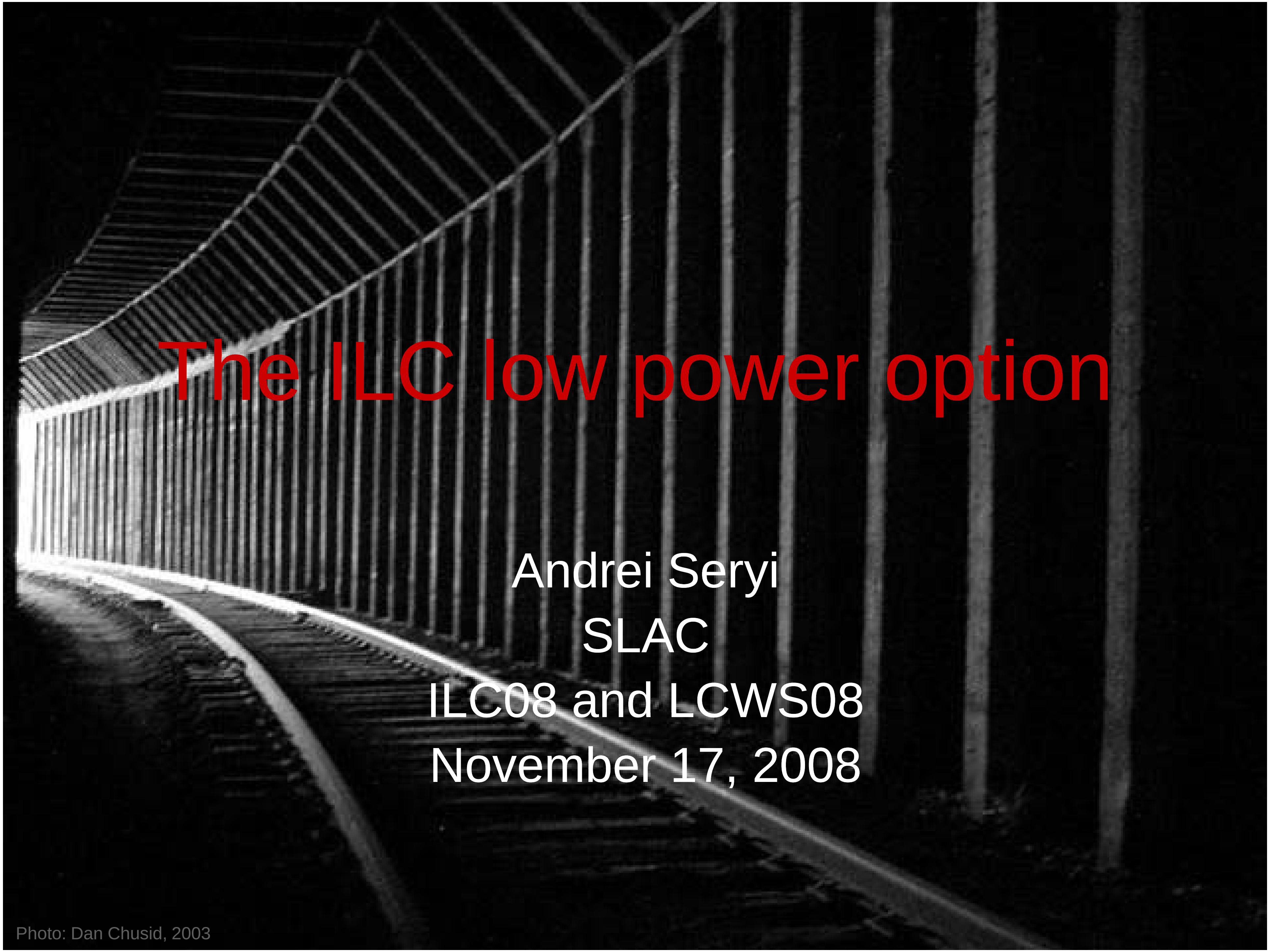

Photo: Dan Chusid, 2003

The ILC low power option

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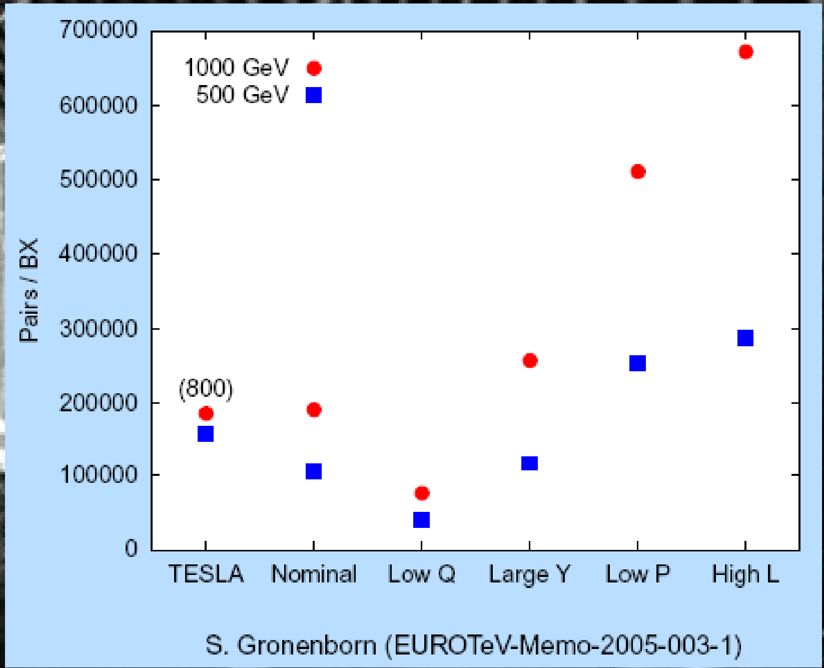
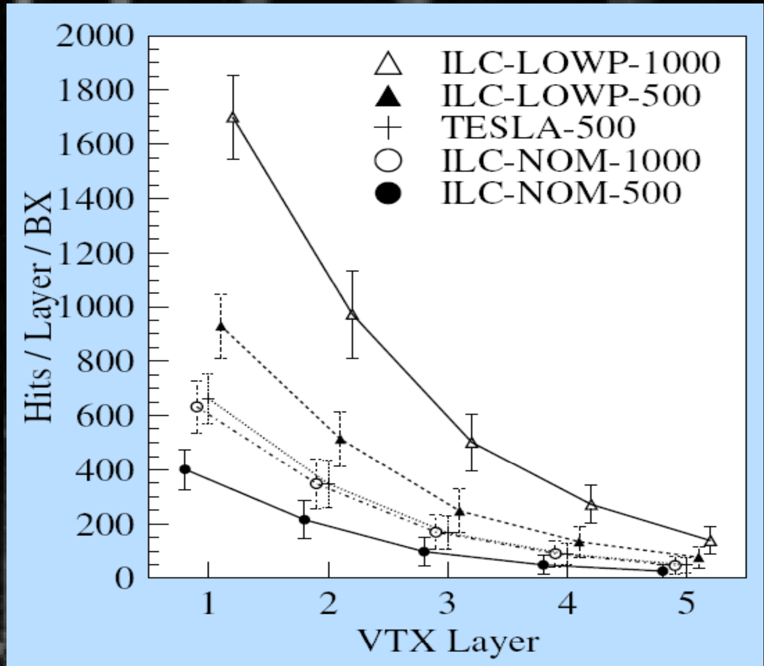
SLAC

ILC08 and LCWS08
November 17, 2008

Low P option in RDR

- The RDR "low power" option may be a **machine** "cost saving" set but it is not a favorite set for detectors:





- Improved Low P may require tighter IP focusing, and use of "travelling focus" [V.Balakin, 1990]

Motivation

- Reduction of beam power => potential cost reduction
  - reduced cryo system; smaller diameter damping rings, etc.
- Application of special techniques to keep luminosity and reduce beamstrahlung
  - travelling focus
  - shaping of longitudinal profile of the bunch
- Reduction of peak luminosity from 2E34 to 1E34 may also be considered => even higher cost saving
  - Oide argues that high peak luminosity is not necessarily optimal from the integrated luminosity point of view
  - Lower peak L~1E34 may give the same integr. L? (to be studied)

