POLARISED POSITRON SOURCES AT THE ILC

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March 2005

- ***ILC Parameters***
- ***Polarised Positrons for ILC***

THE INTERNATIONAL LINEAR COLLIDER (ILC)

THE INTERNATIONAL LINEAR COLLIDER (ILC)

- WORLD Collaboration
- Multi-billion dollar project
- Proposed e^+e^- linear collider
- 0.5-1.0 TeV center-of-mass energies
- Major elements
  - Electron injector
  - Electron damping ring
  - Main electron linac
  - Electron beam delivery to IR
  - **Positron Source**
  - Positron damping ring(s)
  - Main positron linac
  - Positron beam delivery to IR
  - IR
  - Detectors at IR

Parameter	Reference	Upgrade
Beam Energy *(GeV)*	250	500
RF gradient *(MV/m)*	28	35
Two-Linac length *(km)*	27.00	42.54
Bunches/pulse	2820	2820
Particles/bunch (10^{10})	2	2
Beam pulse length *(μs)*	950	950
Pulse/s *(Hz)*	5	5
σ_x(IP) *(nm)*	543	489
σ_y(IP) *(nm)*	5.7	4.0
σ_z(IP) *(mm)*	0.3	0.3
δ_E *(%)*	3.0	5.9
Luminosity $(10^{33} cm^{-2} s^{-1})$	25.6	38.1
Average beam power *(MW)*	22.6	45.2
Total number of klystrons	603	1211
Total number of cavities	18096	29064
AC to beam efficiency *(%)*	20.8	17.5

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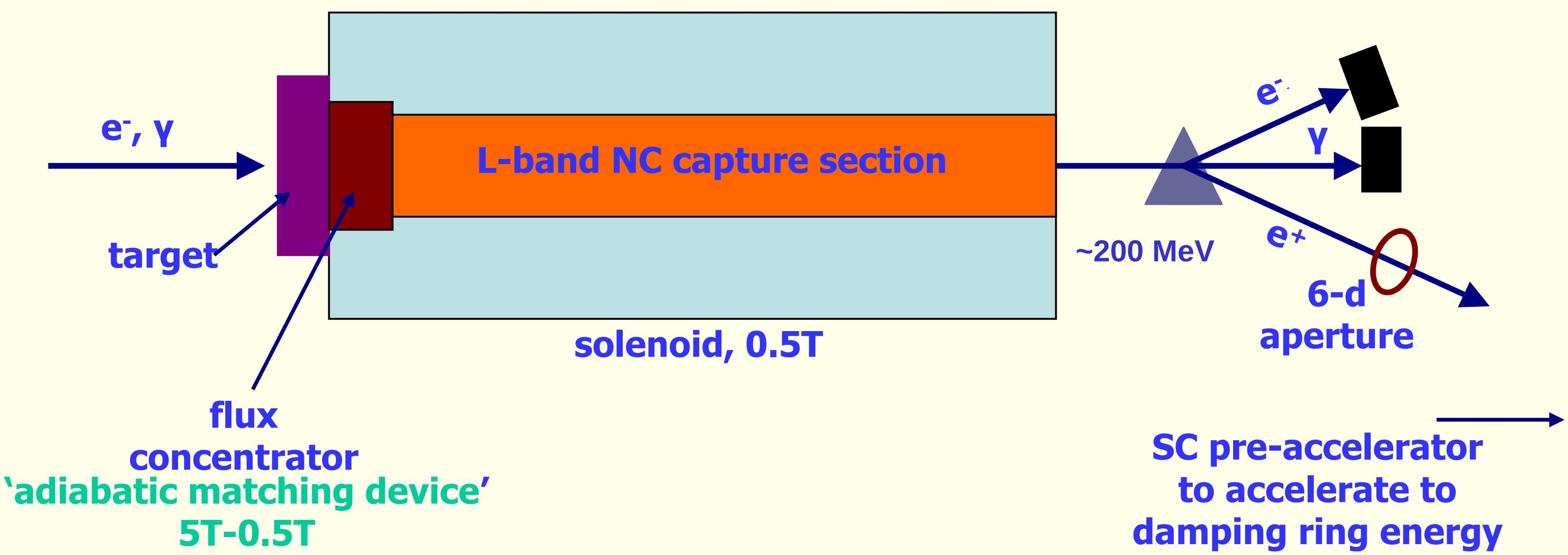
GENERIC POSITRON SOURCE



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POSITRON SOURCE DESIGN ISSUES

- ***Drive beam***
  - *Electrons or **photons***
    - *Photons allow for the possibility of polarized positrons*
  - ***How are the photons made***
    - *Multi-hundred GeV electron beam through an undulator*
    - *Compton back-scattering laser beam on a multi-GeV electron beam*
  - *Drive beam phase space*
- ***Target***
  - *Choice of material*
  - *Target heat/shock/stress*
- ***Positron capture***
  - *Beam heating*
  - *Capture RF*
  - *Capture magnetic field*
  - *Damping ring acceptance*
- ***Target vault***

