Positron Source Parameters

Daresbury, 10 February, 2011

S. Riemann, DESY

Positron Source Components

- **Undulator**
- **Target**
- **OMD**
- **γ collimator**
- Acceleration, bunch compression
- **Spin rotation**

- Auxiliary source
- Remote handling
- Dumps, shielding

Normal Operation

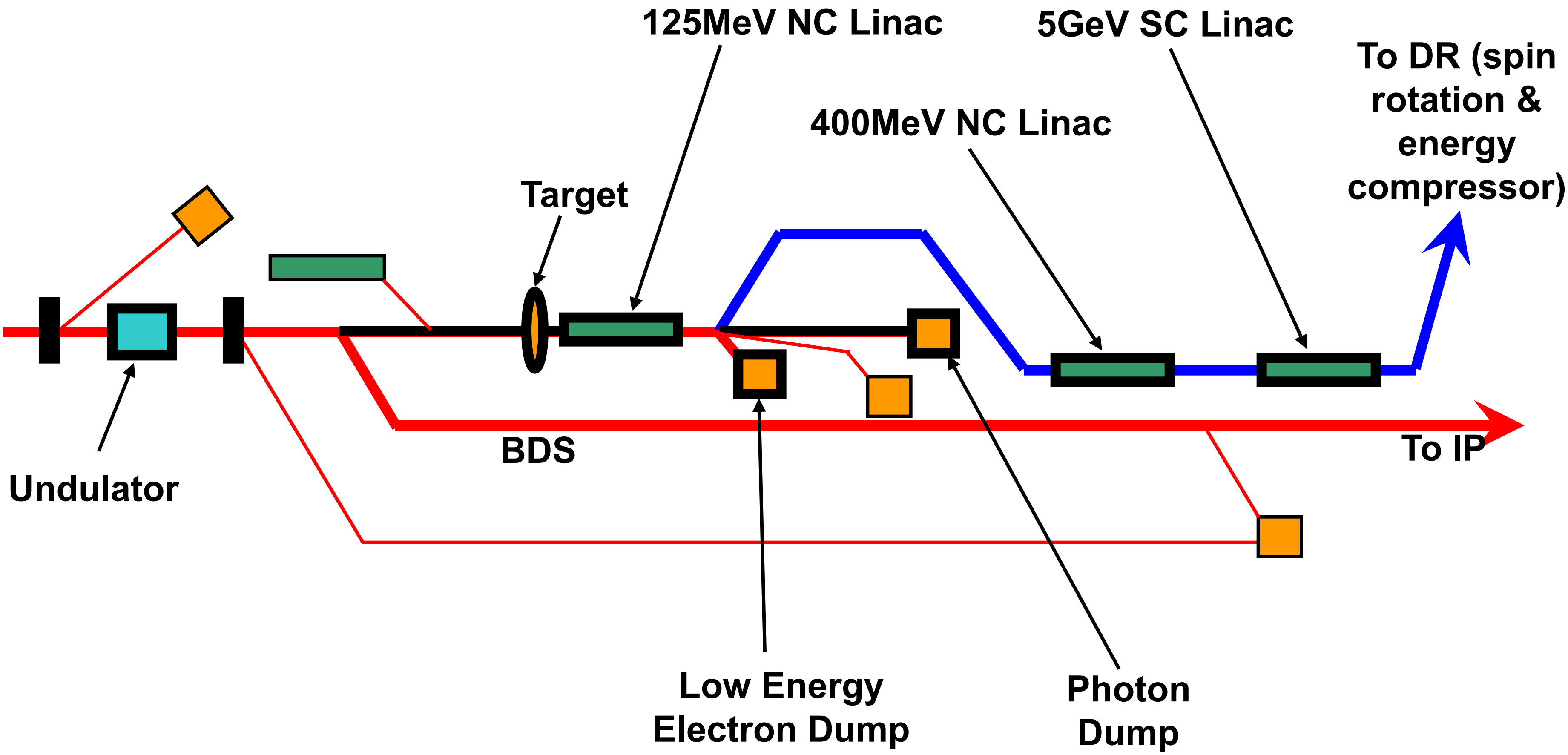
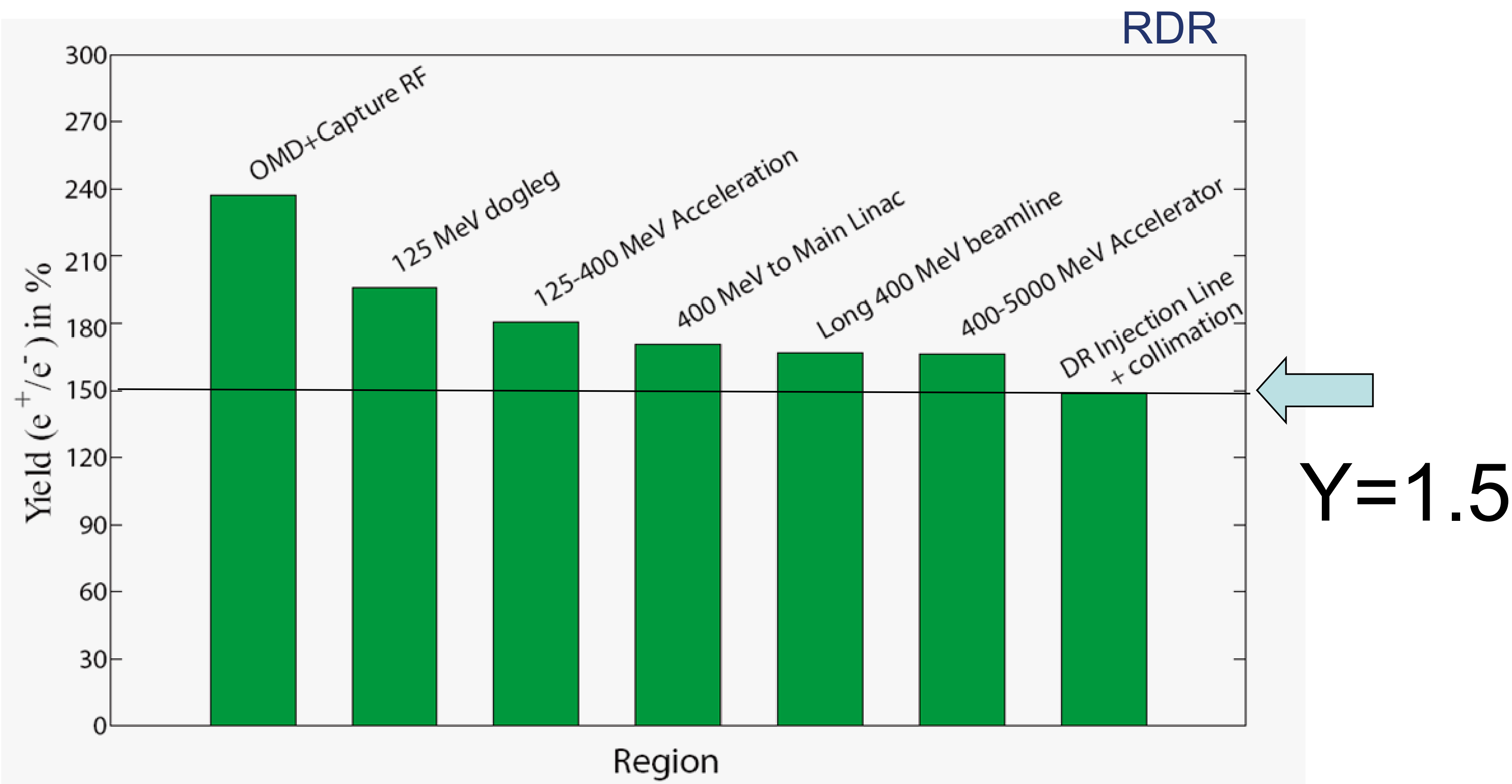


