Report on the AAP Review

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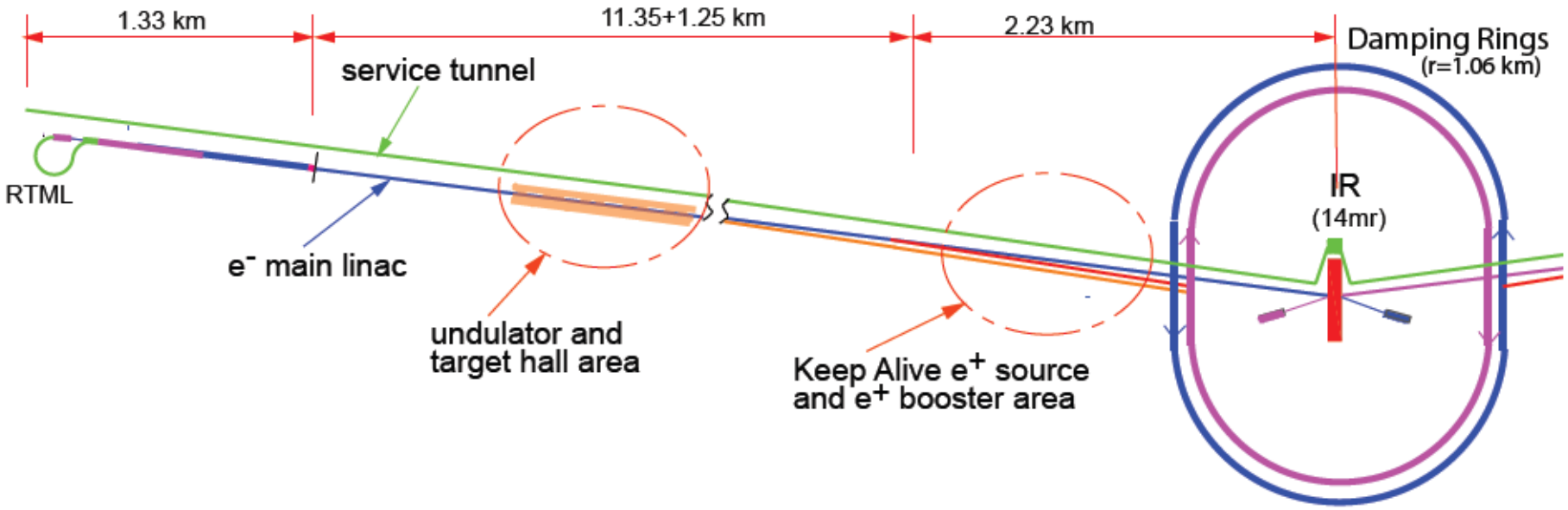
Introduction

- The AAP Review was held 6th to 8th January 2010 at Oxford, UK
- **Participants:**
- C Damerell, J Dorfan, E Elsen, T Himel, M Kuriki, K Oide**, H Padamsee**,T Raubenheimer, D Schulte, W Willis, T Tajima, M Uesaka, F Zimmermann**.
- (**) by phone, part time
- The review dealt exclusively with the Strawman Baseline Proposal SB2009
- The Proposal was presented in the form of a possible new baseline, comprising a number of items that while somewhat interconnected could all be adopted at one time.

