeV KAS
400 MeV
INJECT TO DR
e- ML to 150 GeV
"Protection"
Undulator L = same as
BYPASS ?
400 MeV e+
400 MeV
5GeV
e- ML 150 → 250-50 GeV
"Protection"
BDS
IP
No Service Tunnel for ML
Service Tunnel for e+ Source
No Service Tunnel for ML
Service Tunnel for BDS + KAS
? Does it include "Protection" + Undulator + Drift
Is it Beam. on Accessible ?
Shaft 5 (14m) spill at 150 GeV point
Same length Undulator + Same QUAD for RDR(1) & SB2009
Shaft 3 (14m)
Shaft for Laser (1.5m)
Shaft for Retrocooler HANDLING (4m)
3.3
250 GeV e+
500 MeV Ave Source 400 MeV
Protons 71 GeV
Undulator L = same as
400 MeV e+
5GeV
INJECT TO DR
Lower E 150 GeV
e- Beam to IP
"SPENT" 150 GeV e-
IP
No Service Tunnel for ML
Service Tunnel for e+ Source + BDS
Does it include Protection + Undulator + Drift?
Tunnels
Beam from 150 GeV
Service Tunnel inc Protection Undulator & Drift/Taper
TOT
RDR(1)
8327 m
3594 m
11,921 m
SB2009
7969 m
3236 m
11,205 m
diff
358 m
358 m
716 m
But watch Tunnel Widenings!
Ref
SB2009: 6-11-BCD - 20Nov2009
Some inconsistencies with Norbert Collomb - 12 July 2010 drawings

neater optics sketch for Centralized Positron Source

positron system is schematic only: not to scale or position



cost impacts of moving of e+ source

Cost Differentials for Centralized e+ Source - M ILCUs	Savings	Additions	Notes:
one set of MPS sacrifical collimators, abort, & dump	???		never estimated for RDR
301 m tunnel (for above)	3.0		
301 m tunnel widening (for above)	4.7		
4 m dia rad material handling shaft & grouting	9.5		
Radioactive Materials Handling & Storage Bldg	3.1		
KAS e+ target station & acceleration to 400 MeV	28.2		- see next page for details
electrical power	???	???	not considered yet by CFS
thermal cooling	???	???	not considered yet by CFS
spent 150 GeV e- from undulator => dump 1,166 m dogleg, min FODO, min instrumentation, rastering?		???	to e- tune up dump or to e+ primary dump (backwards)?
100 msec beam switches		???	
corrector magnets for dual energy trajectories		???	
LET bypass around undulator for beam to I.P. (620 m)		???	- do we need/want this?
total change (= savings minus additions) - M ILCU	48.5	???	M ILCU

150 + 125x125 + 37 M ILCU (more)

Centralized e+ Source - 48 M ± ???

tab: needs

Summary - 11 ± ?? M ILCU

RDR Keep-Alive Source Estimates

Cost Estimating of KAS - components

John Shepard - RDR	K ILCU - 2007	Notes
KAS laser (0.5)	0	also needed for aux. source, no differential
KAS gun (0.5)	0	also needed for aux. source, no differential
Sub-Harmonic Buncher (2)	0	also needed for aux. source, no differential
500 MeV KAS e- accelerator	0	also needed for aux. source, no differential
everything below was needed for second e+ production station & acceleration to 400 MeV		
e+ production target	3,937	
Adiabatic Matching Device	2,329	
Target & AMD housing/shield	1,123	
SW Cavities (2)	124	
TW Cavities (12)	3,097	
Warm Station High Level RF (14)	10,839	
SW HL RF distribution (2)	380	
TW HL RF distribution (12)	1,388	
Controls - pro-rated	657	
KAS Instrumentation	968	
KAS Dumps & Collim	210	
KAS Vacuum	780	
KAS Conventional Magnets	1,177	pro-rate KAS magnet costs from PS costs
KAS Power Supplies	1,180	
totals	28,189	K ILCU - 2007