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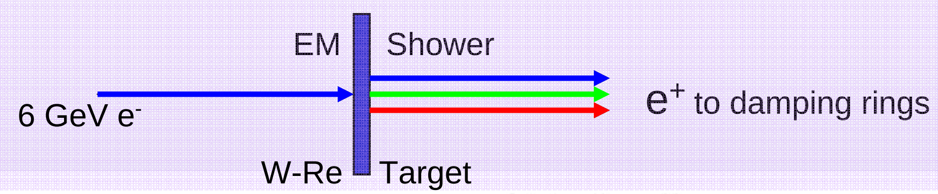
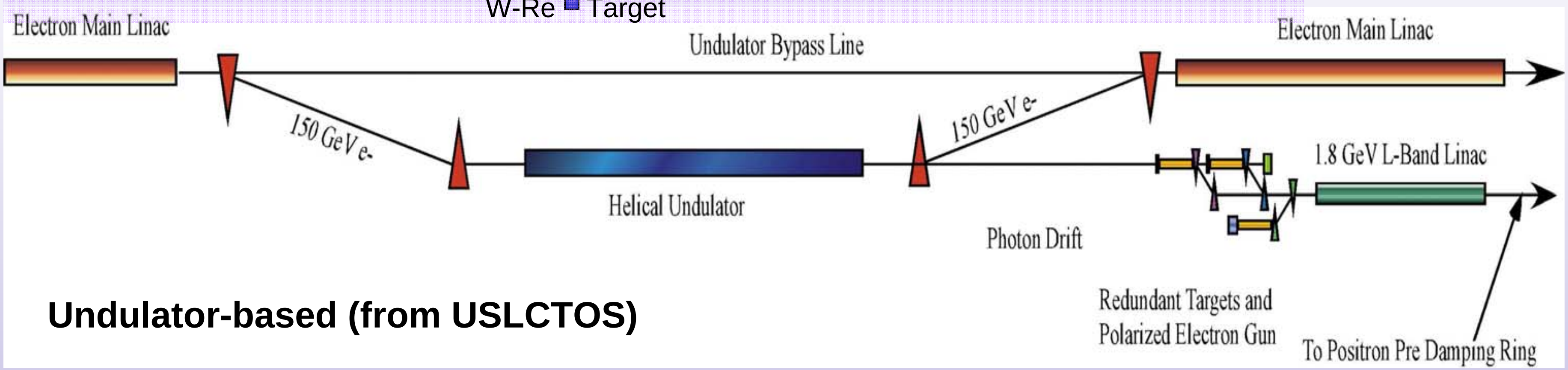
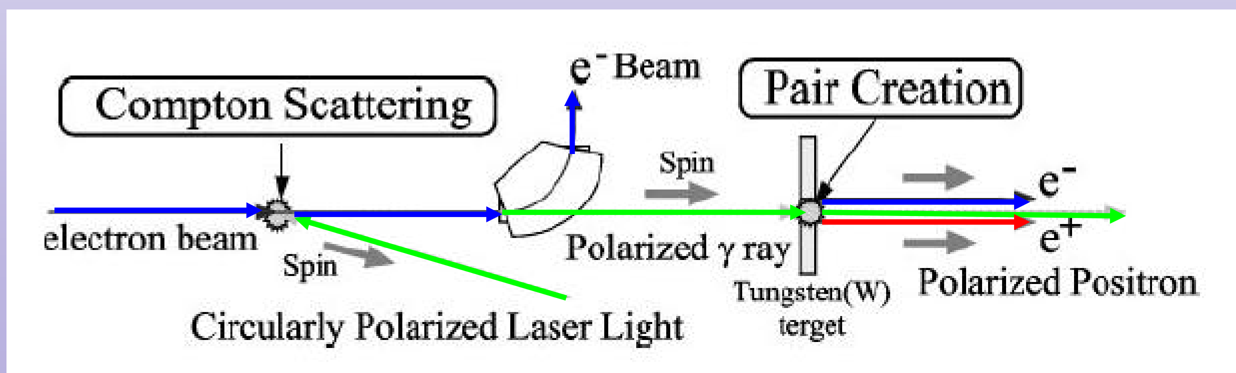
POSITRON PRODUCTION SCHEMES – DRIVE BEAMS

Conventional



Undulator-based (from USLCTOS)