Figure taken from J. Clarke, AAP Review

Positron Yield



Undulator

Helical undulator

	units	RDR	SB2009
e+ per bunch at IP		2 x 1010	1 to 2 x 1010
Bunches per pulse		2525	1312
Normalized horizontal emittance @ IP	mm-mr	10	10
Normalized vertical emittance @ IP	mm-mr	0.04	0.035
Energy e- beam	GeV	150	125(150)-250
Undulator period	cm	1.15	
Undulator strength		0.92	
Active undulator length	m	147	Max. 231
Field on axis	T	0.86	
Beam aperture	mm	5.85	
Photon energy (1st harm. cutoff)	MeV	10.06	28 (@250 GeV)
Photon beam power	kW	131	Max. 102 (at 150 GeV)
Distance undulator center to target	m	500	

Undulator parameters

Yield Calculations Using RDR Undulator Parameters
(137 meter and FC without photon collimators)

W. Gai, BAW-2

Drive beam energy	Yield	Polarization	Required Undulator Length for 1.5 Yield	Emittance Growth X/Y for 1.5 Yield*	Energy Spread from Undulator for 1.5 Yield
50 GeV	0.0033	0.42	Very long		
100 GeV	0.2911	0.39	685 m		
150 GeV	1.531	0.34	137 m	~ -2.5%/-1.6%	0.17%
200 GeV	3.336	0.27	61 m		
250 GeV	5.053	0.23	40 m	~ -1%/-0.4%	0.18%

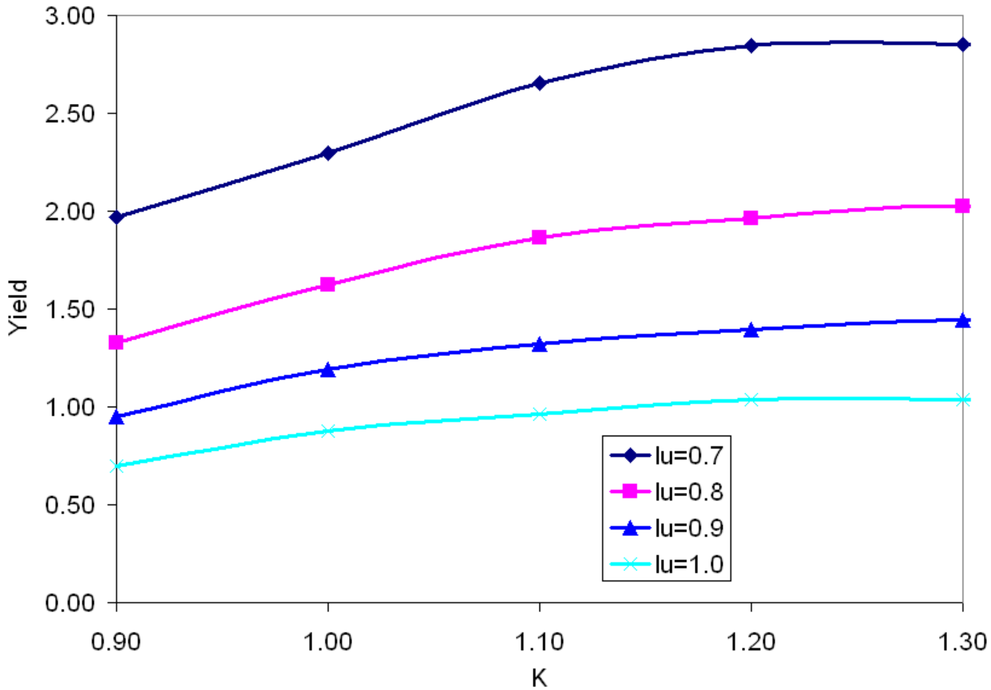
- No Quads misalignment included

- Change undulator parameters to optimize
  - **Yield and polarization**
  - **Emittance growth**
  - **Reduce heat load on target and collimator**