RDR Reminder

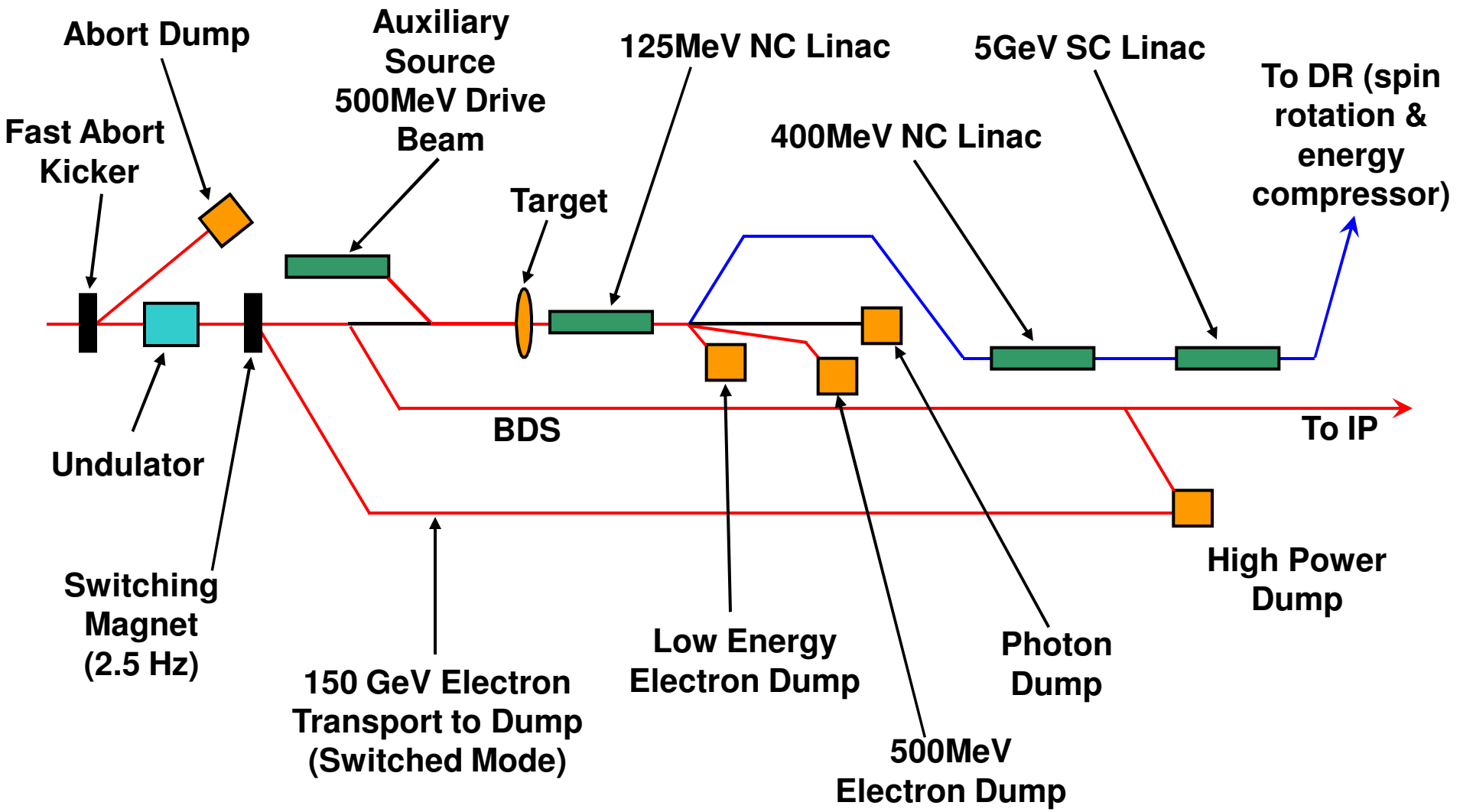
- Undulator at fixed energy of 150 GeV in main linac (in a chicane section)
- Separate Keep Alive Source generated ~10% intensity