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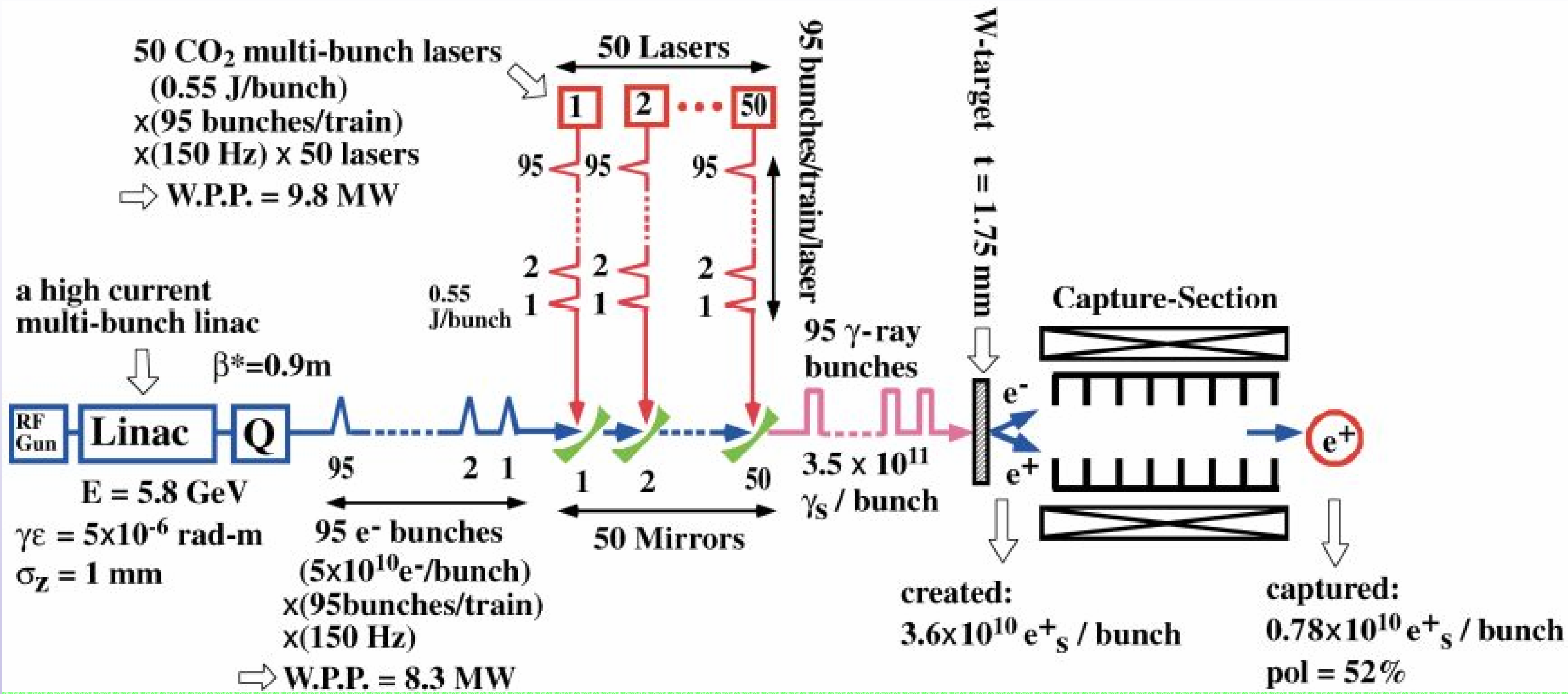
COMPTON-BASED POSITRON SOURCE – LASERS
Talk by Omori



GLC laser power :	9.8 MW peak power per laser bunch
	~ 400 kW average power (**40kW with use of mirrors**)
	~ 73 GW peak power
ILC bunch structure	2820 * 5 ~= 95 * 150
	but 2820 bunch pulse trains
	may be able to use mirrors to relax laser parameters

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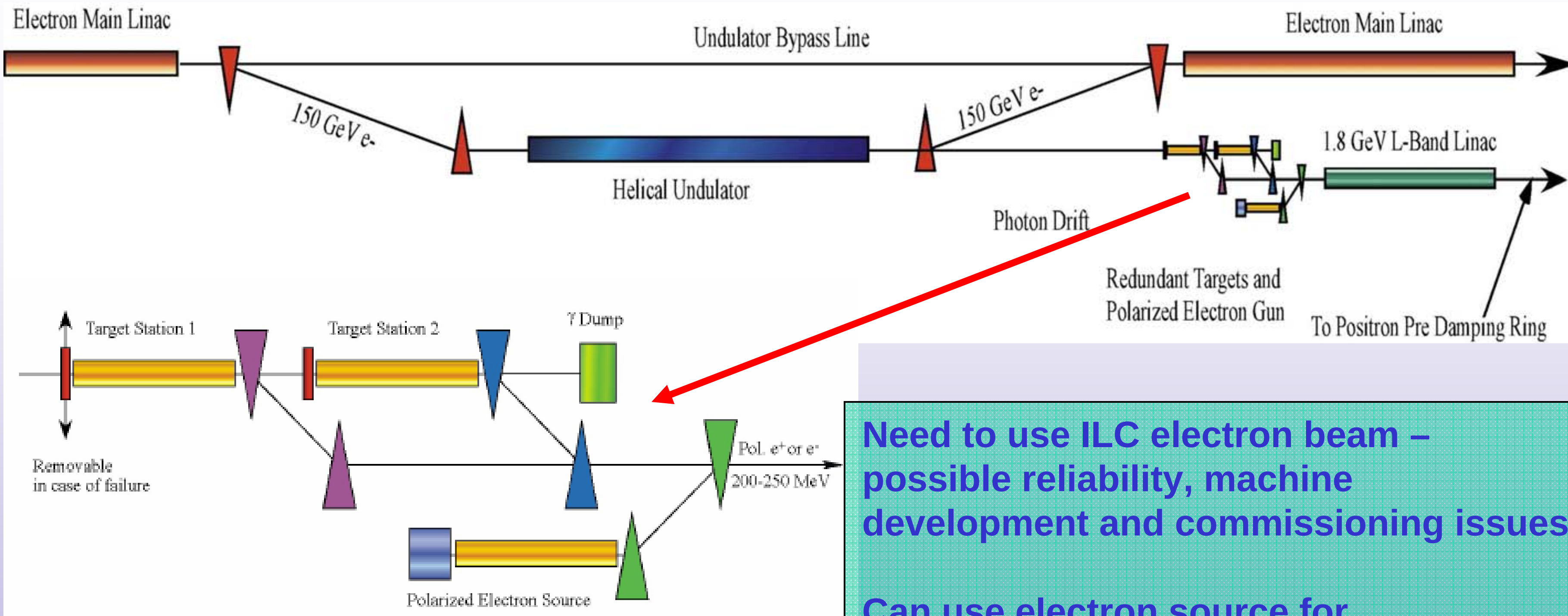
UNDULATOR BASED POSITRON SOURCE