Undulator Parameter Upgrade

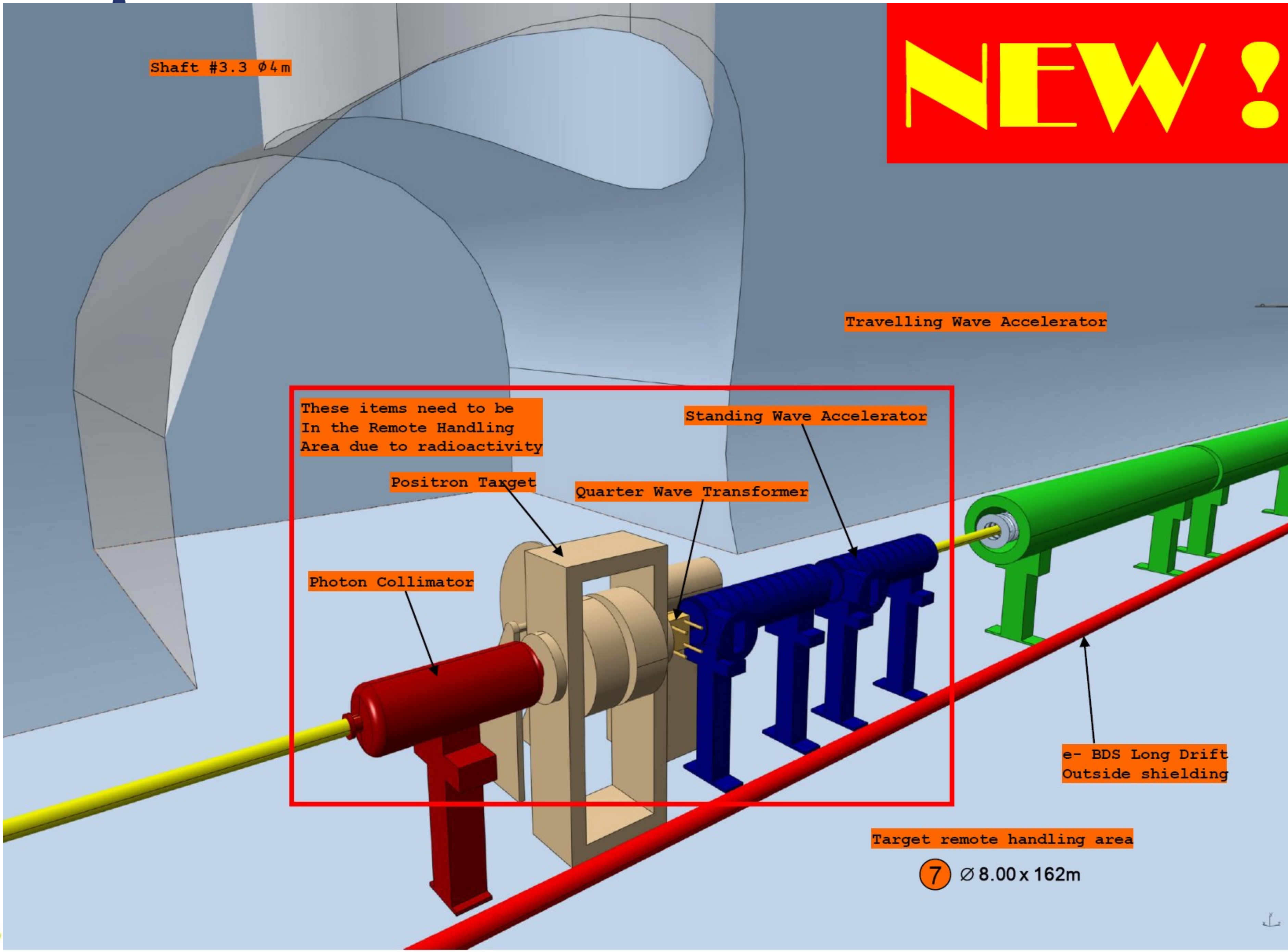
W. Gai, BAW-2

- Assumptions:
  - **Length of undulator: 231m**
  - **Drive beam energy: 100GeV**
  - **Target: 0.4X0, Ti**
  - **Photon Collimation: None**
  - **Drift to target: 400m from end of undulator**
  - **OMD:FC, 14cm long, ramping up from 0.5T to over 3T in 2cm and decrease adiabatically down to 0.5T in 12cm.**
- Probably aperture will be relative small; impact on drive beam to be studied.



High K, short period, 100GeV drive beam

- **Target**
- **Optical Matching Device**
- **Photon Collimator**



NEW !
Shaft #3.3 ϕ4m
Travelling Wave Accelerator
These items need to be
In the Remote Handling
Area due to radioactivity
Standing Wave Accelerator
Positron Target
Quarter Wave Transformer
Photon Collimator
e- BDS Long Drift
Outside shielding
Target remote handling area
7 ∅ 8.00 x 162m

Positron Target

	units	RDR	SB2009
Target material		Ti-6%Al-4%V	
Target thickness	r.l. / cm	0.4 / 1.4	
Target power adsorption	%	8	8 (for E=?)
Incident spot size on target	mm, rms	>1.7	>1.2 (250 GeV)
Diameter target wheel	m	2	2
Rotation speed	m/s	100	100

