# SB2009/ Low energy running for ILC

**International Workshop on Linear Colliders 2010**

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# Outline

- SB 2009 parameter development (end 2009 – early 2010)
  - **Optimization of cost / performance**
    - Central region integration
    - Lower current with tighter & travelling focussing
    - Same Luminosity at nominal energy
    - Challenge at lower E due to reduced collision rate
- LCWS10 – discussion of the parameter set and tentative evaluation of double rep rate at low E
  - **A solution to restore Luminosity at low E was found**
- Mid 2010 – development of the new parameters and finalization of a tentative set
- BAW-2 – January 2011

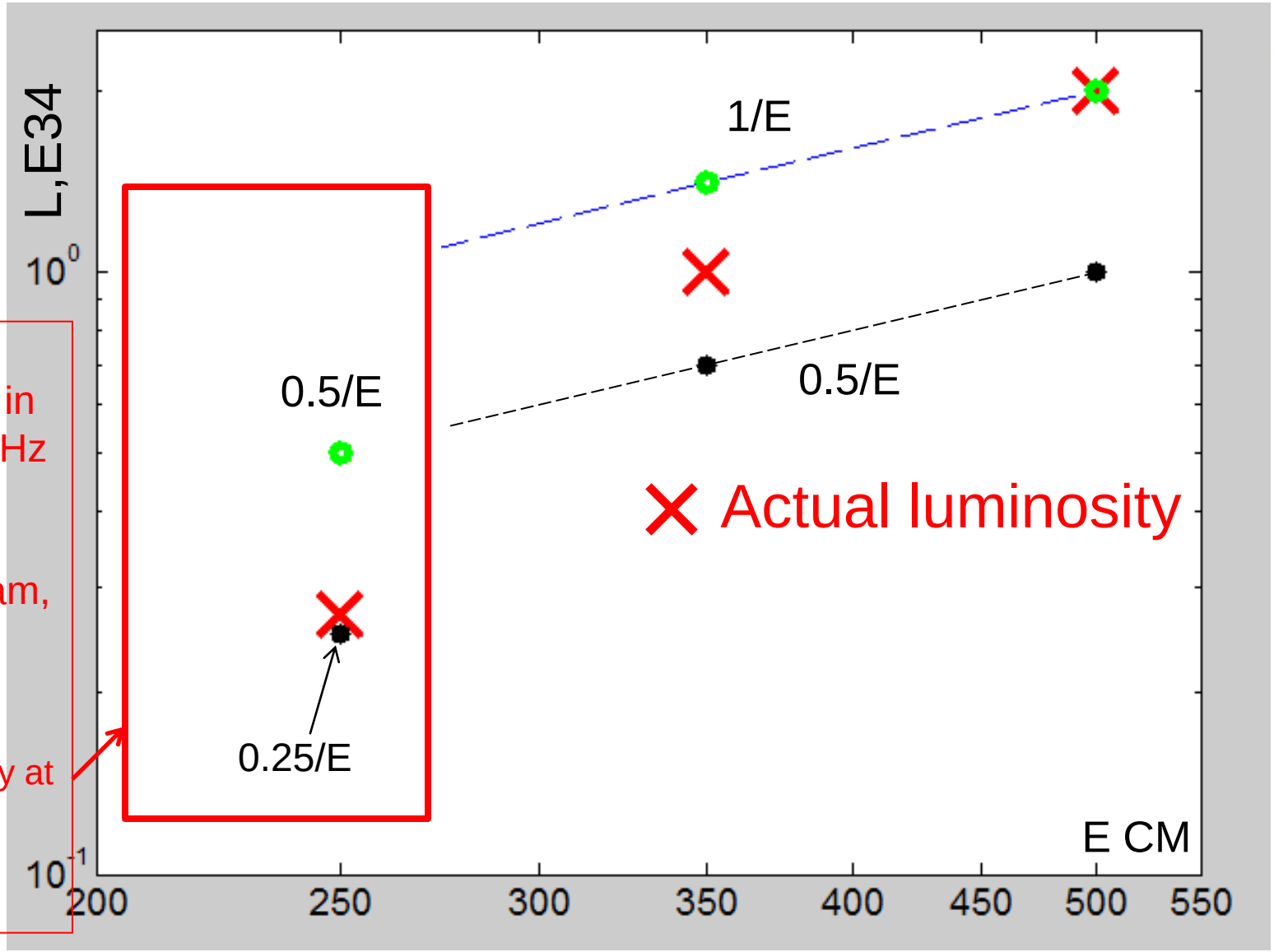
# Beam Parameters

| | 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 |
| $\gamma ex$ ($*10^{-6}$) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| $\gamma ey$ ($*10^{-6}$) | 4 | 4 | 4 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| $\beta x$ | 22 | 22 | 20 | 21 | 21 | 15 | 11 | 21 | 21 | 15 | 11 |
| $\beta y$ | 0.5 | 0.5 | 0.4 | 0.48 | 0.48 | 0.48 | 0.48 | 0.2 | 0.2 | 0.2 | 0.2 |
| $\sigma z$ (mm) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| $\sigma x$ eff ($*10^{-9}$ m) | 948 | 802 | 639 | 927 | 927 | 662 | 474 | 927 | 927 | 662 | 474 |
| $\sigma y$ 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 |

Rate at IP = 2.5Hz,
Rate in the linac = 5Hz (every other pulse is at 150GeV/beam, for e+ production)

Low luminosity at this energy reduces the physics reach

# SB2009 Lumi

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Low luminosity at this energy reduces the physics reach

# Work on mitigations of L(E) with SB2009 during ILC2010

- Discussion of double rep rate was initiated ~month before the ILC2010

  this allowed achieving significant progress at LCWS10

- Doubling the rep rate (below ~125GeV/beam)
  - **BDS WG discussed implications with other Working Groups:**
    - DR => OK (new conceptual DR design was presented)
    - Sources => OK
    - Linac, HLRF, Cryogenics => OK
- FD optimized for ~250GeV CM
  - **Shorter FD reduce beam size in FD and increase collimation depth, reducing collimation related beam degradation**
  - **Will consider exchanging FD for low E operation or a more universal FD that can be retuned**