Cases considered

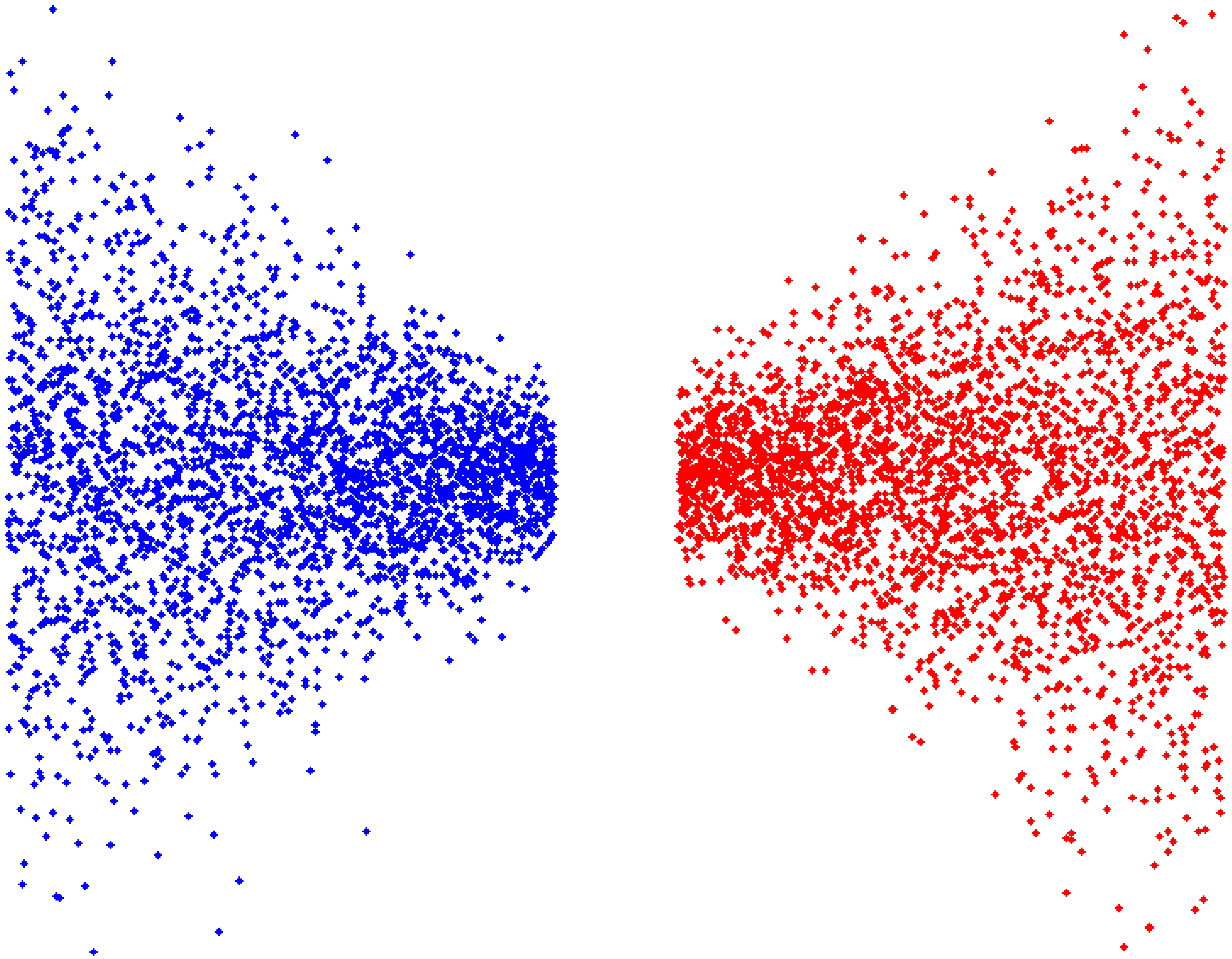
- RDR cases
  - 1: Nominal RDR
  - 2: Low Power RDR
- Travelling focus cases:
  - 3: similar as “2”, but longer σ_z
  - 30: similar as “3”, FLAT Z distribution, lower β_y
  - 4: even Lower P, FLAT Z, long σ_z
  - 5: FLAT Z, not so long σ_z
- Analytical predictions not valid – use Guinea-Pig code

Candidates for new Low P

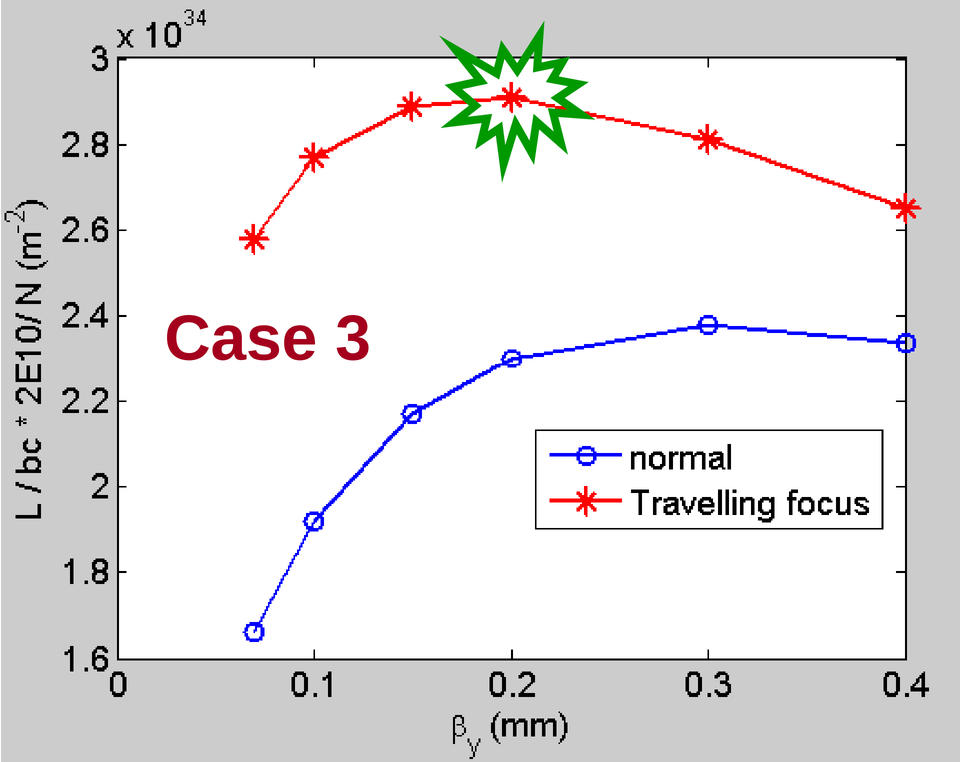
	Nom. RDR	Low P RDR	new Low P	new Low P	new Low P	new Low P
Case ID	**1**	**2**	**3**	**30**	**4**	**5**
E CM (GeV)	500	500	500	500	500	500
N	2.0E+10	2.0E+10	2.0E+10	2.0E+10	2.0E+10	2.0E+10
n_b	2625	1320	1320	1320	**1105**	1320
F (Hz)	5	5	5	5	5	5
P_b (MW)	**10.5**	**5.3**	**5.3**	**5.3**	**4.4**	**5.3**
$\gamma\varepsilon_X$ (m)	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05
