



# The Positron Source

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# Positron Source Designs

- Undulator-based (RDR + SB2009)
  - **This talk**
  - **Draft risk register on Indico**
- Conventional (300Hz operation with novel targets)
  - **Omori-san's talk**
  - **Draft risk register on Indico**
- Compton-based
  - **Not discussed here**



# Scope

- A reviewed and updated [Risk Register](#) for both the RDR and the proposed SB2009.
- An overview (as detailed as possible) of the impact of the changes to the RDR design, with a focus on CFS. (See Ewan's talk yesterday).
- Summary of the pros and cons of SB2009 with respect to the RDR.
- A concise (as possible) status of the answers to the general questions below (and any additional questions that you identify).



# Questions

- What are the options on positron yield with Ebeam<250 GeV.
- What is the associated projected luminosity from 200-500 GeV centre-of-mass.
- What is the incremental impact of a high-field pulsed solenoid (Flux Concentrator) assuming such a device is feasible.
- What is the current summary understanding of the impact on the undulator section on the electron beam emittance. What outstanding questions are there?
- Location of non-beamline components (klystrons, power-supplied etc.)
- Impact on commissioning & availability
- Impact on construction schedule (installation)



## 300Hz Option

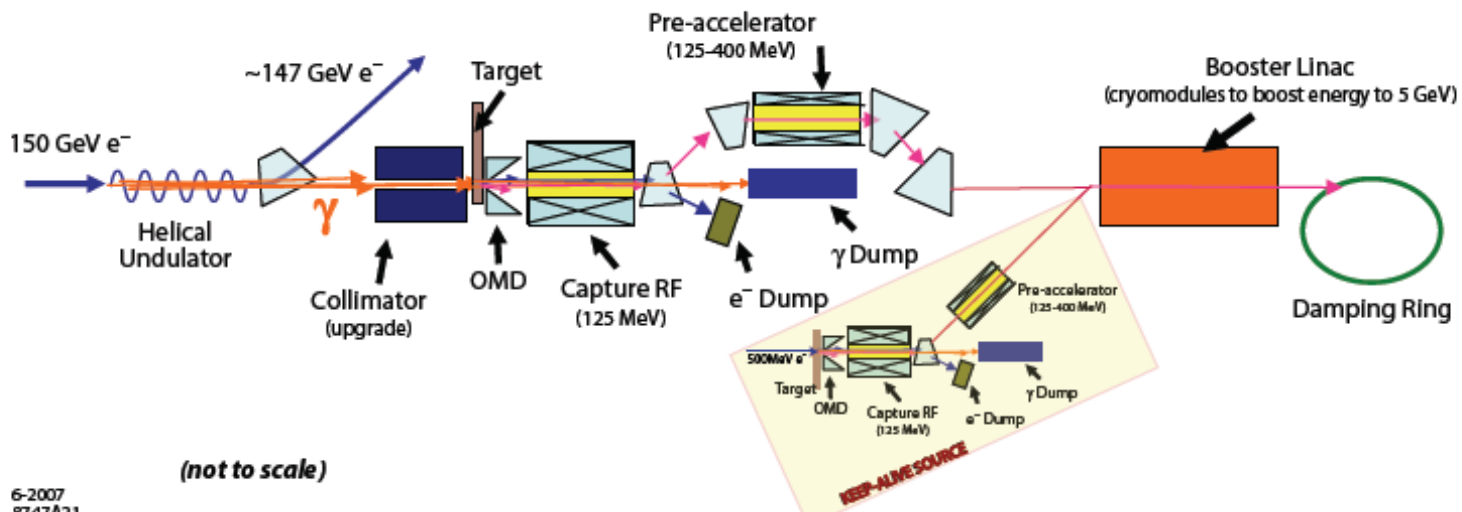
- For the positron source, an alternative 300Hz s-band linac electron-driven target system will also be considered. A risk register for this source should also be included for the May meeting. While not currently being considered as the WA for SB2009, a solution that could replace the undulator source in same accelerator housing in a similar tunnel length should be pursued.