SLIDES FROM LCWS2010

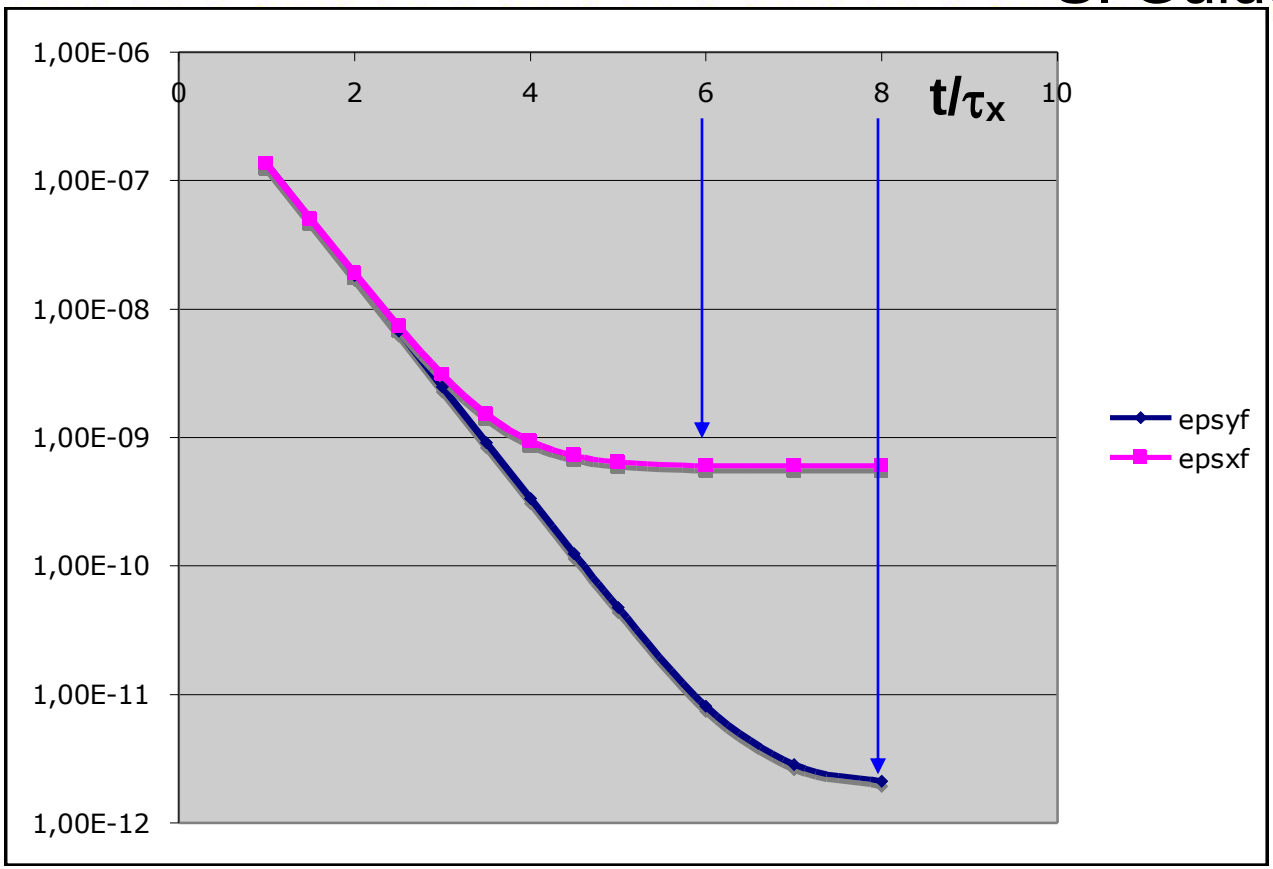
# Lumi(E) dependence in SB2009

- Factor determine shape of L(E) in SB2009
  - **Lower rep ( /2) rate below ~125GeV/beam**
  - **Collimation effects: increased beam degradation at lower E due to collimation wakes and due to limit (in X) on collimation depth**

- Understanding the above limitations, one can suggest mitigation solutions:
  - **1) Consider doubling the rep rate at lower energy**
  - **2) Consider Final Doublet optimized for 250GeV CM**

# Emittance damping

S. Guiducci (LNF)




8 damping times are needed for the vertical emittance

5 Hz ⇒ $\tau_x$ = 26 ms

10 Hz ⇒ $\tau_x$ = 13 ms

SLIDES FROM LCWS2010

# DR Parameters for 10 Hz Operation

S. Guiducci (LNF) et al

| | RDR | TILC08 | SB2009 | High Rep |
|---|---|---|---|---|
| Circumference (m) | 6695 | 6476 | 3238 | 3238 |
| Damping time $\tau_x$ (ms) | 25.7 | 21 | 24 | 13 |
| Emittance $\varepsilon_x$ (nm) | 0.51 | 0.48 | 0.53 | 0.57 |
| Emittance $\varepsilon_y$ (pm) | 2 | 2 | 2 | 2 |
| Energy loss/turn (MeV) | 8.7 | 10.3 | 4.4 | 8.4 |
| Energy spread | $1.3\times10^{-3}$ | $1.3\times10^{-3}$ | $1.2\times10^{-3}$ | $1.5\times10^{-3}$ |
| 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

DR (3.2km) at 10Hz is feasible

# Double rep rate: Sources

- Electron Source:
  - **doubling rep rate is not critical [Axel Brachmann, Tsunehiko Omori et al]**
- Positron Source:
  - **For SB2009 250b case there should be no issues**
    - For 250a, which is not a preferred solution, the most important consequence of the increased rep rate will be the increased average power on the positron target
    - Even for this case there is a hope that it can be managed, but need more detailed studies [Jim Clarke, Wei Gai, et al]

# Linac and double rep rate

- At lower gradient, considering the cryo load (which should not be exceeded) and the efficiency of rf power sources (their efficiency decreases with power) concluded, that at 125 GeV/beam one can work at 10Hz rep rate in the linac

- At 150GeV/beam one can work at 8Hz in the linac
  - **And this is possible only because the e+ source is at the end of the linac!**