$\gamma\varepsilon_Y$ (m)	4.0E-08	3.6E-08	3.6E-08	3.6E-08	**3.0E-08**	**3.0E-08**
βx (m)	2.0E-02	1.1E-02	1.1E-02	1.1E-02	**7.0E-03**	**1.5E-02**
βy (m)	4.0E-04	2.0E-04	2.0E-04	**1.0E-04**	**1.0E-04**	**1.0E-04**
Travelling focus	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Z-distribution *	Gauss	Gauss	Gauss	**Flat**	**Flat**	**Flat**
σ_x (m)	6.39E-07	4.74E-07	4.74E-07	4.74E-07	3.78E-07	5.54E-07
σ_y (m)	5.7E-09	3.8E-09	3.8E-09	2.7E-09	2.5E-09	2.5E-09
σ_z (m)	3.0E-04	2.0E-04	**3.0E-04**	3.0E-04	**5.0E-04**	**2.0E-04**
Guinea-Pig $\delta E/E$	**0.023**	**0.045**	**0.036**	0.036	0.039	0.038
Guinea-Pig L ($cm^{-2}s^{-1}$)	**2.02E+34**	**1.86E+34**	**1.92E+34**	**1.98E+34**	**2.00E+34**	**2.02E+34**
Guinea-Pig Lumi in 1%	1.50E+34	1.09E+34	1.18E+34	1.17E+34	1.06E+34	1.24E+34