Need to use ILC electron beam – possible reliability, machine development and commissioning issues

Can use electron source for commissioning

Long helical undulator, small aperture
- **permanent magnet**
- **warm pulsed**
- **superconducting**

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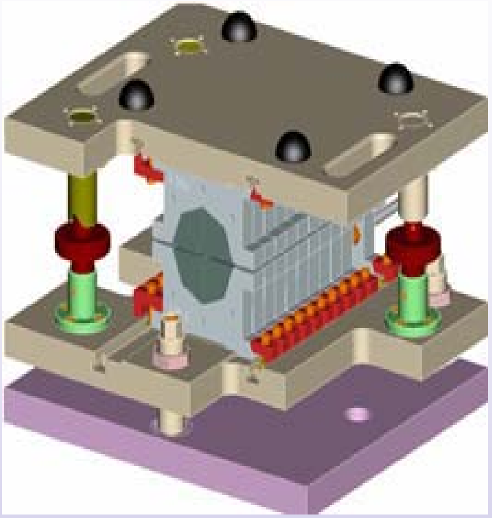
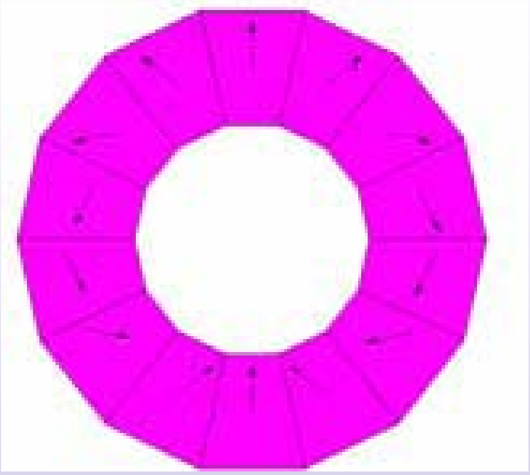
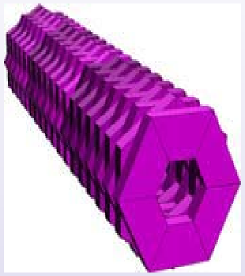
UNDULATOR DESIGN EFFORT – DARESBURY

http://www.astec.ac.uk/id_mag/PDF%27s/EPAC04/MOPKF064.pdf







Permanent magnet undulator

Superconducting undulator

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POSITRON DRIVE BEAM PARAMETERS (USLCTOS)

Parameter	γ-beam (und)	e-beam
Electron Drive Beam Energy (GeV)	153	6.2
Electron Drive Beam Intensity (10**10/bunch)	2	2
Beam Energy Loss (GeV)	4.9	–
Beam Energy Spread In %()	0.5	–
Beam Energy Spread Out (%)	0.46	–
Additional linac length (m)	170	230
Undulator length (m)	150	–
Undulator insertion length (m)	790	–
Positron source length (m)	450	450
Photon energy (MeV)	10.7	–
Undulator type	K=1; helical	–
Undulator field (T)	1.07	–
Undulator period (cm)	1	–
Undulator full gap (mm)	6	–
Positron yield†	1.5	1.5
Expected Positron Polarization (@ full luminosity)	40-70%	–