Chris Adolphsen, et al

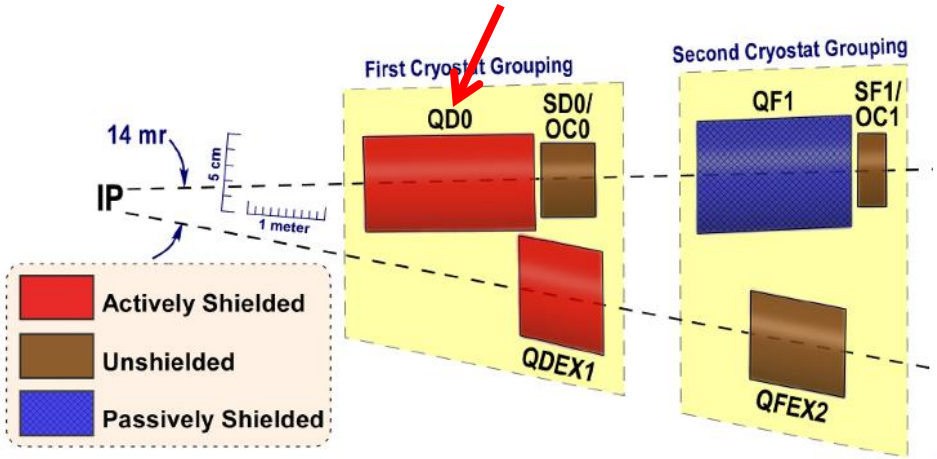
**=> SB2009 OK for linac rep rate 10 Hz for 125 GeV/beam & 8 Hz for 150 GeV/beam**