# Other Requests

- From Nick's presentation
  - **Energy upgrade scenario**
  - **Luminosity upgrade scenario**
  - **List of required beam simulations**
- From Ewan's presentation
  - **Remote-handling footprint**
  - **Auxiliary source footprint**
  - **Costing details of target station, etc for Albuquerque**
- In addition strong request from Yokoya-san to discuss R&D priorities.
  - **See spreadsheet on Indico**

# The Baseline Source



	SLC	ILC
Positrons per Bunch	$3.5 \times 10^{10}$	$2 \times 10^{10}$
Bunches per Macropulse	1	2625
Macropulse Rep Rate (Hz)	120	5
Positrons per second	<b><math>4.2 \times 10^{12}</math></b>	<b><math>2.6 \times 10^{14}</math></b>



# Updated RDR Risk Register (1)

(1) Undulator increases electron beam emittance	Low	0E/P	Low	0VeryLow	VeryLow	Careful measurement of field quality, simulations of electron beam, test of undulator with beam
(2) Undulator alignment inadequate	Low	0E/P	Low	0VeryLow	VeryLow	Develop alignment strategy and demonstrate straightness requirements are met using test of undulator with beam
(3) Synchrotron radiation inhibits undulator operation	Low	0E/P	Low	0VeryLow	VeryLow	Quench tests. Add more photon stops in undulator lattice if needed.
(4) Electron beam mis-steered and damages undulator	Low	0E/P	Low	0VeryLow	VeryLow	Develop design for high-power collimator at start of undulator.
(5) Target fails due to pressure shock waves	Med	0E/P	Low	0Low	N/A	Numerical and analytic simulations, material tests with test beam (FLASH?)
(6) Water leak from water-cooling channels in target station	Low	0E/P	Low	0Low	VeryLow	Engineering design, prototype wheel with water-cooling channel. Radiation damage studies, prototype target soak test (no beam). Remote-handling provision for target replacement.
(7) Target Lifetime shorter than design lifetime	Low	0E/P	Low	0Low	VeryLow	
(8) Remote Handling of Target fails	Low	0E/P	Low	0Low	VeryLow	Engineering design





# Updated RDR Risk Register (2)

(9) Flux concentrator does not meet spec	Med	0E/P	Low	0Low	VeryLow	Paper design, build of prototype, comprehensive tests
(10) Low gradient in warm capture sections at full power	Low	0E/P	Low	0Low	VeryLow	Comprehensive testing of prototype
(11) Positron losses too high in transport line to DR	Low	0E/P	Low	0Low	VeryLow	Design of beamline collimator system

- **WA for Positron Source**
  - **Undulator-based e<sup>+</sup> source located at the end of the electron Main Linac (250 GeV)**
  - **Reduced parameter set (with respect to the RDR) with nb = 1312**
  - **Integration of the e<sup>+</sup> and e<sup>-</sup> sources into a common “central region beam tunnel”, together with the BDS**
  - **Undulator length optimised for a yield of 1.5-2.0 (TBD) assuming a QWT Optical Matching Device at an electron beam energy of 250 GeV**
  - **A warm-linac electron driven auxiliary source, using same target and capture section, with a  $\leq 10\%$  intensity**



# Pros of SB2009

- Undulator moved to the end of the linac
  - Removal of the 1.2km insert at 150 GeV
  - Sharing of the tunnel (and shaft) with the BDS
  - Higher yields at high electron energies (so greater safety margin & polarised positrons available)
- Reduced Parameter Set (nb = 1312)
  - Half average power on target, dumps, capture linac, collimators
  - Half average power needed from RF, warm linac section easier
  - Less activation/radiation damage



# Pros of SB2009

- Assuming a QWT Optical Matching Device
  - **Very low risk compared with flux concentrator**
- A warm-linac electron driven auxiliary source, using same target and capture section
  - **This allows for sharing of infrastructure**