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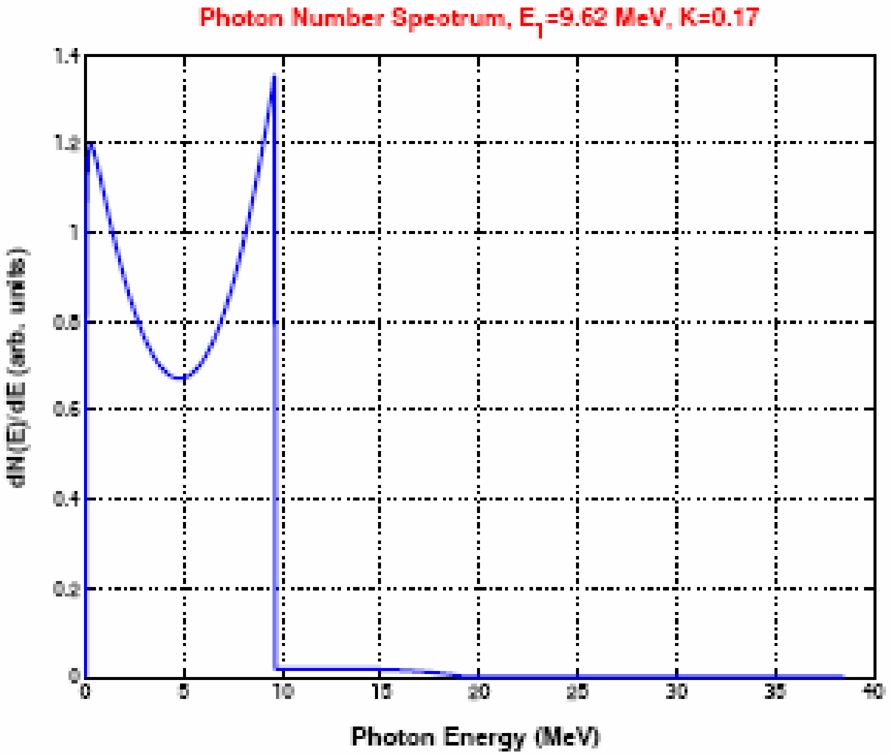
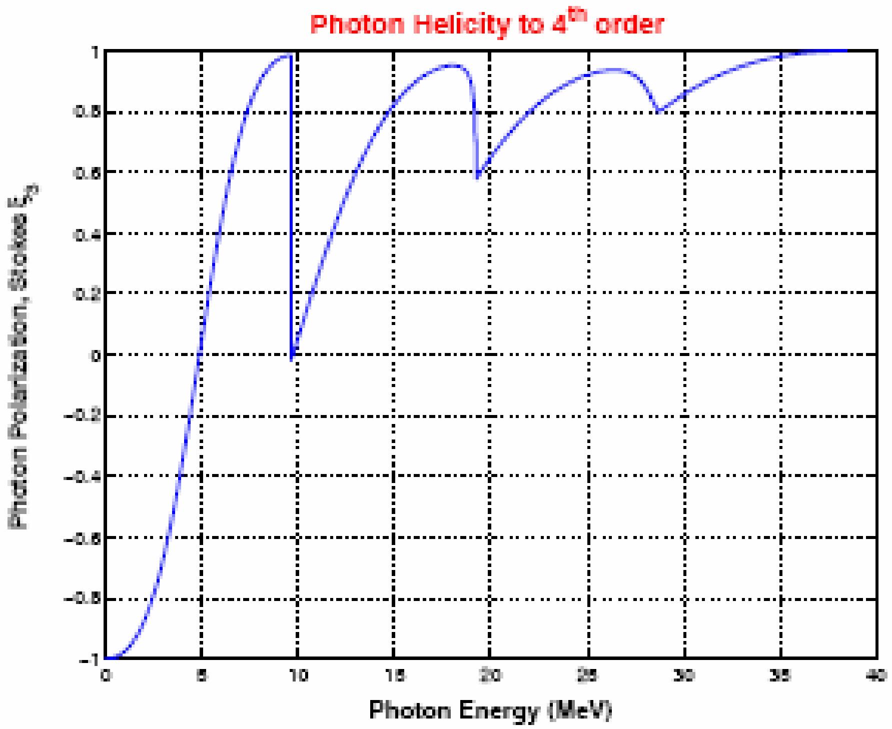
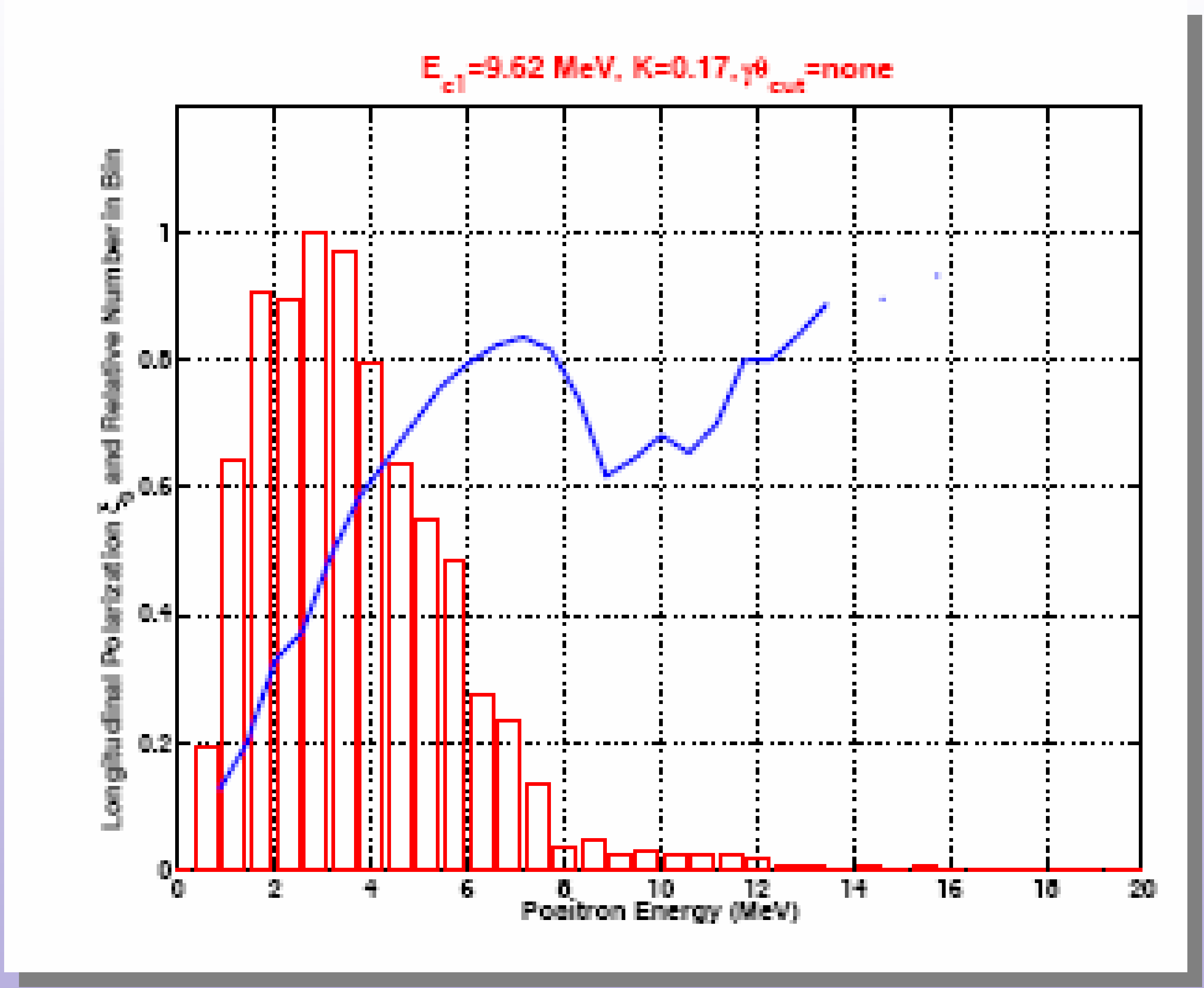
PHOTON SPECTRA & HELICITIES