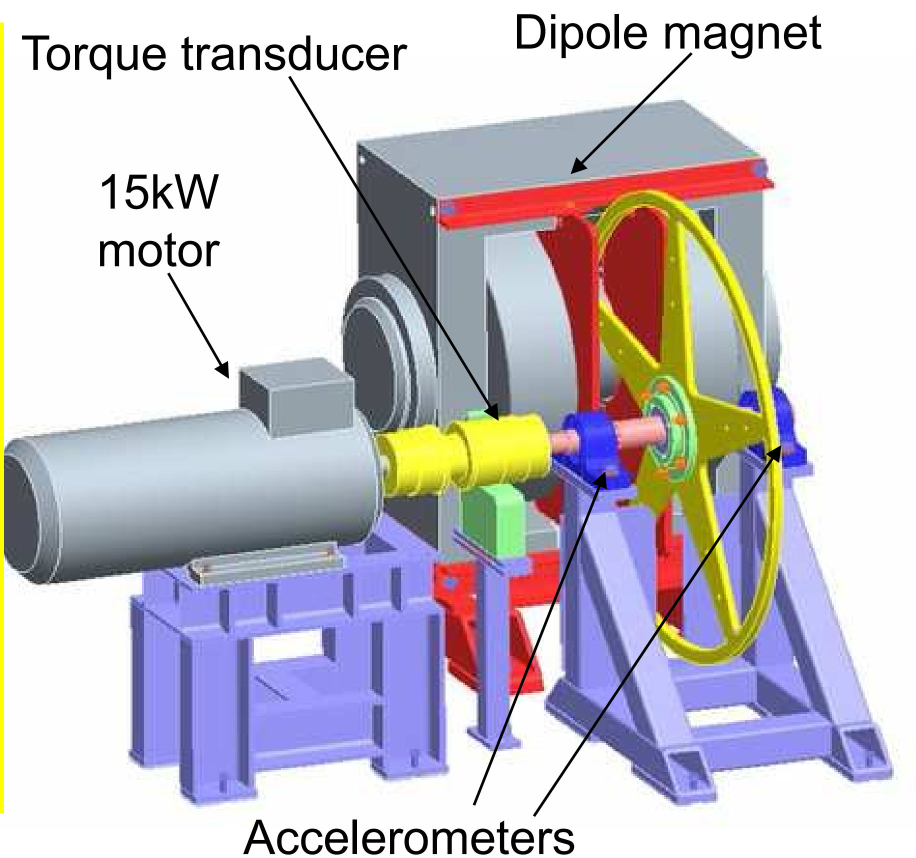
- **Is target thickness optimal?**
- **What is the incident spot size?**
  - No Gaussian profile
- **Material parameters (heat load, shock wave,…)**
- **Immersed target → eddy currents:**
  - **Extrapolation to 8 kW at 2000 rpm in B=1T (I. Bailey et al.)**

Target Prototype Experiment

Test eddy currents and mechanical stability
Cockroft Institute

Bailey et al., THPEC033, IPAC2010

Ken Davies - Daresbury Laboratory



Measurements

- Torque associated with eddy current production in target wheel depending on
  - Immersion depth
  - Magnetic flux densities
- All measurements taken for revolution rates <1800 rpm in fields up to 1.5 T

Results

- Measured torque values correspond to heat loads up to 4.7 kW for fields of 1T at 1500rpm
- Extrapolation to 8 kW at 2000 rpm

➔Should be within the capabilities of water-cooled ILC target wheel

Power deposition in target

- Dependence on drive beam energy for a fixed collimator

W. Gai, BAW-2

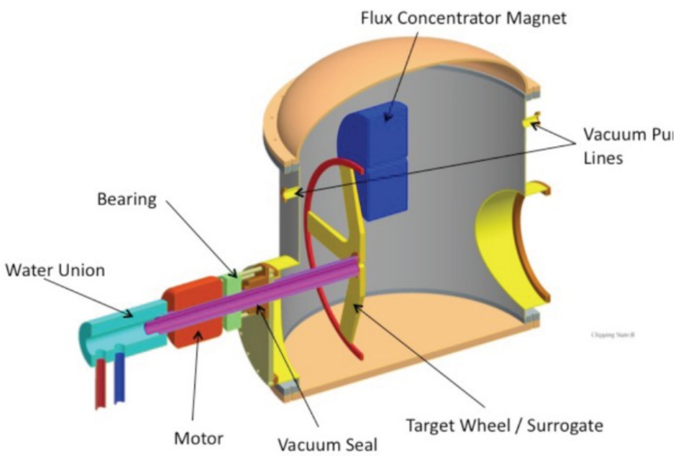
1.5 yield / 3e10 e+ captured	Ti target (ρ =4.5 g/cm^3)				
	Thickness for highest yield (X0)	Energy deposition (J/bunch)	Average power (KW)	Peak energy density	
				(J/cm^3)	(J/g)
150GeV,FC (137 m)	0.4	0.72	9.5	348.8	77.5
250GeV, FC (40 m)	0.4	0.342	4.5	318.8	70.8
150GeV, QWT (231 m)	0.4	1.17	15.3	566.7	126
250GeV, QWT (76 m)	0.4	0.61	8.01	568.6	126.4

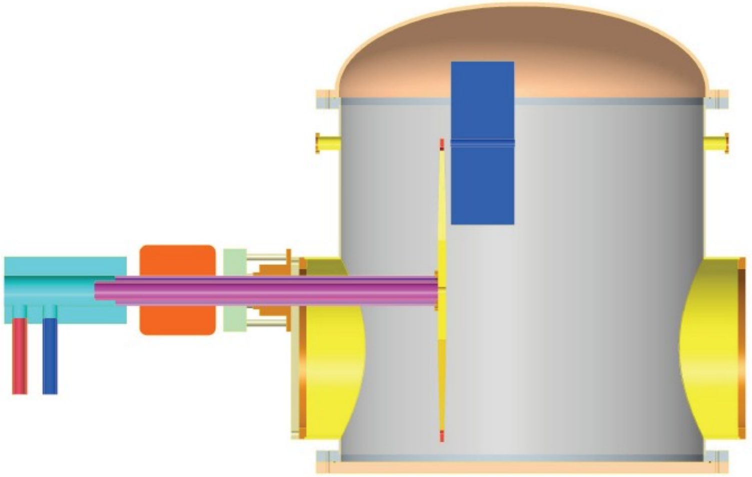
- Limit for peak energy density in Ti ?
- Shock wave studies (S. Hesselbach, L. Fernandez-Hernando et al.): see https://znwiki3.ifh.de/LCpositrons/TargetShockWaveStudy