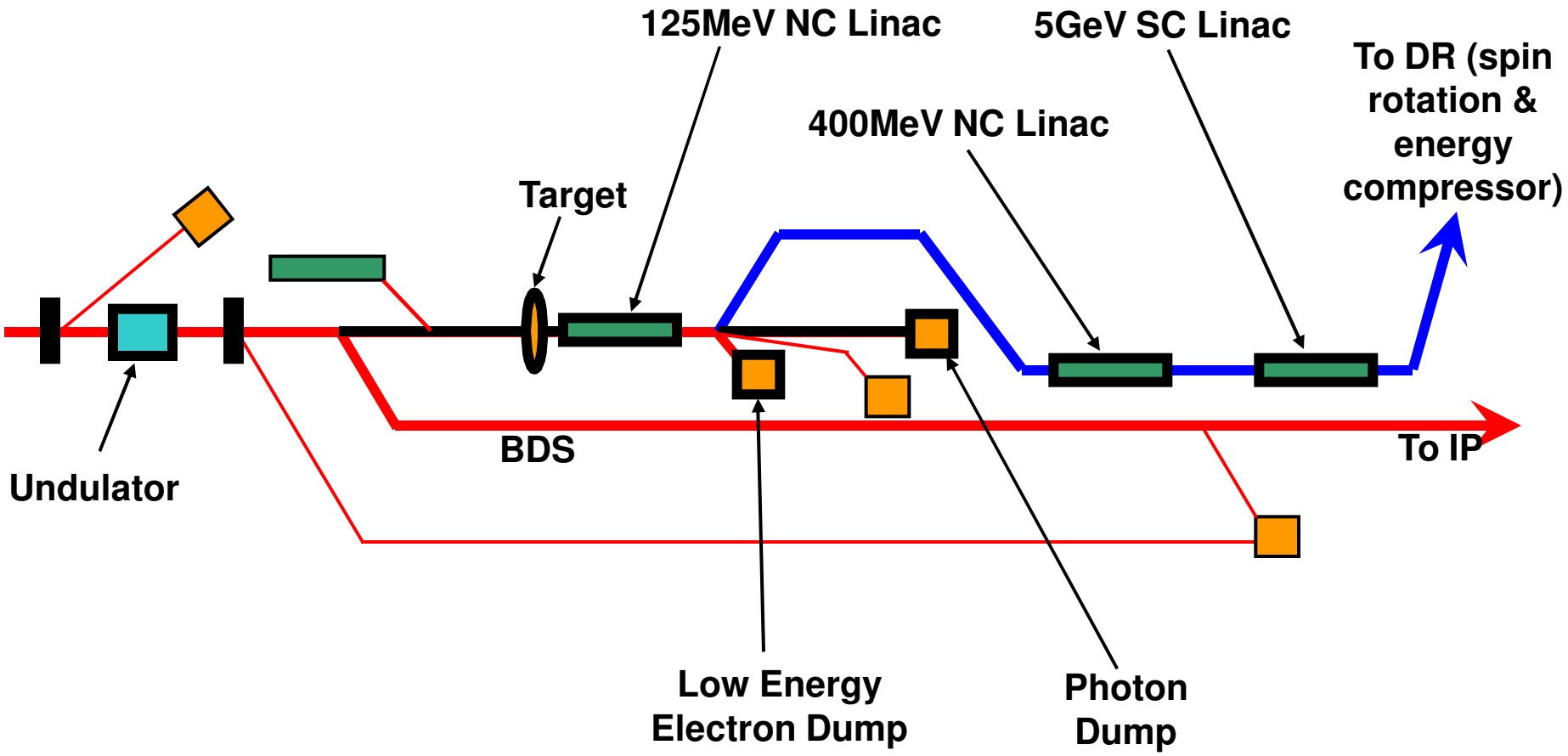
SB2009

- Undulator moved to end of main linac (on-axis)
- Flux concentrator replaced by simpler quarter wave transformer to reduce risk
  - **Independent of change in undulator location**
  - **Reduces positron capture so need more photons on target (longer undulator)**
- Keep Alive Source (~10% intensity) replaced by Auxiliary Source (few % intensity) which now uses same target, capture magnet, linacs, etc as main positron source

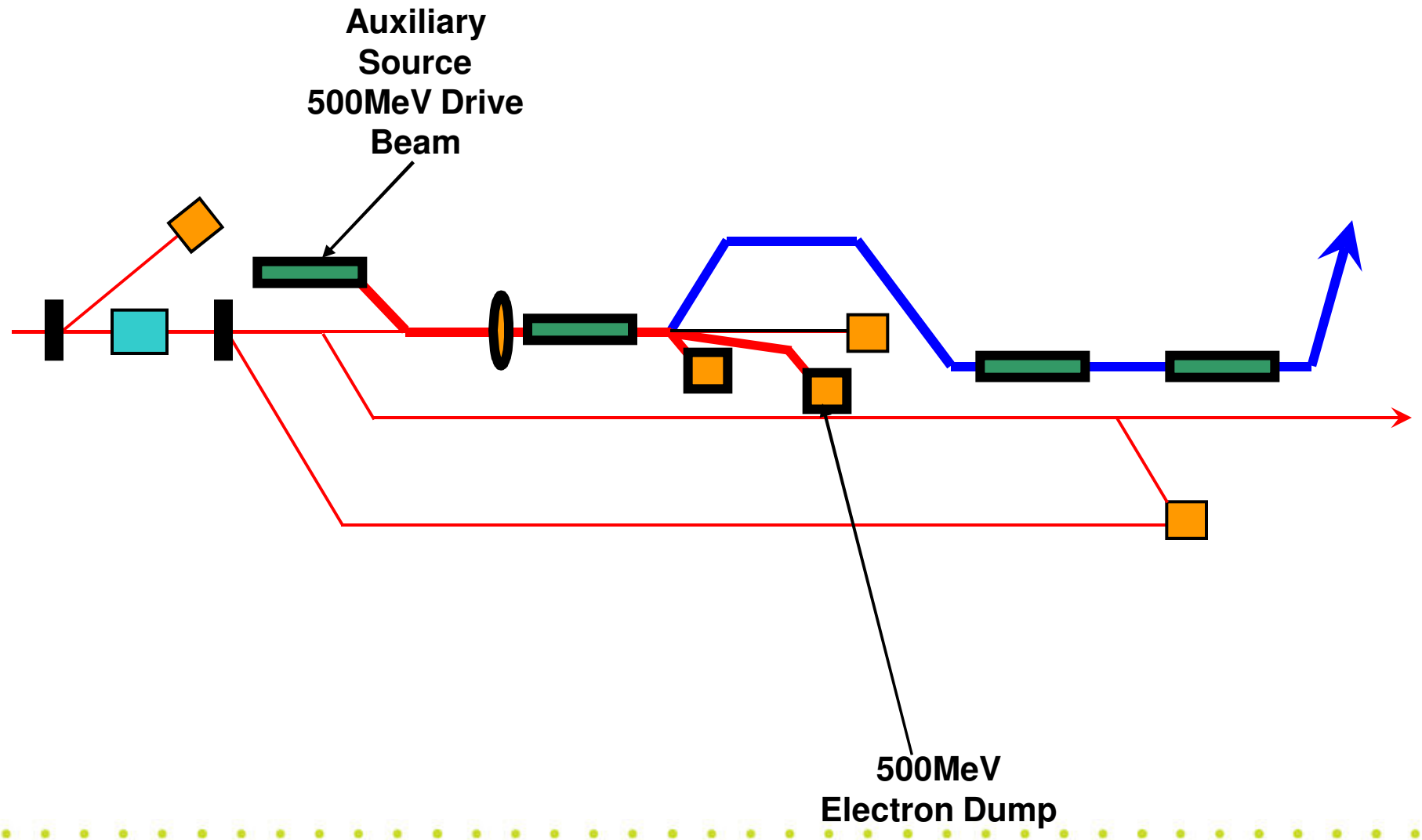
Schematic Layout



Normal Operation



Auxiliary Source Mode



Consequences of SB2009 (1)

- Machine protection systems for the smaller energy acceptance undulator and BDS beamlines can be combined into a single system, located immediately downstream of the main linac
- The undulator source can be better integrated into the upstream area of the BDS, where more tunnel space and more freedom of lattice design are available than in the main linac.
- All sources of restricted energy bandwidth are localised in the central region, leaving both the main SCRF linacs as systems with high energy bandwidth.