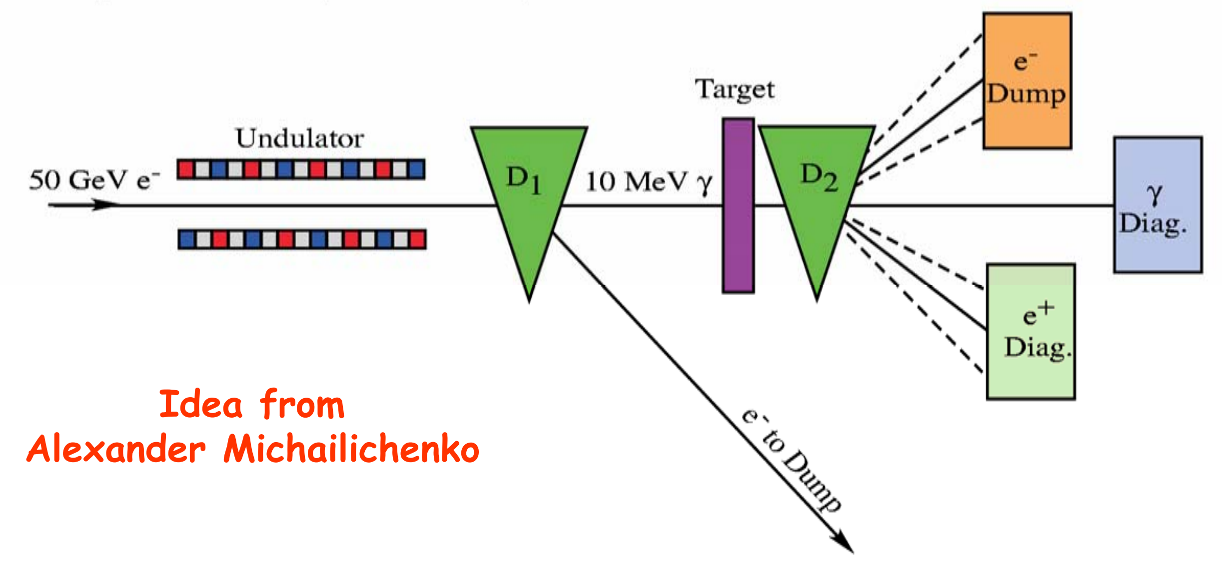
POSITRON SPECTRA & POLARIZATION



EXPERIMENT: E166 @ SLAC

Talk by Roman Poeschl

- *E166 (SLAC) – http://www.slac.stanford.edu/exp/e166/*
  - *Demonstration experiment for production of polarized e^+*
  - *Final focus test beam (FFTB) at SLAC with 50 GeV*
  - *1 m long helical undulator produces circular polarized synchrotron radiation 0-10 MeV*
  - *Conversion of photons to positrons in 0.5 rad Ti-target*
  - *Measurement of polarization of positrons by Compton transmission method*



Idea from
Alexander Michailichenko

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POSITRON TARGET PARAMETERS

- SLAC Linear Collider experience
  - 30 GeV e^-beam, 24 kW
  - 4×10^{10} e^-/bunch
  - 120 Hz
  - W75Re25 target, worked for years
  - Yield 1.0
- ILC positron source
  - Few hundred kW beam power
  - For e- beam, need thick (4rl) target, use high-Z material such as tungsten-rhenium alloy (e.g. $W_{77}Re_{23}$)
  - For γ beam, need thin (0.4rl) target, can use stronger material such as titanium alloys (e.g. $Ti_{90}V_4Al_6$)
- Problems: instantaneous target heating, associated shock/stress, damage

Parameter	γ beam	e- beam
Pulse energy on target [kJ]	44	28
Ave. power per target [kW]	222	140
Spot size on target [mm]	0.75	2.5
Target material	Ti-alloy	W-Re25
Target thickness [r.l.]	0.4	4.0
Target energy absorption[%]	8	14
Target Radius [m]	0.80	1.0
Revolution Rate [rpm]	1200	1200
Pulsed Temp. Rise (ºC)	410	256
Number of targets/spares	1/1	2/3