Rotating Vacuum Seal Tests

- Test at LLNL:

http://ilcagenda.linearcollider.org/getFile.py/access?contribId=494&sessionId=83&resId=0&materialId=slides&confId=4507





Evaluating commercial ferrofluidic seals
- Leakage
- vibrations

Altered layout
- diagnostics setup, developing drawings
- acquire LLNL ES & H approval for operating plan

Optical Matching Device (OMD)

W. Gai, BAW-2

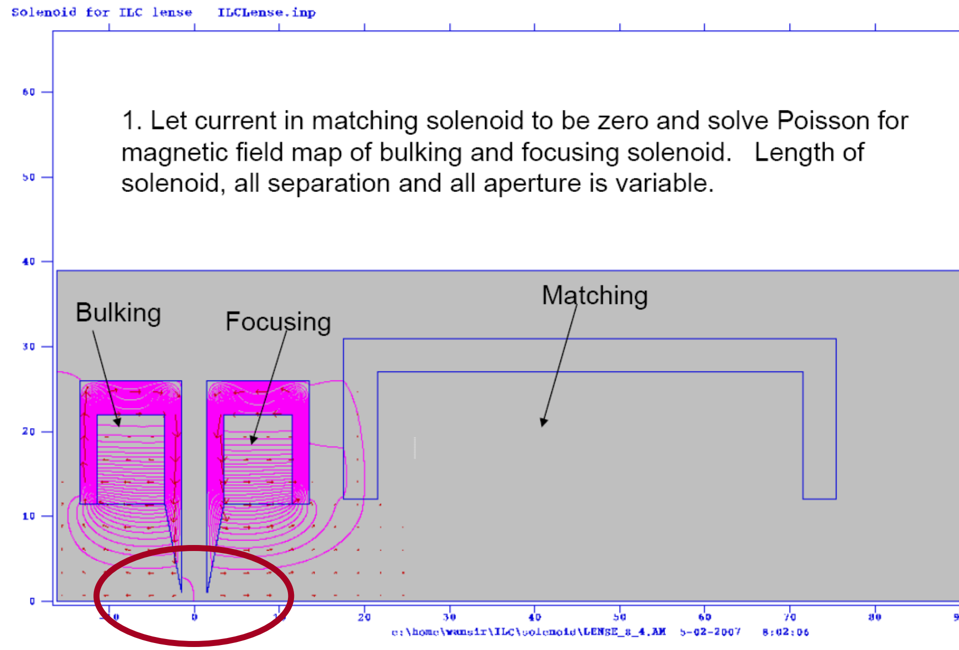
OMD	Capture efficiency
Immersed target, AMD (6T-0.5T in 20 cm)	~30%
Non-immersed target, flux concentrator (0-3.5T in 2cm, 3.5T-0.5T 14cm)	~26%
1/4 wave transformer (1T, 2cm)	~15%
0.5T Back ground solenoid only	~10%
Lithium lens	~29%

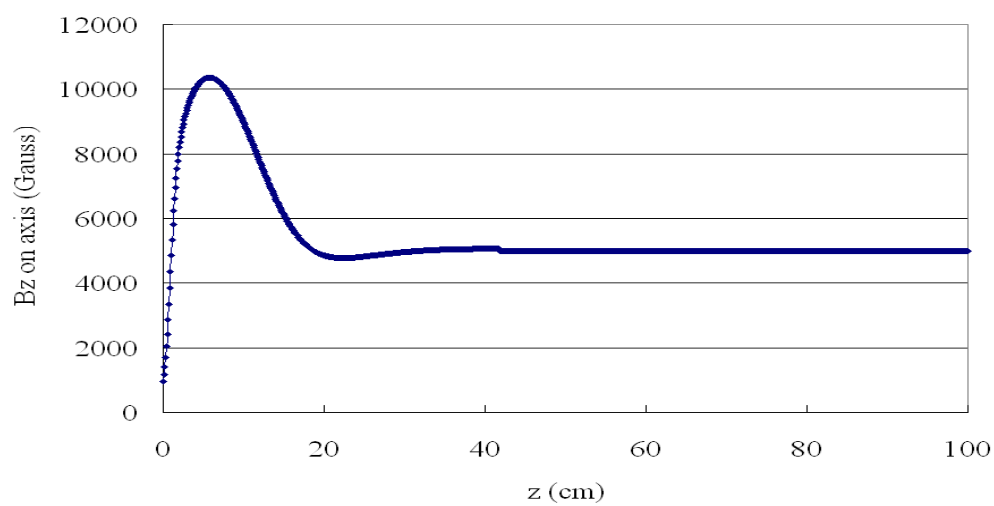
- Beam and accelerator phase optimized for each OMD
- Distance between target and OMD (QWT, FC) influences yield and also polarization

QWT

ANL ¼ wave solenoid simulations

Heat load can be high
→protection, cooling?