Consequences of SB2009 (2)

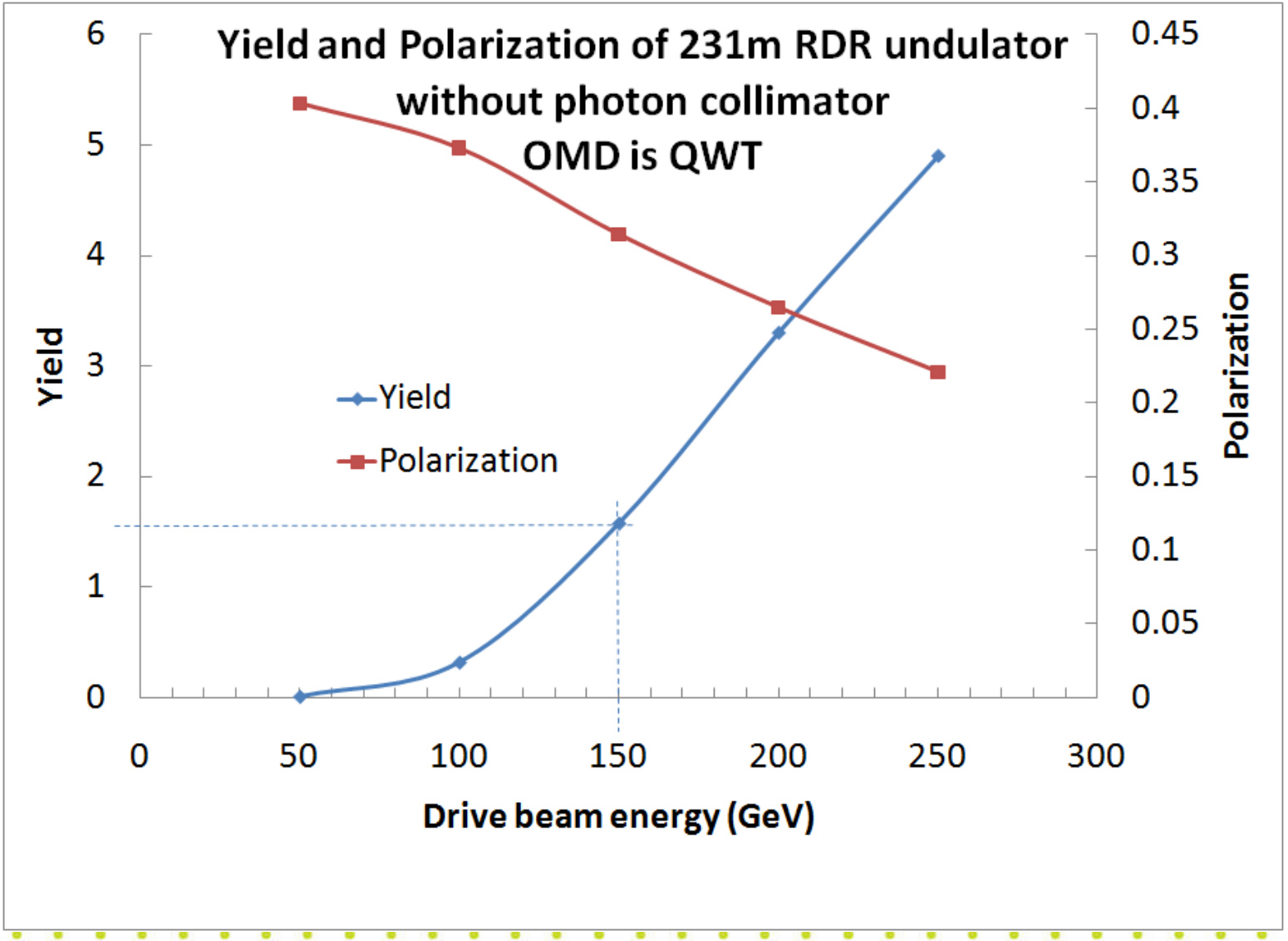
- All the high-radiation environment systems located within the central area
  - **expected to be beneficial for certain host sites (radiation safety and environmental impact).**
- A large energy overhead is available to drive the undulator source, which allows operational margin for the early commissioning in the event that the maximum-performance of the main linacs system is not achieved
- The energy of the electron beam passing though the undulator will vary with the required centre-of-mass operation

Consequences of SB2009 (3)

- Adoption of Quarter Wave Transformer reduces project risk at expense of longer undulator
- The Auxiliary Source removes the need for replication of many systems that were previously used by the Keep Alive Source (Target, Capture Magnet, Linacs, Remote Handling, etc)
- Long low energy transfer line to DR no longer needed