## Cons of SB2009

- Undulator moved to the end of the linac
  - **Variable energy drive beam, need to retune source when energy changed (?)**
  - **Yield decreases with energy, at some energy may be too small – how to cope with this?**
  - **Conflict with BDS**
- Assuming a QWT Optical Matching Device
  - **Lower yield, longer undulator, more power on target etc**
- A warm-linac electron driven auxiliary source, using same target and capture section
  - **Target not optimal (vary thickness radially?), low yields likely**
  - **Reduction in independence between two sources**



# SB2009 Risk Register c.f. RDR

## Changes in risk c.f. RDR

(7) Target Lifetime shorter than design lifetime

Low

0E/P Low

0Low

VeryLow

Radiation damage studies, prototype target soak test (no beam). Remote-handling provision for target replacement.

(9) Flux concentrator does not meet spec

N/A to SB2009

## New risks c.f. RDR

(12) Yield at low energies <1.5

Low

Q VeryLow

NA

NA

Yield can be increased with longer undulator or alternative layout but need clear decision on requirements

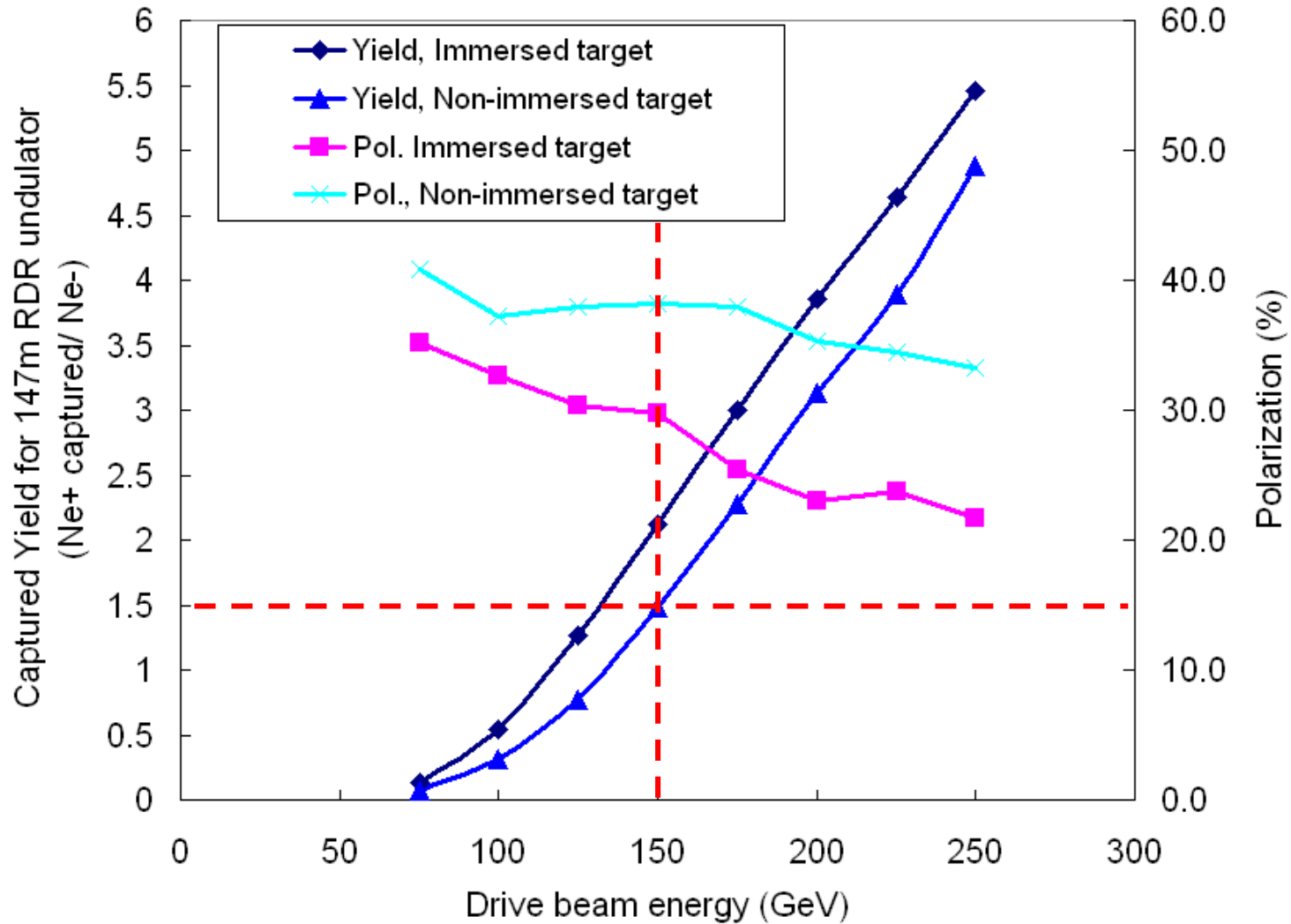