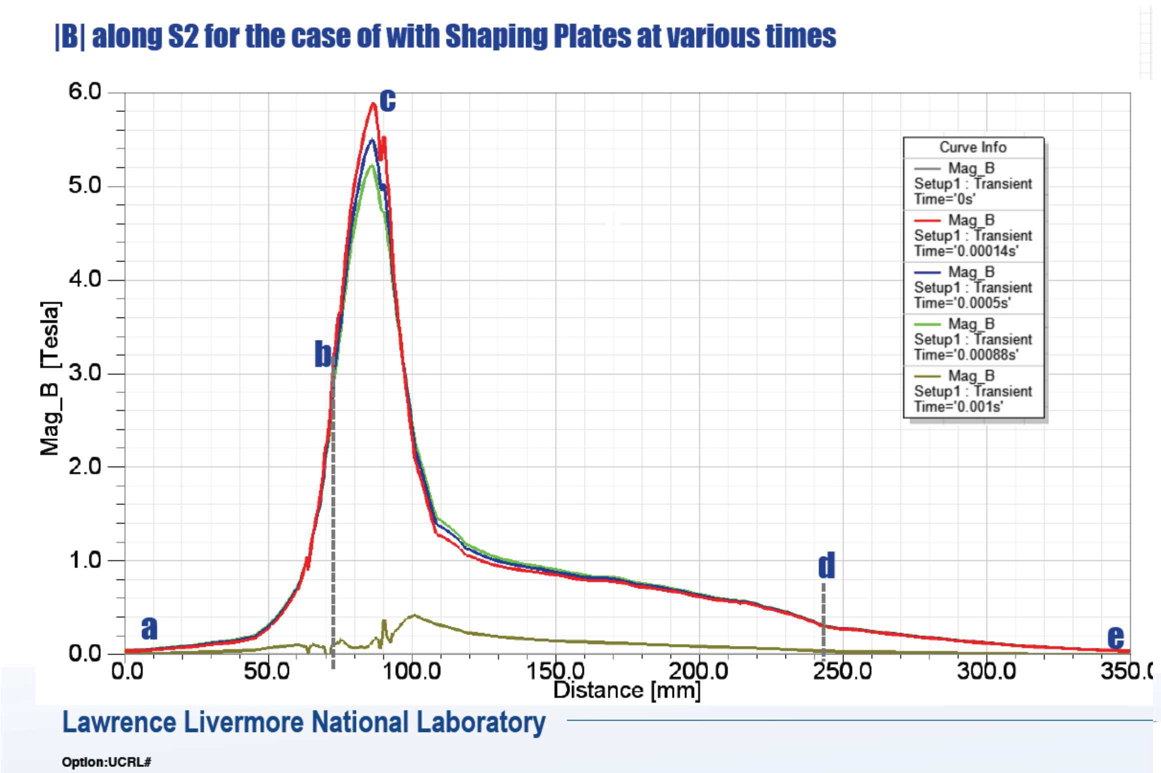


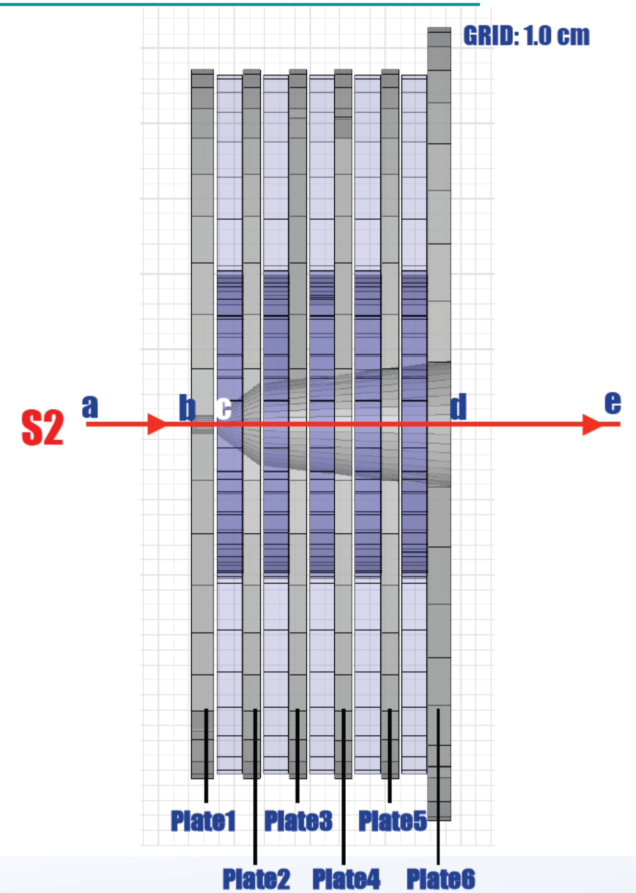


Flux concentrator

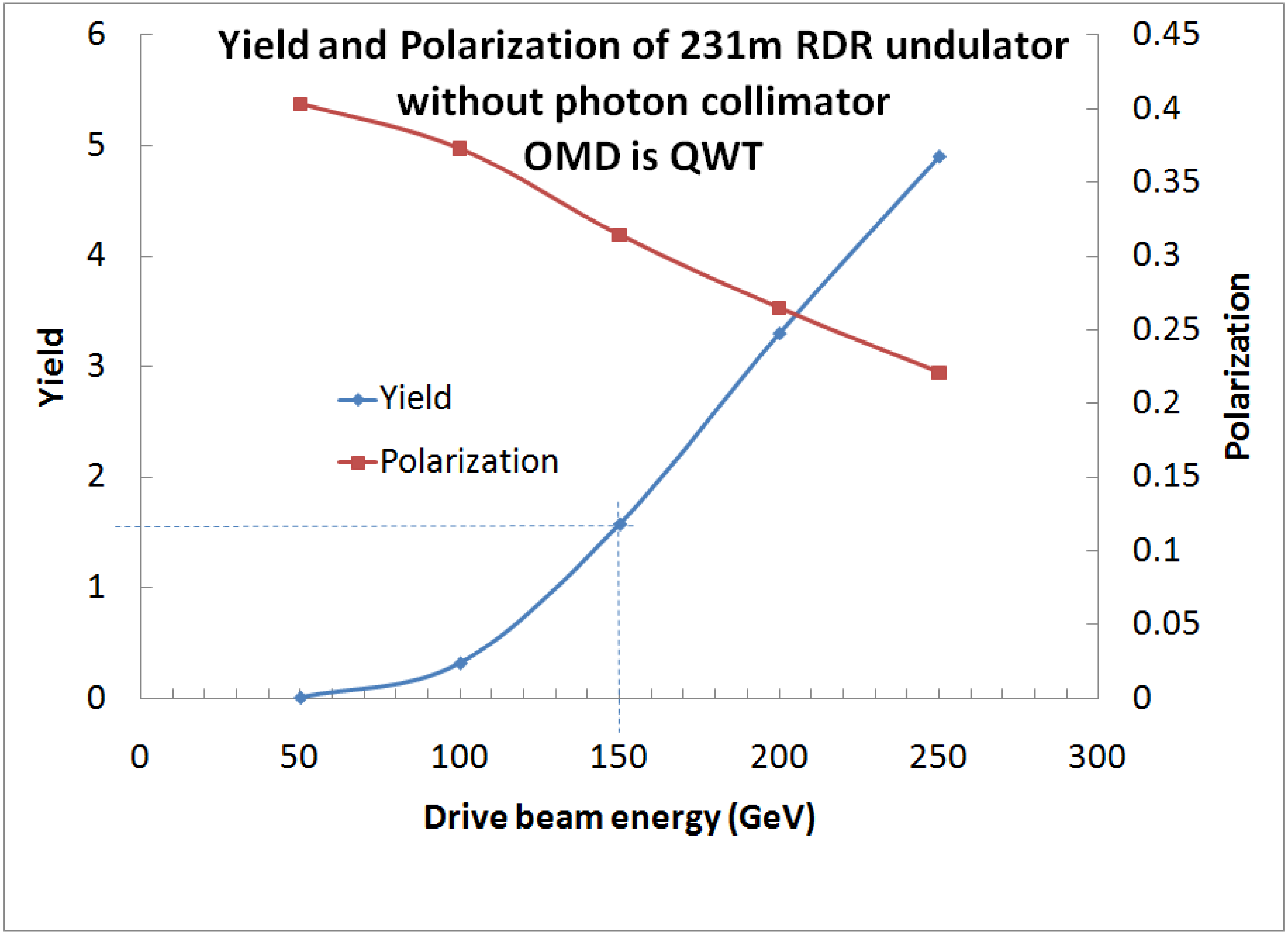
LLNL design (Gronberg, Piggott):

http://indico.desy.de/getFile.py/access?contribId=24&sessionId=1&resId=0&materialId=slides&confId=3061





Positron Yield and Polarization



Undulator + photon collimator

W. Gai, BAW-2

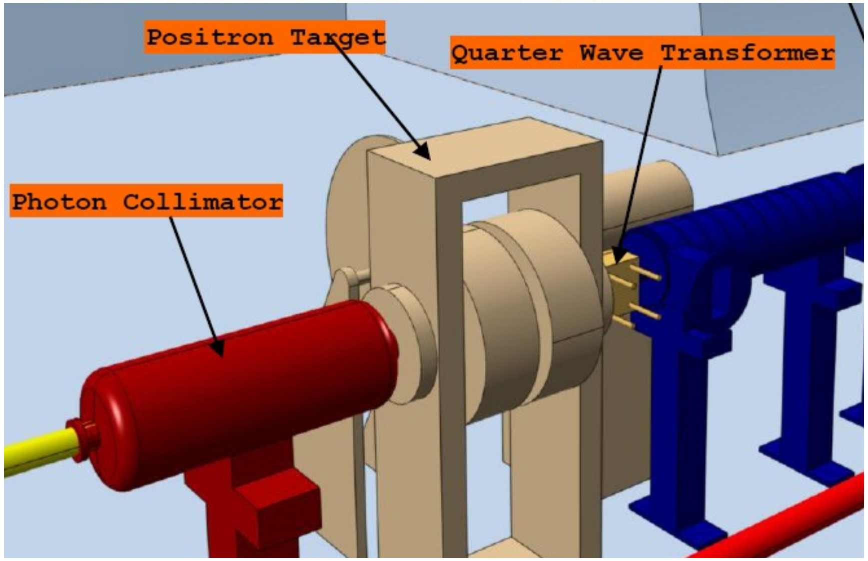
Drive beam energy	Energy loss per 100m	Energy loss for 1.5 yield	yield	polarization
100 GeV	~900 MeV	n/a	0.054	0.72
150 GeV	~2 GeV	~8.9 GeV	0.78	0.60
200 GeV	~3.6 GeV	~5.3 GeV	2.37	0.47
250 GeV	~5.6 GeV	~4.7 GeV	4.09	0.36

- 231m RDR undulator,
- ¼ wave transformer,
- radius of collimator: 0.17cm

Photon Collimator

Final Collimator design still missing

(Length, iris, material, cooling)