Parameter	RDR	SB2009	Units
Positrons per bunch at the IP	2×10^{10}	1 to 2×10^{10} (see Figure 4.3.3 for details)	
Bunches per pulse	2625	1312	
Pulse repetition rate	5	5 (125 to 250GeV) 2.5 (50 to 125GeV)	Hz
Positron energy (DR Injection)	5	5	GeV
DR transverse acceptance	0.09	0.09	m-rad
DR energy acceptance	±0.5	±0.5	%
Electron drive beam energy	150	125 to 250	GeV
Electron energy loss in undulator	3	0.5 to 4.9 (see Figure 4.3.4 for details)	GeV
Required additional electron linac overhead	3	4.1	GeV
Undulator period	11.5	11.5	mm
Undulator strength	0.92	0.92	
Active undulator length	147 (210 after polarisation upgrade)	231 (maximum, not all used when >150GeV)	m
Field on axis	0.86	0.86	T
Beam aperture	5.85	5.85	mm
Photon Energy (1^{st} harmonic)	10	1.1 (50 GeV) to 28 (250 GeV)	MeV
Photon beam power	131	102 at 150 GeV (less at all other energies)	kW
Target material	Ti – 6%Al – 4%V	Ti – 6%Al – 4%V	
Target thickness	14	14	mm
Target power adsorption	8	8	%

Positron Yield



High Energy Operation

- Beyond 150 GeV, the yield increases quite significantly, reaching a value of ~5 at a beam energy of 250 GeV
- In practice, some sections of the undulator will be switched off in order to bring the yield down towards 1.5
  - **inherently large safety margin at high energy**

Polarisation

- In RDR needed a simple upgrade (undulator length increased from 147 to 210m and addition of photon collimation) of positron source to achieve 60%
- SB2009 could upgrade in the same way but then undulator so long that photon powers become worrying and electron energy loss very high
- A better upgrade path is to replace the QWT by a flux concentrator (plus a photon collimator)
- Basically end up with similar system as RDR just in different location
  - **Disruption during upgrade would be minimal**

TDP2 (1)

- Main area of risk for the SB2009 is the target. The adoption of the QWT increases the length of the undulator (similar length as RDR polarisation upgrade length) and this enhances the peak photon beam power on the target
- The reduction in the number of bunches by a factor of two reduces the average power on the target, which effectively **increases the performance risk margin**
- The RDR target issues still remain to be resolved and the solutions validated
  - **pressure shock wave impact**
  - **the eddy current effect (an experiment is ongoing)**
  - **rotating vacuum seals to be confirmed suitable**

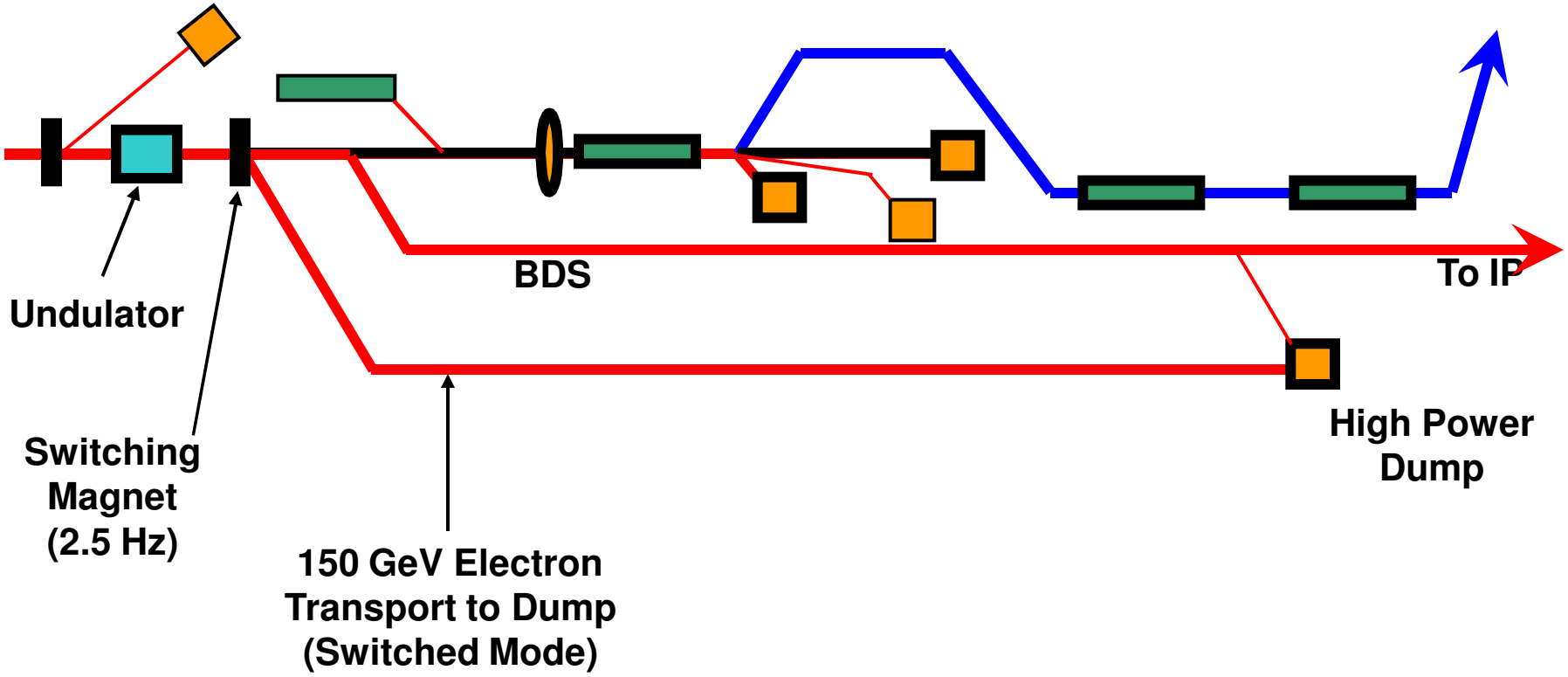
TDP2 (2)