tab: needs

Backup Slides

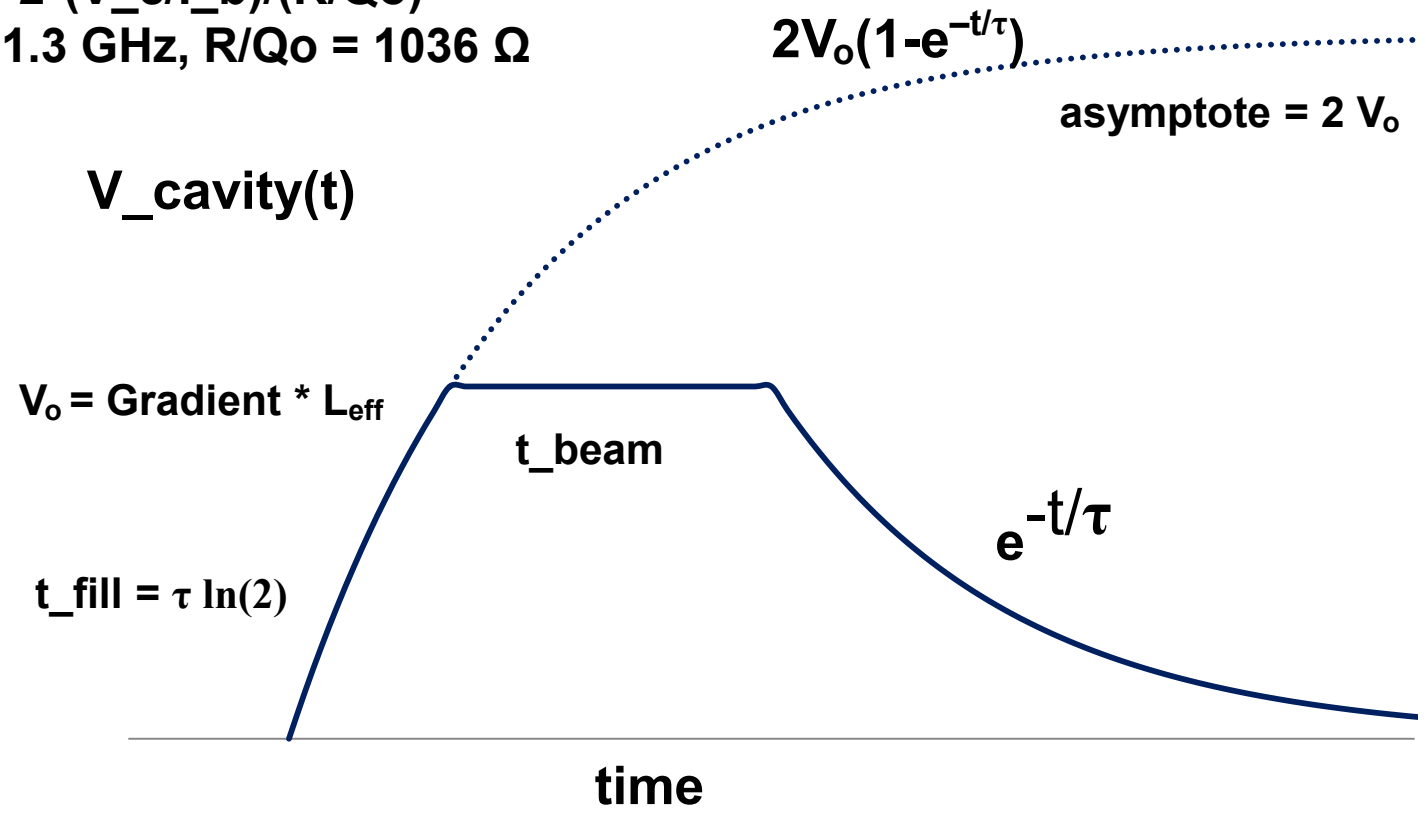
(skip) quick thoughts on e- ML power

Remember that we started with capability of one e- ML pulse at 250 GeV, and now we are considering the maximum of 150 GeV + 125 GeV (gross sum = 275 GeV), but we have to look at details of three things:

- **relative widths of t_fill, t_beam_ and t_r these will affect total power and cooling and cryogenic plant power due to dynamic cryogenic loads in the cavities**
- **efficiencies of klystrons running at 60%/50%**
- **capabilities of modulators and power supplies**
- **RF parameters and Q_L optimized for 150 GeV, will not be matched at E < 150 GeV (reflections)**