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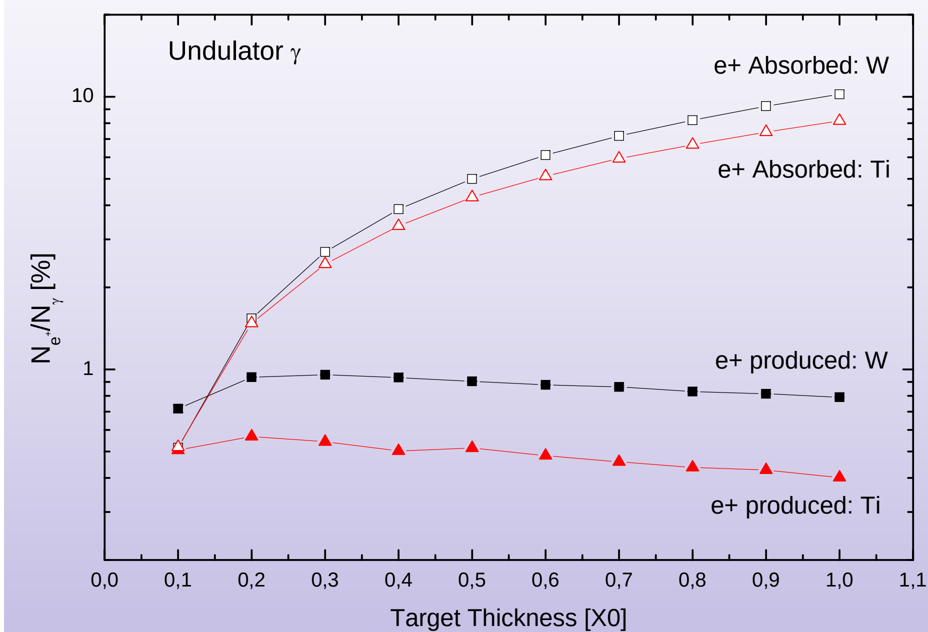
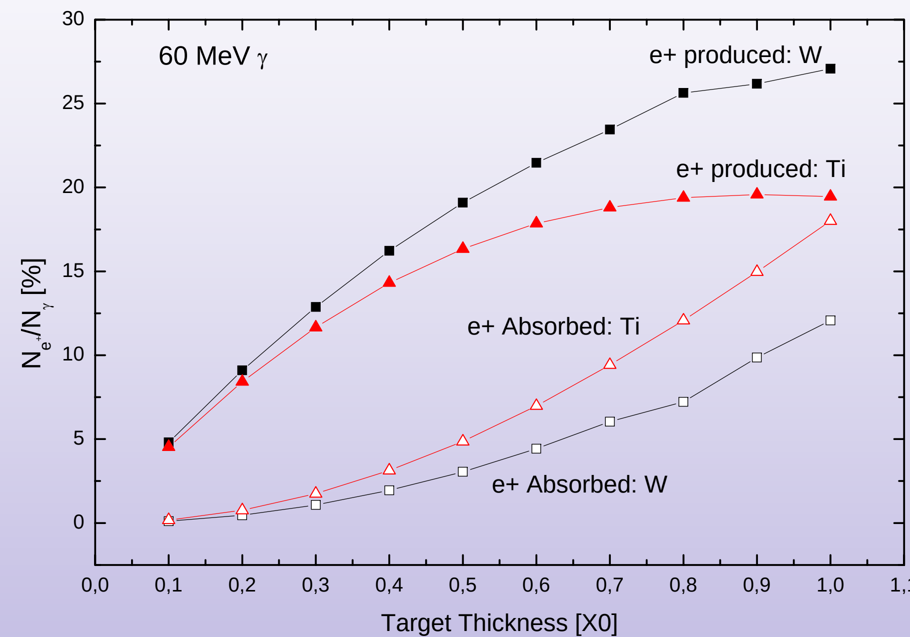
POSITRON PRODUCTION vs TARGET THICKNESS & TARGET MATERIAL

~10 MeV photon spectrum (USLCTOS)



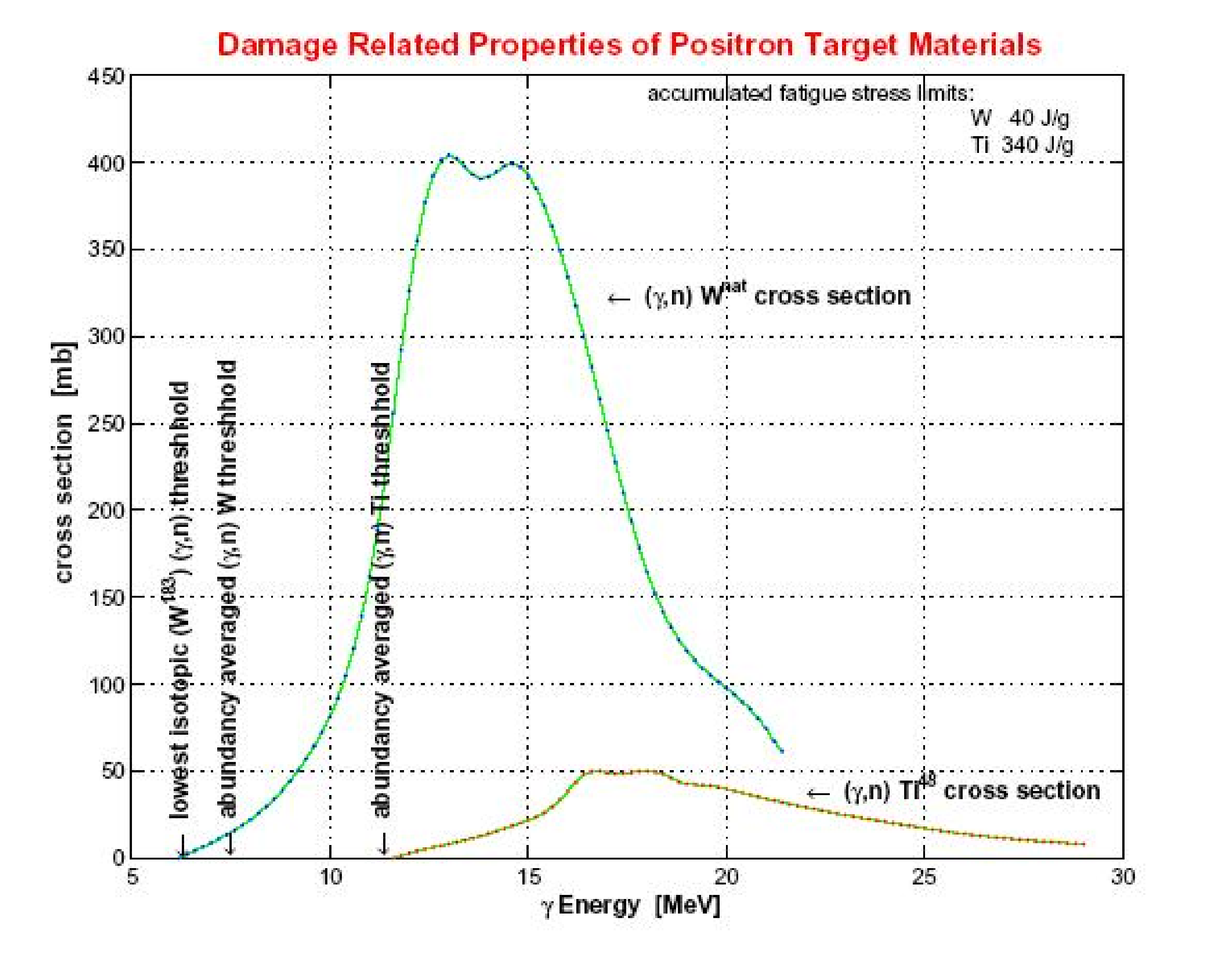
10 MeV – yield ~ one percent, almost independent of target thickness.
Produced positrons "range out"