- An SB2009-specific issue is the performance of the target when used as the Auxiliary Source in conjunction with a 500 MeV electron beam
- The performance of the source with realistic undulator magnets is planned for TDP 2
  - **Two full-length undulators have been constructed and tested**
  - **Use measurements to evaluate the actual spectral output from these devices.**
- A beam test with a full-scale undulator cryomodule would be desirable to check for unexpected issues, such as vessel heating, as well as confirm the photon spectrum.
- These are general issues with the undulator source, and not specific to SB2009

TDP2 (3)

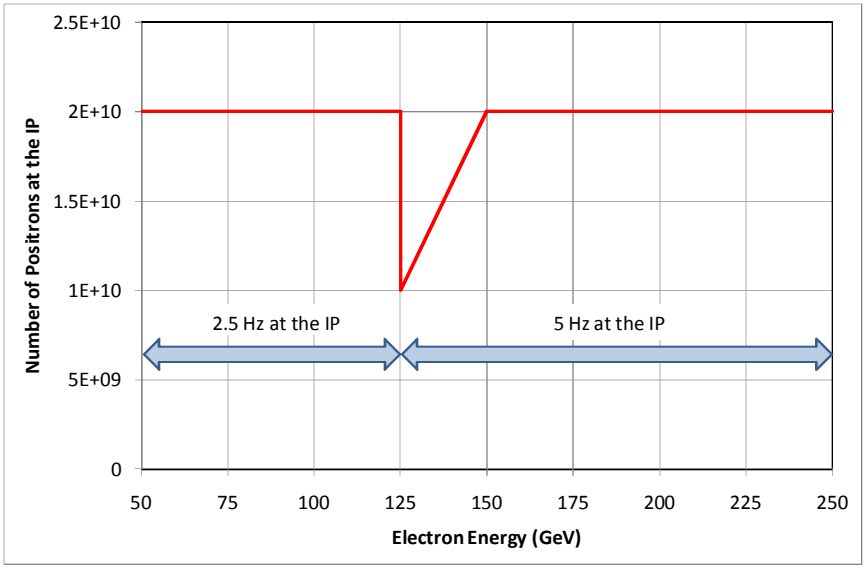
- Since the best route to polarised positrons is through the flux concentrator, this device should continue to be studied. A feasible solution is still to be generated, although the latest findings are encouraging. This issue is not SB2009 specific.
- The remote handling unit still needs careful design and the operating scenarios need to be assessed in more detail. This issue is not SB2009 specific.

Switched Mode

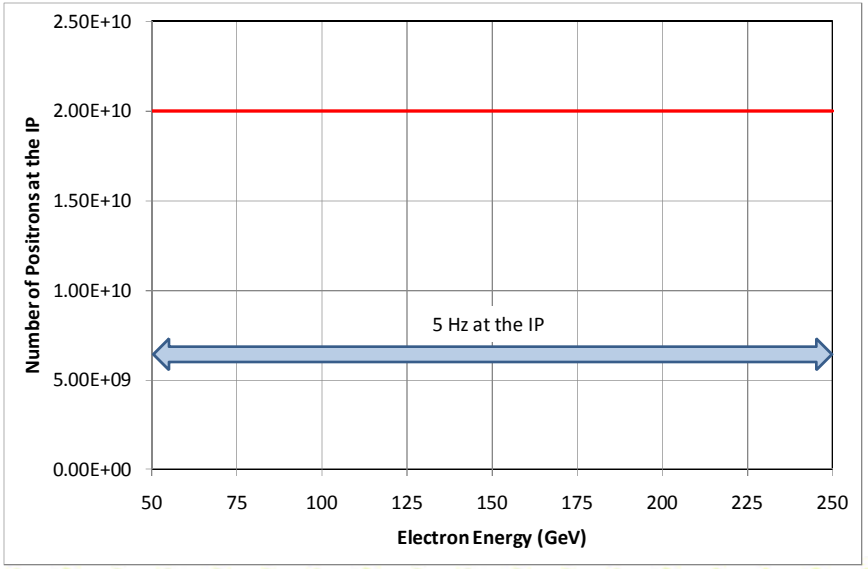


Number of Positrons per Bunch

SB2009



RDR



Energy Spread Assumptions

- Energy spread at the entrance to the main linac is 1.5% at 15 GeV for RDR and 1.08% at 15GeV for SB2009 (N Solyak)
- No growth due to linac etc
- In RDR case e+ are generated by e- at 150GeV
  - **e- are either accelerated or decellerated after the undulator to achieve their required energy at the IP**
- In SB2009, energy of e- is variable in the undulator
  - **125 to 250GeV @ 5Hz operation or**
  - **150 GeV @ 2.5Hz operation**
  - **Length of undulator is varied (modules are switched on/off) to keep yield at 1.5e+/e-**