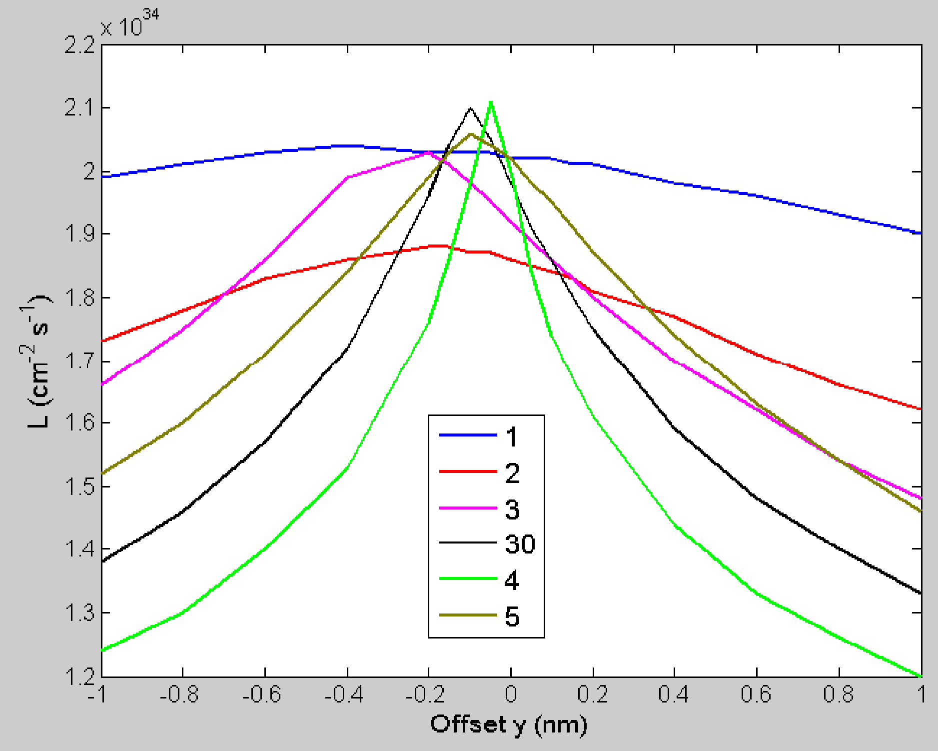
*for flat z distribution the full bunch length is $\sigma_z*2*3^{1/2}$