~60 MeV photon spectrum (KEK/Compton)



60 MeV – yield ~ 20 percent
Thicker targets indicated
Depolarization?

NEUTRON PRODUCTION CROSS-SECTIONS



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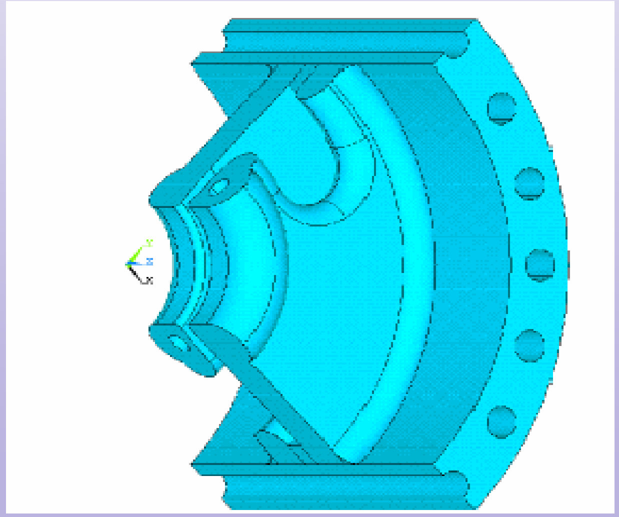
POSITRON CAPTURE – L-BAND BEAM HEATING

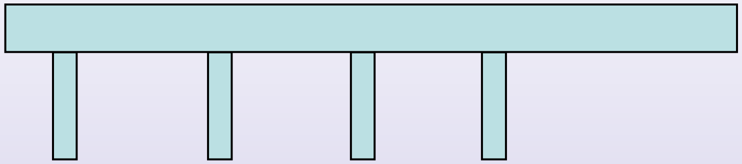
The target absorbs 10-20% of the incoming beam power, the rest is lost in the beam capture section. For e-beam, most of the power is deposited in the L-band capture RF adding to the difficulty of its design

ACTUAL CAVITY

Inner iris radius = 26 mm
Outer iris radius = 89 mm
Iris spacing = 115 mm
Effective iris thickness (along z axis) = 26 mm
Radial thickness of outer wall = 20 mm
Number of cells in first two SW cavities = 20



SIMULATED STRUCTURE USING FLUKA



	UND	CONV
Beam E (MeV)	2-10	6200
Total beam power (kW)	220	280
Total L-band power (kW)	13.480	148.418
Total iris power (kW)	9.790	125.126
Inner irises power (kW)	3.200	60.689
Target Power Dep.(kW)	22.614	35.371

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POSITRON SOURCE VAULT

- *Design of positron source needs to be integrated into the design of the positron vault.*
- *Lower photon drive beam energies (e.g. 10.7 MeV) is below the peak for neutron production, positron target radiologically cleaner*
- *e- drive beam*
  - *Activation of target, capture section, target vault*
  - *Need to design vault to make replacement and maintenance of target station feasible*
  - *Remote handling expertise needed*
- *So far, least amount of work done on this issue*

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SUMMARY & PLANS

- ***Polarized positron source using helical undulator and the ILC main linac electron beam is feasible***
  - *As easy as an undulator-based **unpolarized** source*
  - *Reliability issues need to be fully understood*
- ***Positron workshop in Daresbury (April 10-13)***
  - *Discuss issues for all positron source schemes*
  - *Organize who is doing what*
  - *Prepare plan for Snowmass*
- ***Snowmass August 14-27***
  - *CDR plan*
  - *R&D plan for TDR*

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