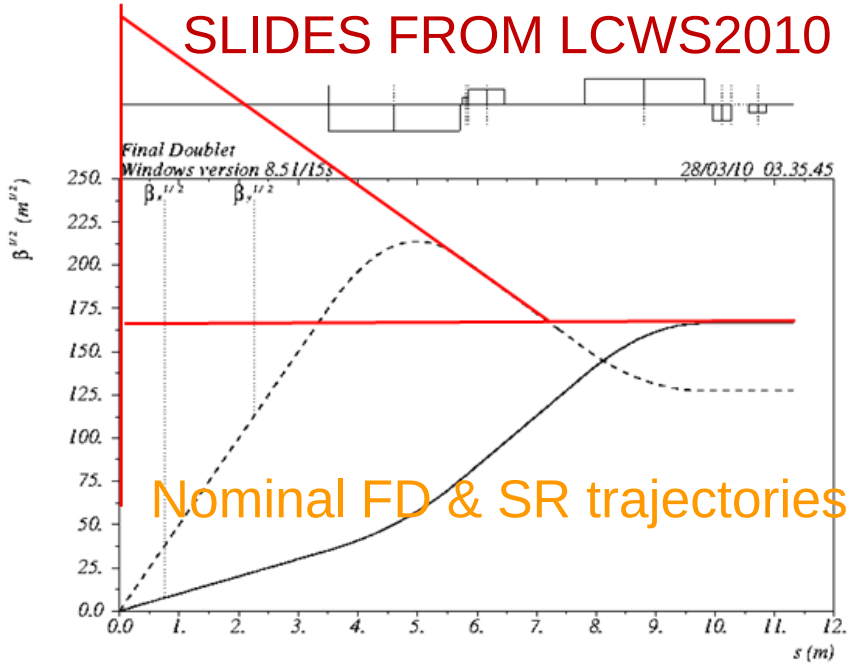
# FD for low E

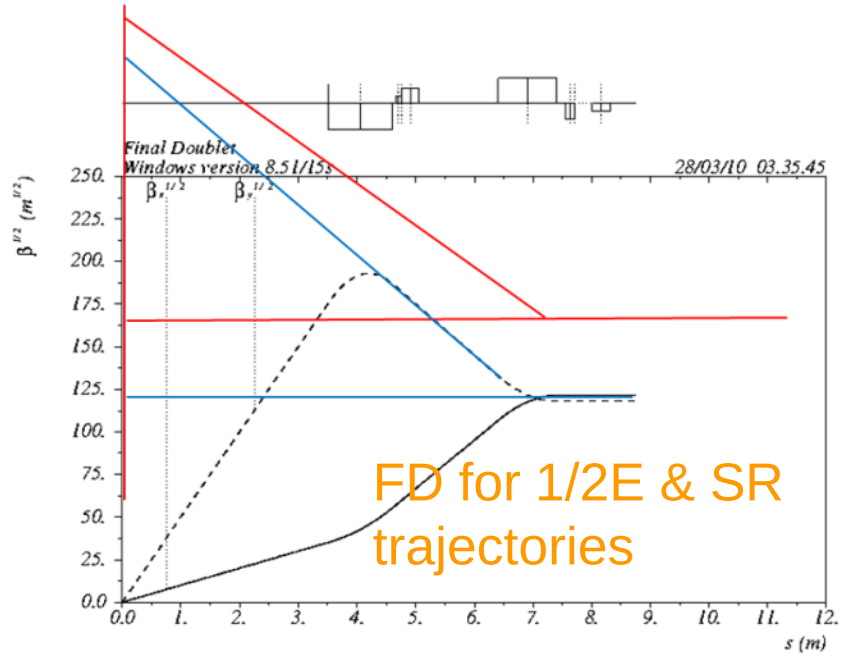
SLIDES FROM LCWS2010

**FD optimized for lower energy will allow increasing the collimation depth by ~10% in Y and by ~30% in X (Very tentative!)**

- One option would be to have a separate FD optimized for lower E, and then exchange it before going to nominal E
- Other option to be studied is to build a universal FD, that can be reconfigured for lower E configuration (may require splitting QD0 coil and placing sextupoles in the middle)