Case 4: even Low P, TRAV_FOCUS, FLAT_Z



Case 3 Low P & offset sensitivity

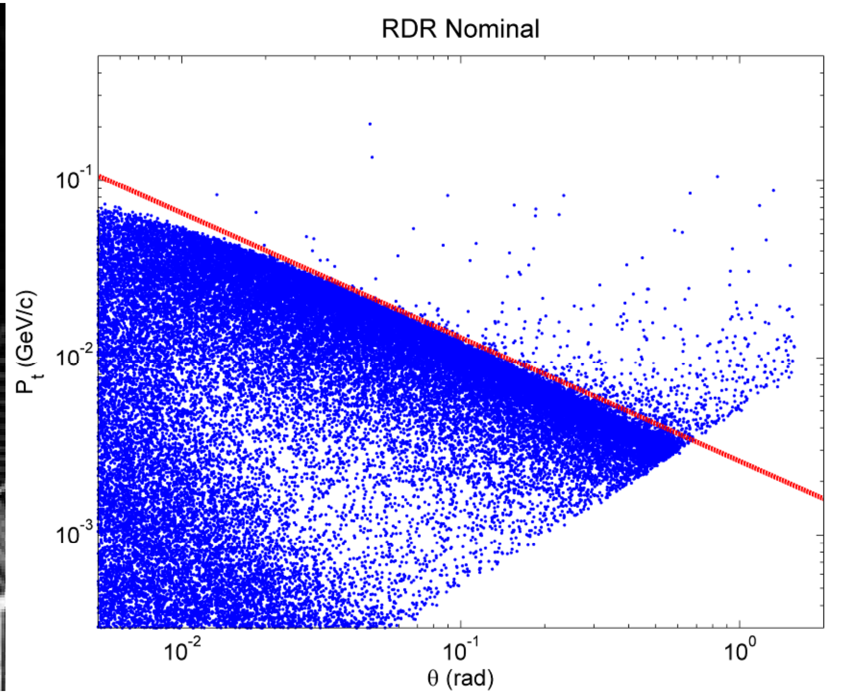


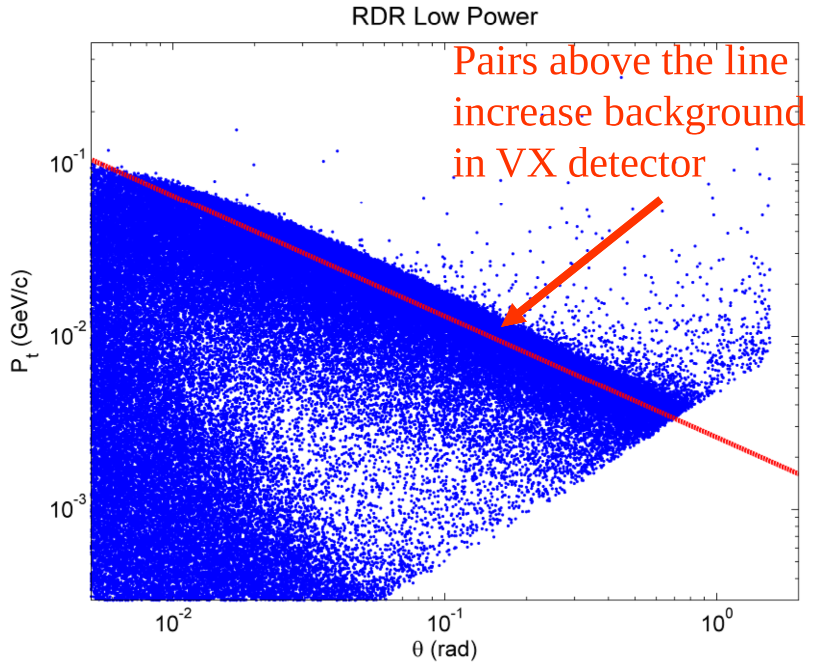


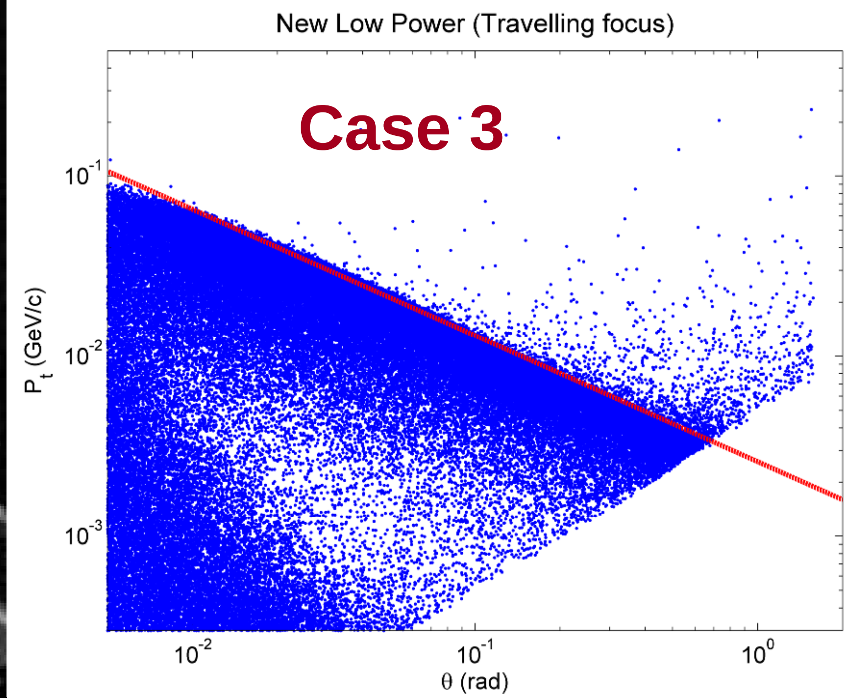
- Luminosity kept by tighter focusing ($\beta^*_y<\sigma_z$) while the moving focus and beam-beam force keep beam focusing each other
- Higher disruption needed, which produces higher sensitivity to offset of the beams
- Operation of intratrain luminosity optimization is more challenging

e+e- pairs

- Edge of pairs distribution in θ-P_t important for VX background
- RDR Low P: edge higher=> unfavorable for background
- New Low P: edge location similar as RDR Nominal