RF pulse for constant klystron power

$\tau = 1/(2\pi f_o)*2*(V\_c/I\_b)/(R/Qo)$
where f_o = 1.3 GHz, R/Qo = 1036 Ω

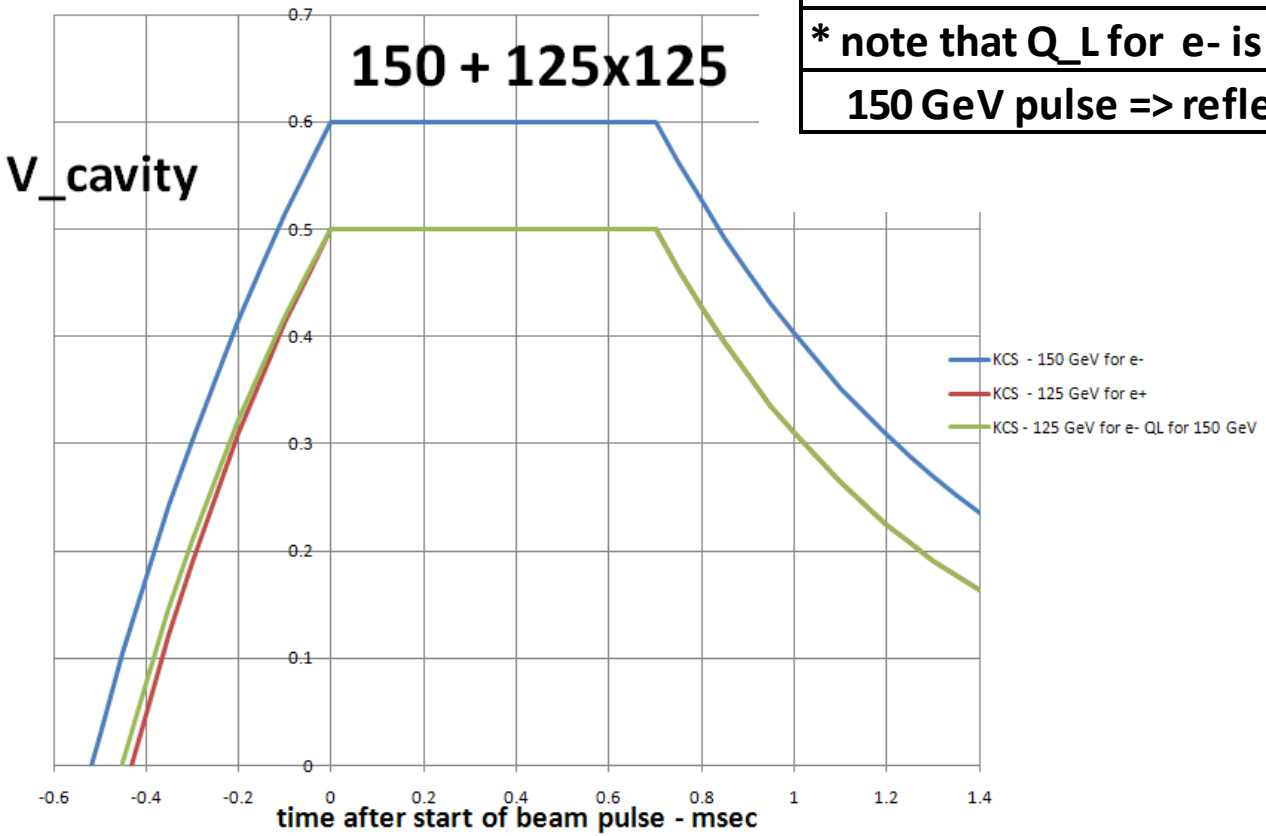


DRFS for 150 + ≤ 125x125

- Shigeki just sent 110115A on Sunday, Jan 16 which said, “In the case of low-energy 10 Hz case, DRFS HLRF hardware configuration is the same as SB2009 and not cost change.”
- Shigeki did ***not*** send power and cooling requirements for 150 + 125x125 to CFS
- I didn’t see Shigeki’s presentation until yesterday
- Shigeki previously said details with new estimates will not be available until Summer 2011
- So I can’t say too much more on DRFS…

RF parameters for KCS

KCS 150 + 125*125 @ 6.2 mA	e+ 125	e- 150	e- 125 *
I_beam mA	6.2	6.2	6.2
t_fill msec	0.432	0.518	0.452
t_beam msec	0.702	0.702	0.702
t_rf msec	1.134	1.22	1.154
fall time τ msec	0.623	0.748	0.623
* note that Q_L for e- is set for no reflection during			
150 GeV pulse => reflections furing 125 GeV pulse			



KCS parameters for 150 + 125*125

- Keep t_beam = 0.702 msec, I_beam = 6.2 mA
- Need parameters: does t_fill change between 150 and 125?, ChrisN (1/12) and ChrisA (1/14) has for constant power klystron output pulse

t_fill(150 GeV) = 0.517 msec

t_fill(E)/t_fill(150 GeV) = ln(1+E/150 GeV)/ln(2)

t_fill(125 GeV) = 0.874*t_fill(150) = 0.452 msec

reflected power ratio = (1/4)*(1-E/150)^2 ~ 0.7%

Dependence of Cryo Dynamic Loads

RF load ~ $V^2_{cav}*(t_{beam}+1.11*t_{fill})$

Input Coupler load ~ $V_{cav}*(t_{beam}+t_{fill})*I_{beam}$

HOM (beam) load ~ I_{beam}

Don't ask, I don't have simple breakdown by dynamic load component, or even dynamic to static sum, only listed as function of coolant temperature (2 K, 5 K, 40 K)

Cryo Loads: Full Power (both) 10* 4.42 MW
Reduced # bunches: KCS 10* 4.12 MW
DRFS 10* 4.72 MW

one miniscule correction

- ChrisN incorrectly had ln(1+***sqrt***(E/150))/ln(2) which gave t_fill(125 GeV) = 0.483 msec,
  instead of 0.458 msec when Q_L is set for 150 GeV which TomP used for the cryogenics dynamic load for 125 e-
  What is the difference for e- beam?
- $P^{cryo}_{dynamic}$(0.483 msec) = 10 x 3.55 MW - **X**
- $P^{cryo}_{dynamic}$(0.458 msec) = 10 x 3.54 MW - √