Positron Energy Spread

- e+ energy spread is **independent** of the source (set by DR & RTML)
  - **Scales as inverse of IP energy**
  - **RDR and SB2009 are different**

	RDR	SB2009
Positron Energy at the IP (GeV)	Relative Positron Energy Spread (%)	Relative Positron Energy Spread (%)
50	0.450	0.324
75	0.300	0.216
100	0.225	0.162
125	0.180	0.130
150	0.150	0.108
175	0.129	0.093
200	0.113	0.081
225	0.100	0.072
250	0.090	0.065

Electron energy spread

- When e^- emit SR in undulator energy spread is **increased**
- The SR induced contribution is added in quadrature to inherent energy spread

RDR

Electron Energy at the IP (GeV)	Relative Electron Energy Spread (%)
50	0.679
75	0.453
100	0.340
125	0.272
150	0.226
175	0.194
200	0.170
225	0.151
250	0.136

Electron energy spread

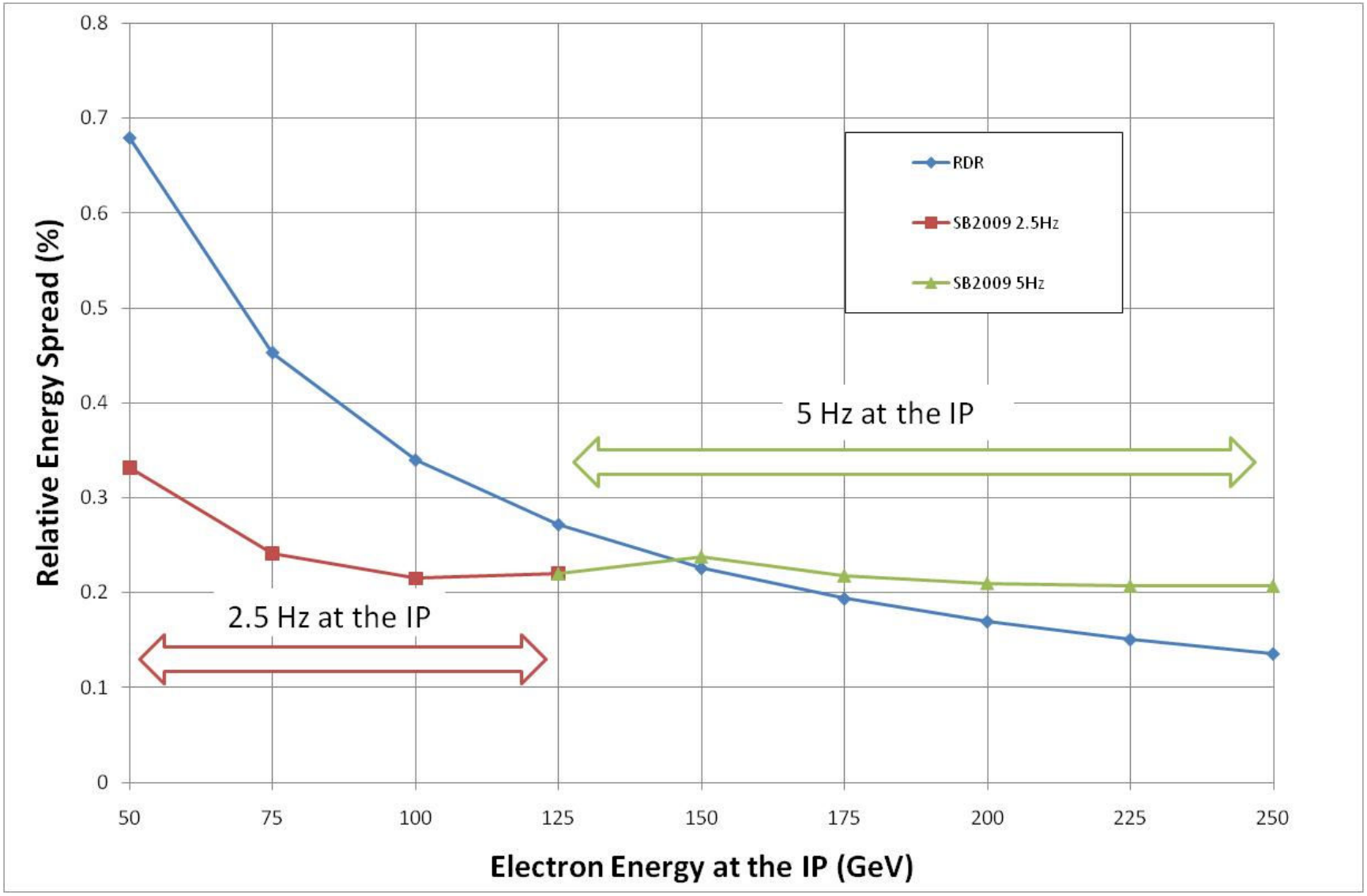
- SB2009 has two modes of operation
  - **First mode (5Hz) have to account for changing undulator length**
  - **Second mode (2.5Hz), although e- beam for IP is not used to generate e+ it still travels through the undulator and emits SR**