Need to be verified by full simulations

Creating travelling focus, 2 ways

- Small (~%) uncompensated chromaticity and E-z correlation
  - Need σ_z=k L* δ_E
    - where k is relative amount of uncompensated chromaticity
    - and δ_E is 2-3 times > incoherent spread in the bunch
  - E.g. δ_E = 0.3%, k=1.5%, L^*_{eff}=6m
- Transverse deflecting cavity giving z-x correlation in one of FF sextupoles
  - That gives z-correlated focusing
    - parameters to be figured out

Couple more peculiar cases…

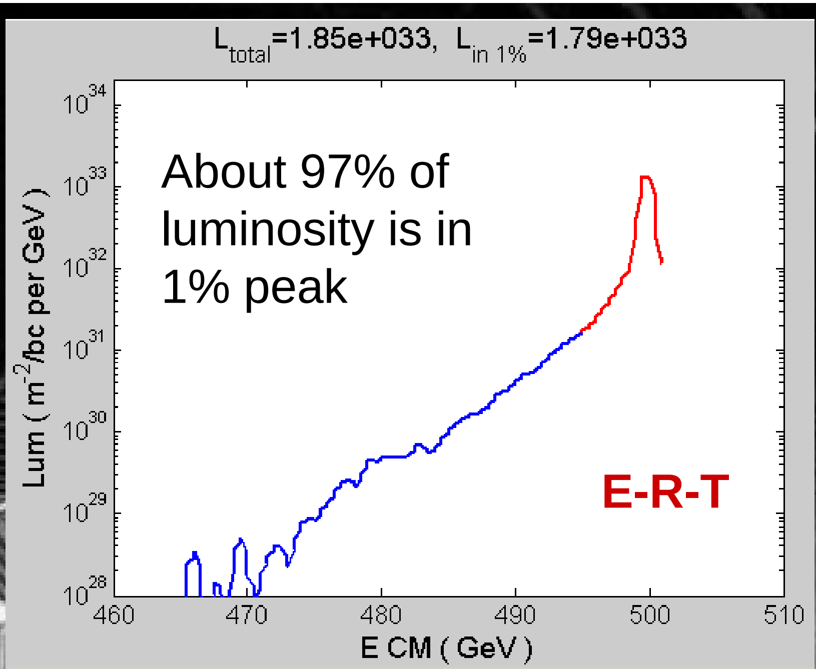
- Although this may have only academic interest…
- There are parameter cases which give L~1E34, and have extremely low beamstrahlung energy spread…
- Two examples are shown below
- You will see their possible applications in a moment…

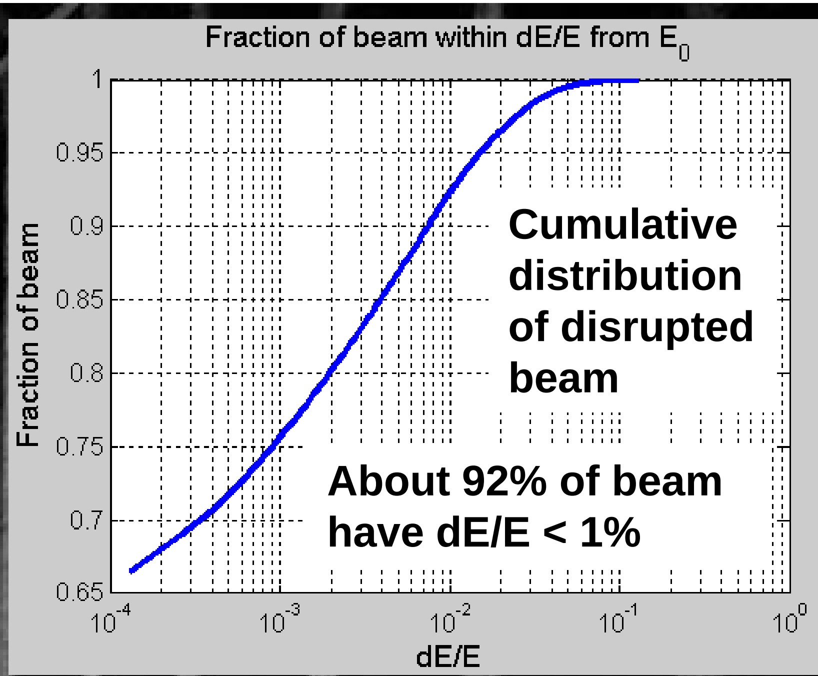
	Nominal RDR	E-R-N	E-R-T
E CM (GeV)	500	500	500
N	2.0E+10	**5.0E+09**	**5.0E+09**
n_b	2625	**15000**	**11000**
Tsep (ns)	369.2	90.0	90.0
Iave in train (A)	0.0087	0.0089	0.0089
f_{rep}(Hz)	5	5	5
P_b (MW)	**10.5**	**15.0**	**11.0**
$\gamma\varepsilon_X$ (m)	1.0E-05	2.0E-06	4.0E-06
$\gamma\varepsilon_Y$ (m)	4.0E-08	2.0E-08	2.0E-08
βx (m)	2.0E-02	4.0E-02	2.0E-02
βy (m)	4.0E-04	1.0E-03	4.0E-04
σ_x (m)	6.39E-07	4.04E-07	4.04E-07
σ_y (m)	5.7E-09	6.4E-09	4.0E-09
σ_z (m)	3.0E-04	3.0E-04	6.0E-04
Dx	0.17	0.11	0.21
Dy	19.0	6.7	21.2
Uave	0.047	0.018	0.009
δ_B	**0.023**	**0.004**	**0.002**
P_Beamstrahlung (MW)	0.24	0.060	0.024
ngamma	1.29	0.52	0.53
Hd	1.70	1.84	**1.53**
Geom Lumi (cm-2 s-1)	1.14E+34	5.77E+33	6.69E+33
Luminosity (cm-2 s-1)	**1.95E+34**	**1.06E+34**	**1.02E+34**