# Running at $<250$ GeV

- If we use the RDR source, running above 150GeV will increase the yield
  - **gives greater safety margin and allows some undulator modules to be turned off**
  - **Would also allow for high degree of polarisation without any upgrade**
- Running below 150GeV the yield will fall below 1.5 (unless more undulator modules are installed)



# Running at <250 GeV: RDR Example

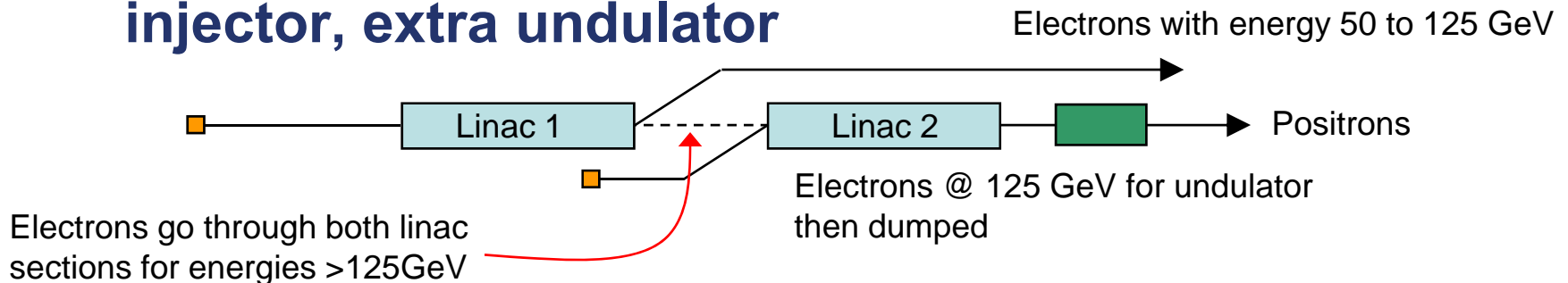






# Low Electron Energy Operation

- An undulator of length sufficient for 125 GeV operation could be installed (~400m if use QWT)
- Then a second injector could be installed at the 125 GeV point in the linac and a bypass line
  - This would allow one beam to generate positrons at 125 GeV and a second beam (covering 50 to 125GeV) could be transported to the BDS
  - No loss in luminosity at any energy
  - Additional cost of long electron transport line, new injector, extra undulator





# Low Electron Energy Operation

- If the positron yield is to be maintained at 1.5 at all electron energies then the direct benefit of putting the undulator at the end of the linac is no longer clear
- The associated benefits (eg to CF&S) may still make it a worthwhile change