Electron energy spread

- SB2009

Electron Energy at the IP (GeV)	Undulator Energy (GeV)	Undulator Length (m)	Relative Electron Energy Spread (%)
50 (2.5Hz)	50	231	0.332
75 (2.5Hz)	75	231	0.241
100 (2.5Hz)	100	231	0.215
125 (2.5Hz)	125	231	0.22
125 (5Hz)	125	231	0.220
150 (5Hz)	150	231	0.238
175 (5Hz)	175	147	0.218
200 (5Hz)	200	108	0.210
225 (5Hz)	225	86	0.207
250 (5Hz)	250	71	0.207

Electron energy spread



Mitigating the Low Energy Impact

- The present 'breakpoints' of 150 GeV and 125 GeV are somewhat arbitrary
- Once the mass of Higgs is known the ILC can be tailored to provide improved performance
- If the mass is ~120 GeV then higher rep rate operation of the ILC (ie >5 Hz) during pulse switching is an option
- If the mass is ~140 GeV then a ~20% longer undulator would restore the present loss in positron yield

The AAP Report

- http://ilcdoc.linearcollider.org/record/26987/files/Report-on-AAP-Review_Jan2010.pdf?version=1
- "The cost savings laid out in the Proposal sum up to 12.6%"
- *"The technically driven RDR design is fairly mature and the cost not so far away from the optimum."*
- *"The AAP acknowledges the importance of containing the cost of the ILC at the level of the RDR estimate."*
- *"The ILC must be able to operate between 200 and 500 GeV."*
- "Components that require considerable R&D with some uncertainty in the outcome should not enter the baseline at this time even if the benefits are seen to be large."
- "*The cost savings related to the Consolidation of the central region are about 1.6%.*"

AAP – General Comments

- "Individual elements of this cumulative savings are each no more than a few percent and many either add disproportionate risk or significantly reduce operational flexibility."
- "*The AAP does not recommend adopting SB2009 as a whole as the new baseline.*"
- *"The AAP does not recommend the adoption of the Low Power Option."*

AAP – Positron Source Comments

- "In SB2009 the undulator is moved to the end of the linac to the 250 GeV position dramatically boosting the photon yield at design energy"
- *"The AAP welcomes the boost in positron intensity for operation at the highest energy."*
- "The AAP observes that the energy spread at 150 GeV increases because of the excessive length of undulator required by the adoption of the Quarter Wave Transformer in the baseline. The AAP also notices that the intensity demands on the target itself increase with worse collection efficiency."
- "*The AAP encourages research to return to the Flux Concentrator for positron collection."*
- "The AAP notices that the research in the feasibility of the target has not sufficiently advanced due to lack of funding."
- "*The AAP encourages intensification of the R&D on the positron target."*

AAP – Positron Source Comments

- "Energies below 150 GeV (300 GeV CM) are difficult to serve in this scheme."
- "The AAP is concerned about the loss of luminosity in an energy region that is particularly interesting. The smooth scanning in the energy range from LEP II to the highest energies is hampered."
- "*The AAP recommends finding a solution that matches the requirements of the "Parameters for the Linear Collider" Document for positron production for all beam energies."*
- "The AAP observes that the RDR implementation at the 150 GeV energy position may be marginal. This location was chosen to allow deceleration of the beam to 50 GeV for a Z factory. This requirement is not part of the Parameter Document and could be dropped. Consequently the undulator could move to a higher energy position, e.g. 175 GeV, and still satisfy the demands on the energy range. Such position would increase the intensity and create either an extra margin or allow for further reduction of the undulator length."

AAP – Keep Alive Source Comments

- "*The AAP recognizes the advantages of co-locating the undulator and Keep Alive Source.*"
- *"The AAP recommends that the intensity of the Keep Alive Source and the beam diagnostics sensitivities be adequately matched to most machine development activities."*
- "Significant R&D may become necessary if the intensity requirements for the Keep Alive Source turn out to be high."

PM Preliminary response

- “the panel had big reservations concerning the relocation of the positron-production undulator to the end of the high-energy linac. It is very important to note that we believe this move is strategically motivated and does not have a substantial cost impact. Our main motivation for including the controversial move in the Proposal was to facilitate the central region integration design activity. The undulator-based source requires a combination of beam power and energy, and we believe that the most advantageous location for the source is where both are largest - at the end of the linac. However, the panel pointed to the original physics 'scope' document and urged a solution that meets the requirements set forth in it (notably to maintain a contiguous operational range between 200 to 500 GeV CM with sufficient luminosity). We intend to continue studies of the various trade-offs and options for the source in TD Phase 2. The panel also recognized the need for additional positron-target system resources, which we will make every effort to find.”

Director's Corner (18/3/10)

- "We have decided that their general caution is good advice while we still believe that all the proposed changes have considerable merit. As a result, we proposed to re-institute a formal configuration control process similar to the change control board that existed during the RDR phase that was chaired by Nobu Toge, and to make a more systematic schedule for considering each proposed change one at a time over the period from autumn 2010 to summer 2011. This new schedule will still be consistent with our goal of producing a TDR by the end of 2012."