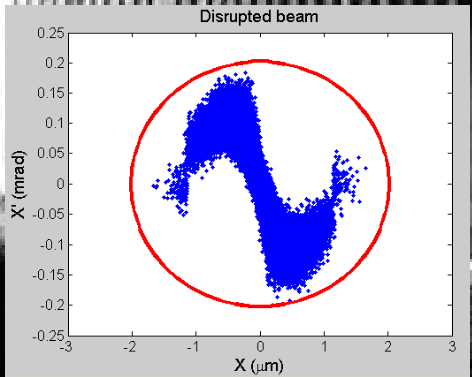
- Parameter sets with very low beamstrahlung
  - N: normal
  - T: travelling focus (Gauss z distr.)
- Further optimization is possible

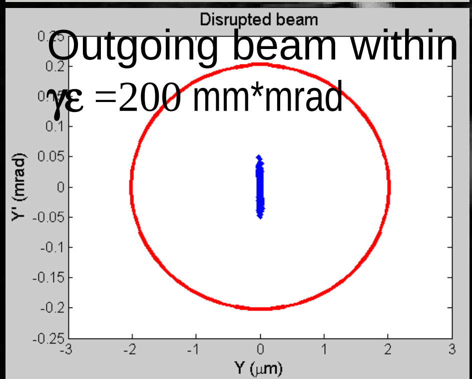
Low beamstrahlung

Analytical, except:
Calculated with Guinea-pig







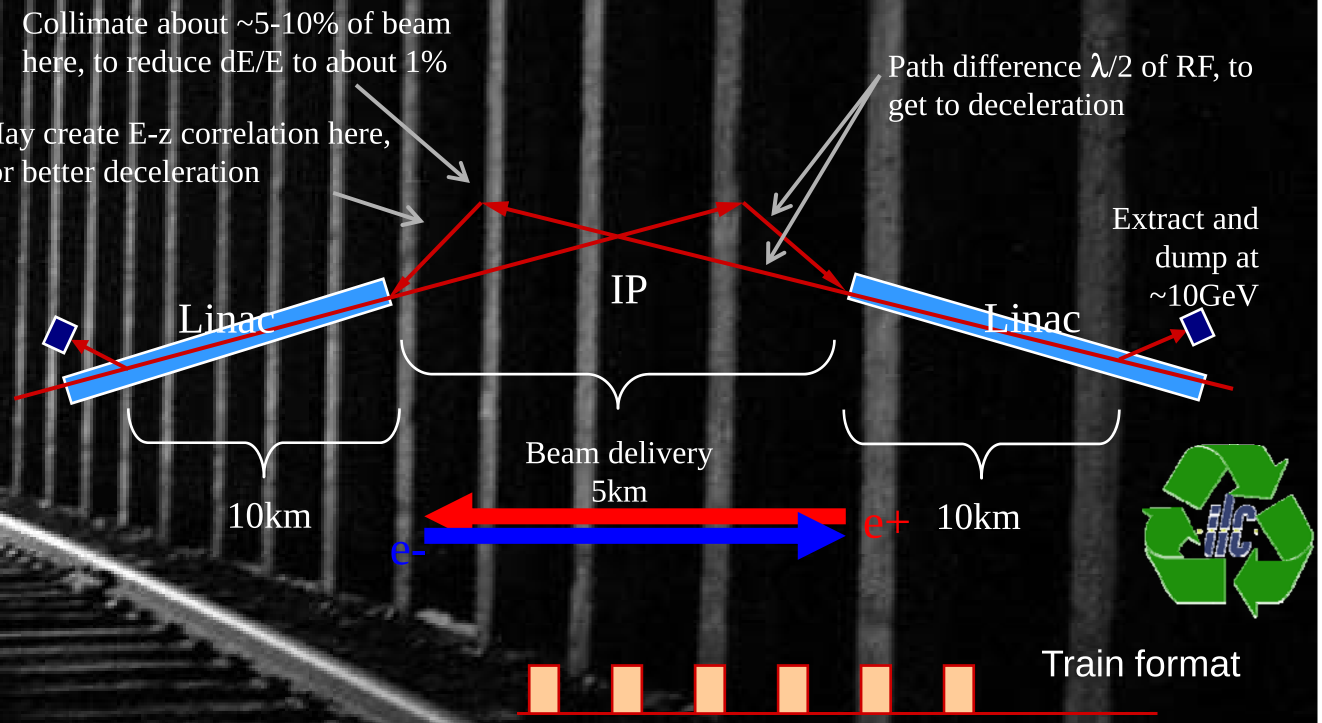


Outgoing beam within $\gamma\varepsilon$ =200 mm*mrad

- 92% of the beam can be decelerated from 250GeV/beam down to 10GeV
  - Where its dE/E will be 25%
  - Emittance do not limit deceleration
- => beam and/or its energy can be recycled
  - recover major part of RF energy, dump the beam at low energy or reuse it
  - environmentally friendly: electricity and radiation

Beam & Energy recycling?

- Certainly not very serious at the moment
- If it were possible, one would need to avoid collision of bunches in the linac, e.g. like this:

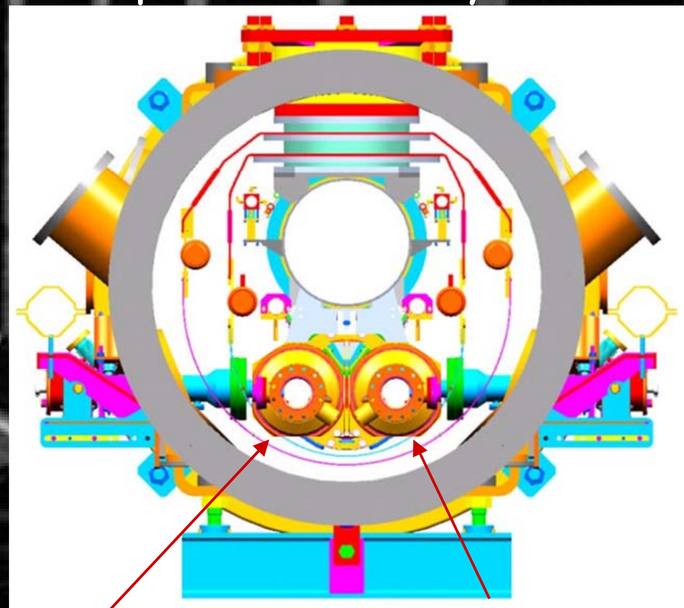


Use mini-trains with gaps to avoid collisions in the linac:
→ length of mini-trains equal to full length of beam delivery
→ gap between mini-trains = 2* linac length to extraction point + BDS length

Beam & Energy recycling?

- The previous slide, where recycled beam decelerated in the same linac, require longer RF pulse (more cryo loss), possibly redesign of cavities to reduce HOMs, etc.