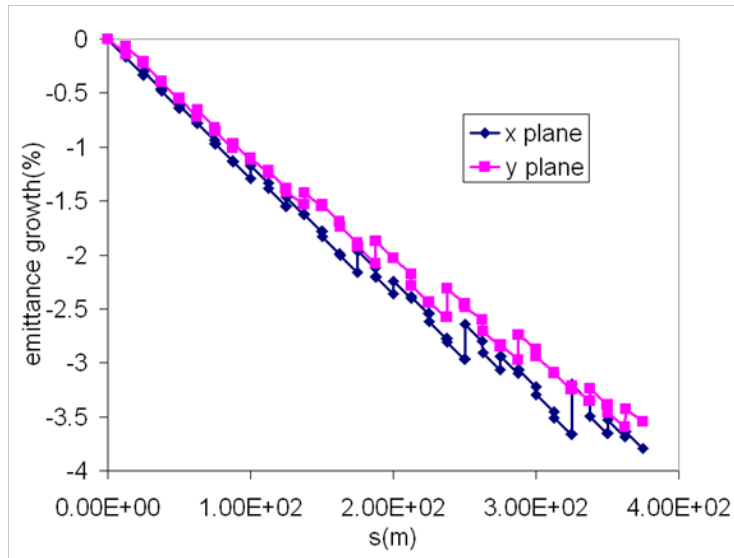
# Flux Concentrator

- Assuming the RDR undulator at the end of the linac
- Using the low risk QWT as the capture magnet means the undulator will need to be ~206m ('unpolarised')
- A flux concentrator will reduce this to 147m long ('unpolarised')
- Remember that the use of the QWT does not just increase the undulator length by 40% but also the photon beam power – implications for subsequent systems (target, RF, collimators, etc) – should still be ok but needs to be taken account of



# Undulator Impact on Emittance

- Impact due to Emission of SR by electrons only assessed by ANL (PAC 09) ([see paper on Indico](#))
- Simulations with Elegant with RDR electron beam and undulator parameters
- FODO lattice included in model (quads every 12.4m)



Undulator system damps emittance of drive beam by few %

Backed up by analytic study

Off axis injection increases damping as beam sees stronger field and so loses more energy



# Undulator Impact on Emittance

- Impact due to Quad-BPM error has been studied by 4 groups
- ANL (PAC 09)
  - No undulator, just simple 250m FODO section,  $\varepsilon_y$  increase 0.35% due to energy spread, and ~5% with Q-BPM misalignment rms error of 20 $\mu\text{m}$
- Daresbury (Eurotev-2007-07)
  - Worst case transverse wake due to undulator in 290m long system – causes no  $\varepsilon_y$  increase at all (assumes no Q-BPM misalignment)
  - Off axis entrance to undulator section in position and angle. No Q-BPM errors. See  $\varepsilon_y$  increase ~1% for errors of  $\sigma_y$  or  $\sigma_{y'}$



# Undulator Impact on Emittance

- Daresbury (contd)
  - BPM misalignments  $\sim 10\mu\text{m}$ , see  $\varepsilon_y$  increase  $\sim 8\%$
- Kubo (TILC09)
  - Simple undulator model included, Q offsets of 0.3mm and 0.3mrad, no wakes, orbit corrected by kick minimisation. BPM misalignment rms  $10\mu\text{m}$ , 0.3mrad.
  - see  $\varepsilon_y$  increase  $\leq \sim 2\%$  with undulator,  $\leq \sim 1\%$  without undulator
  - Transverse wake, see no problem with fast orbit jitter
  - Transverse wake (pessimistic model), beampipe misalignment better than  $240\mu\text{m}$  required



# Undulator Impact on Emittance

- Schulte (ILC-LET Daresbury Jan 07)
  - Kick minimisation gives for Q-BPM misalignment rms error of  $30\mu\text{m}$ ,  $\varepsilon_y$  increase  $\sim 10\%$
- Summary
  - Transverse wakes negligible
  - Need Q-BPM misalignment  $\sim 10\mu\text{m}$  for  $\varepsilon_y$  increase  $\sim \text{few}\%$  (horizontal negligible)
  - Undulator will provide damping of few % in both planes