# Beam Parameters & mitigation

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| $\gamma ex$ ($*10^{-6}$) | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
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| $\beta x$ | 22 | 22 | 20 | 21 | 21 | 15 | 11 | 21 | 21 | 15 | 11 |
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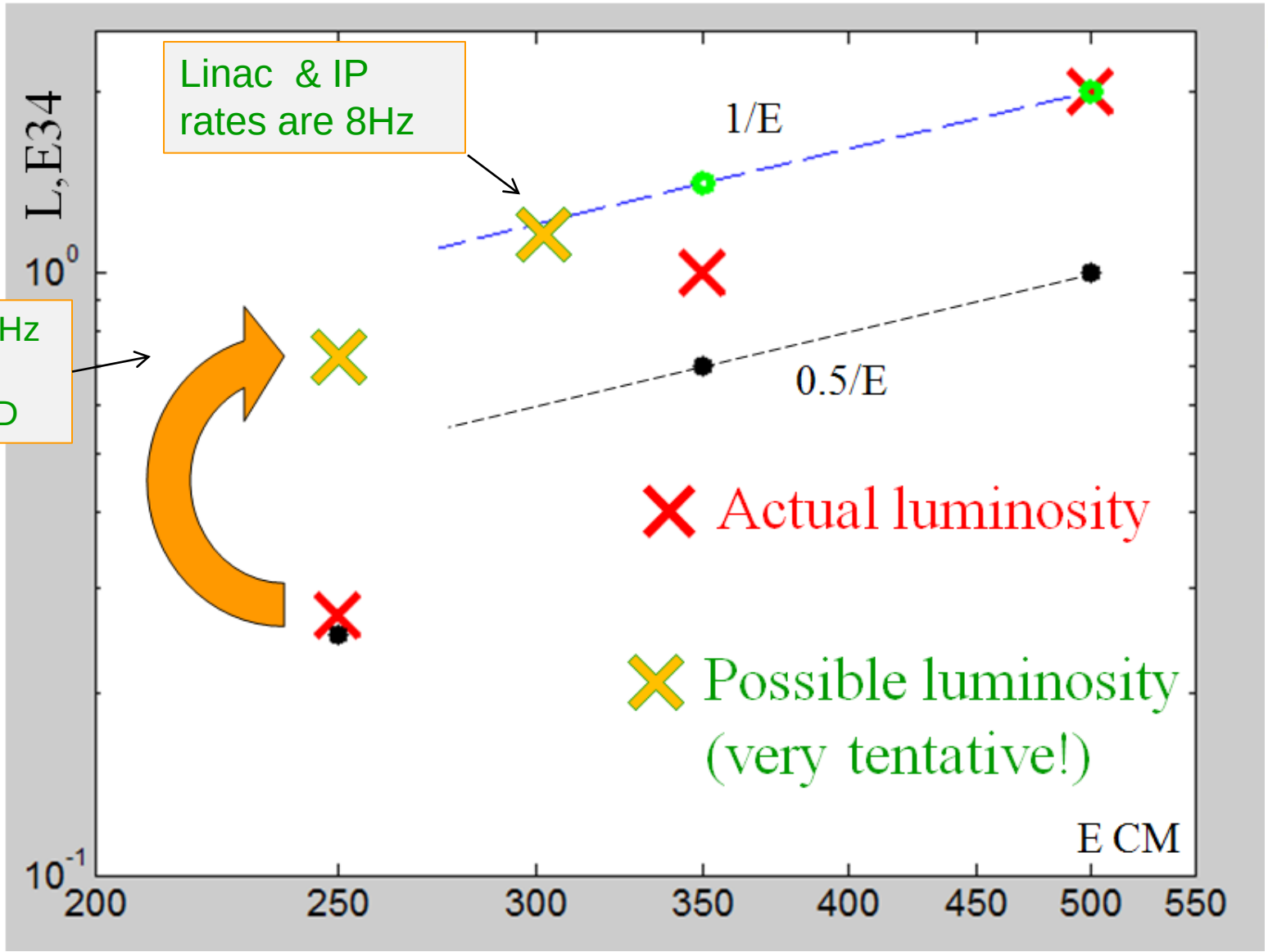
- Tentative! At 250 GeV CM the mitigations may give
  - *** 2 L due to double rep rate**
  - *** about 1.4 L due to FD optimized for low E**