- Alternative approach is to make dual aperture cryomodule?
  - Cryomodule more expensive, but not factor of two
  - No need for longer train and gaps

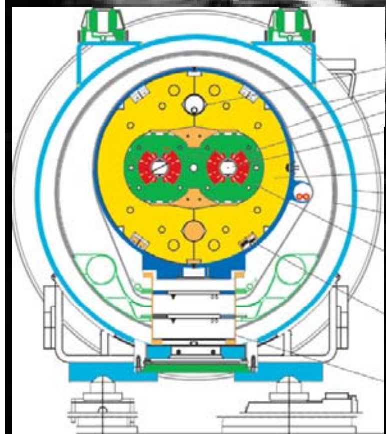
Dual aperture ILC cryomodule?



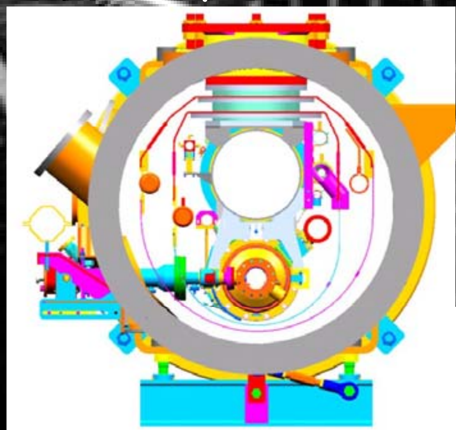
For acceleration

For deceleration

LHC, dual bore



ILC cryomodule



Beam & Energy recycling?

- For ILC, beam and energy recycling may likely be very difficult or practically impossible…
- The approach to parameter optimization, resulted in very low δ_B, is worth applying to multi-TeV case, to study if there are possibility to reduce beamstrahlung
- Acknowledgement of comments and critics on beam/energy recycling: Chris Adolphsen, Greg Loew, Nikolai Solyak, Slava Yakovlev

Conclusion

- New low P parameter set
  - Gives 2E34 with ½ of beam power
  - Better for background than RDR Low P
- Travelling focus helps recovering luminosity while keeping lower beamstrahlung δ_B and Y and avoiding the need to have short bunches
  - Rely on tighter focusing
  - Have higher sensitivity to beam offset at IP
- Need to be evaluated by full background simulations
- Will be further discussed within ILC “minimal machine” study