# SB2009 Lumi


Linac & IP rates are 8Hz
Linac rate 10Hz (IP rate 5Hz) and special FD
1/E
0.5/E
Actual luminosity
Possible luminosity (very tentative!)
L,E34
E CM
$10^0$
$10^{-1}$
200
250
300
350
400
450
500
550

# Post LCWS10 developments

- Working group to evaluate various aspects of new parameter sets – led by PMs
- All (almost) questions resolved on the feasibility level
  - A new issue related to DR duty factor has been identified – under investigation
- Detailed design studies should follow

# New parameters based on the following assumptions

- **Starting point: parameters developed by the Physics Questions Committee (B. Foster, A. Seryi, J. Clarke, M. Harrison, D. Schulte, T. Tauchi) in December 2009.**
- **Take into account progress on 10Hz rep rate for low E achieved after LCWS10**
  - There are issues with DR duty cycle that are being studied, however assume that they will be solved
- **Assume that we will develop and use new universal FD that gives additional luminosity improvement (only) for 200 and 250 GeV energies**
- **Consider the following energies: 200, 250, 350, 500 GeV CM**
- **Assume single stage bunch compressor (min sigma_z=230um – will use 300um and consider 230 as an overhead or safety margin)**
- **Assume 10Hz and 1300 bunches**
- **Consider separately the cases with and without Travelling Focus**
- **Energy and rep rate:**

| | | | | | |
|---|---|---|---|---|---|
| E= | 200 | 250 | 350 | 500 | GeV CM |
| IP rep rate | 5 | 5 | 5 | 5 | Hz |
| Linac rate | 10 ( double pulsing ) | 10 | 5 | 5 | Hz |

# BAW-2 Themes

| | | | | | | | | *upgrade* |
|---|---|---|---|---|---|---|---|---|
| **Centre-of-mass energy** | $E_{cm}$ | **GeV** | **200** | **230** | **250** | **350** | **500** | **1000** |
| **Luminosity** | $L$ | $\times 10^{34}$ cm$^{-2}$s$^{-2}$ | **0.5** | **0.5** | **0.7** | **0.8** | **1.5** | **2.8** |
| **Luminosity (Travelling Focus)** | $L_{TF}$ | $\times 10^{34}$ cm$^{-2}$s$^{-2}$ | **0.5** | | **0.8** | **1.0** | **2.0** | |
| Number of bunches | $n_b$ | | 1312 | 1312 | 1312 | 1312 | 1312 | 2625 |
| Collision rate | $f_{rep}$ | Hz | 5 | 5 | 5 | 5 | 5 | 4 |
| Electron linac rate | $f_{linac}$ | Hz | 10 | 10 | 10 | 5 | 5 | 4 |
| Positron bunch population | $N_+$ | $\times 10^{10}$ | 2 | 2 | 2 | 2 | 2 | 2 |

Formally agreed parameter sets across energy range
ILC-EDMS document ID 925325

http://ilc-edmsdirect.desy.de/ilc-edmsdirect/document.jsp?edmsid=*925325

# Conclusion

- The RDR (2007) focused on nominal energy
- Parameter set that maintains the physics reach and optimizes the cost/performance has been developed
- Future studies
  - **Design of the universal final doublet**
  - **Optimization of collimation depth**
  - **Study of FF tuning with needed beta***
  - **Detailed beam-beam studies**
  - **Damping ring design**
  - **…**