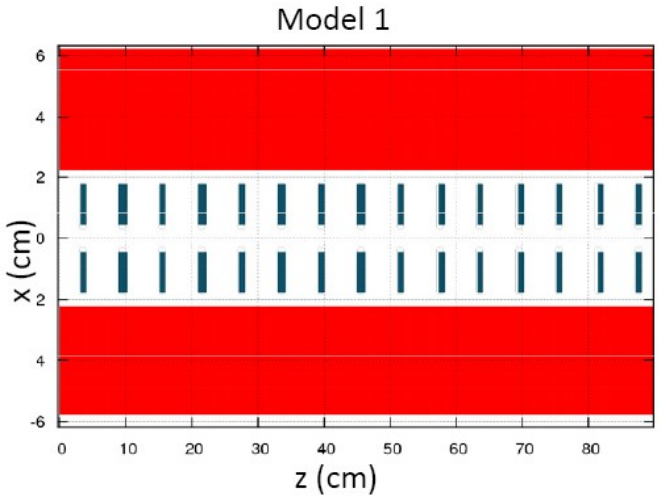


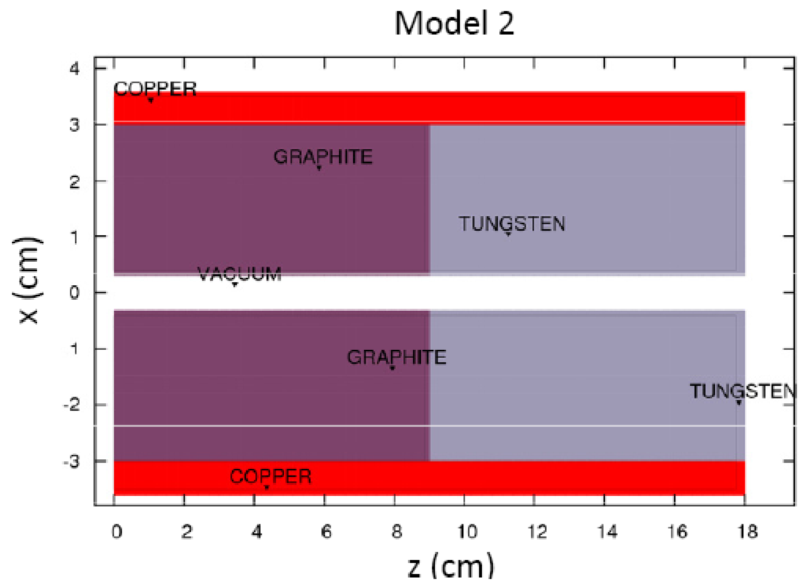
Collimator designs considered:

- **I. Bailey, L. Zang, A. Wolski,** http://www.ippp.dur.ac.uk/export/sites/IPPP/LCsources/PhotonCollimator/MO6RFP093.pdf
- **A. Mikhailichenko, EPAC2006,** http://accelconf.web.cern.ch/accelconf/e06/PAPERS/MOPLS105.PDF

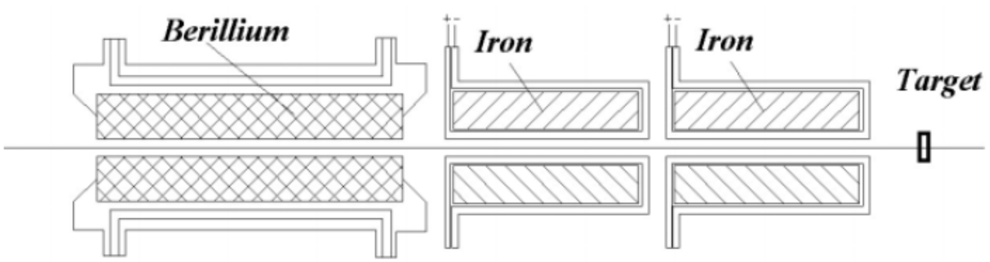
Collimator Designs

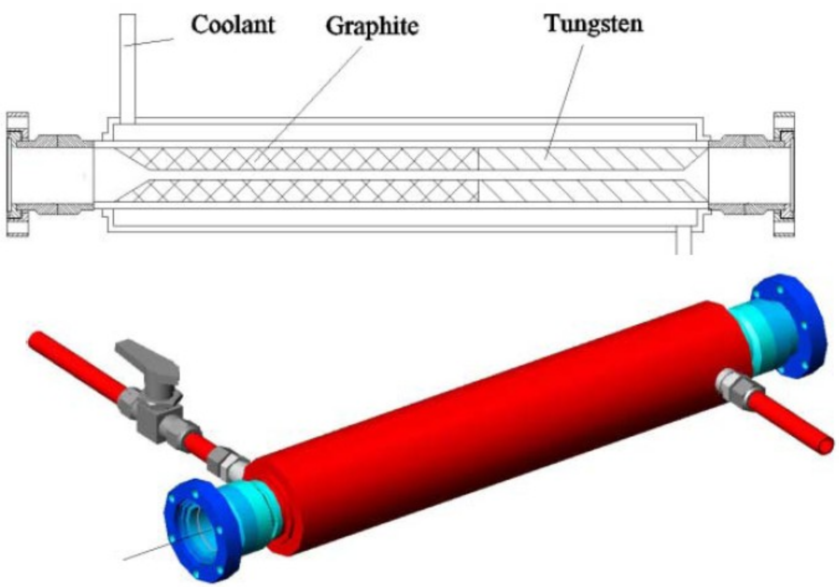
- Bailey, Wolski, Zang:





- Mikhailichenko



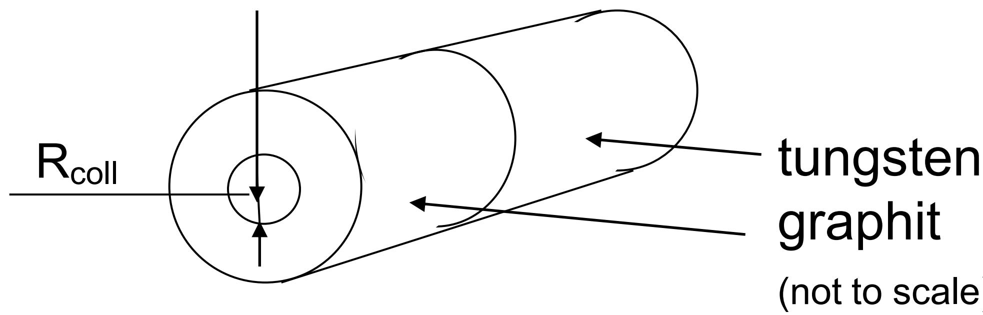


Positron polarization and SB2009

Energy deposition in photon collimator

- Rough estimate of total energy deposition (E_{dep}) and peak energy deposition density (PEDD) in photon collimator (normalization 1.5e+/e-), using AMD
- Simplified collimator design:

(similar to Bailey, Zang, Wolski)



	E=150GeV 2820 bunches/pulse		E=250GeV 1312 bunches/pulse	
R_{coll} [mm]	—	2.3	2	1.35
P[%]	34	45	30	45
E_{dep} [kW]	—	19.3	2.7	10.7
PEDD [J/(g·pulse)]	—	**290**	38.5	**200**
ΔT_{max} [K]/pulse in **tungsten**	—	**2150**	290	**1440**

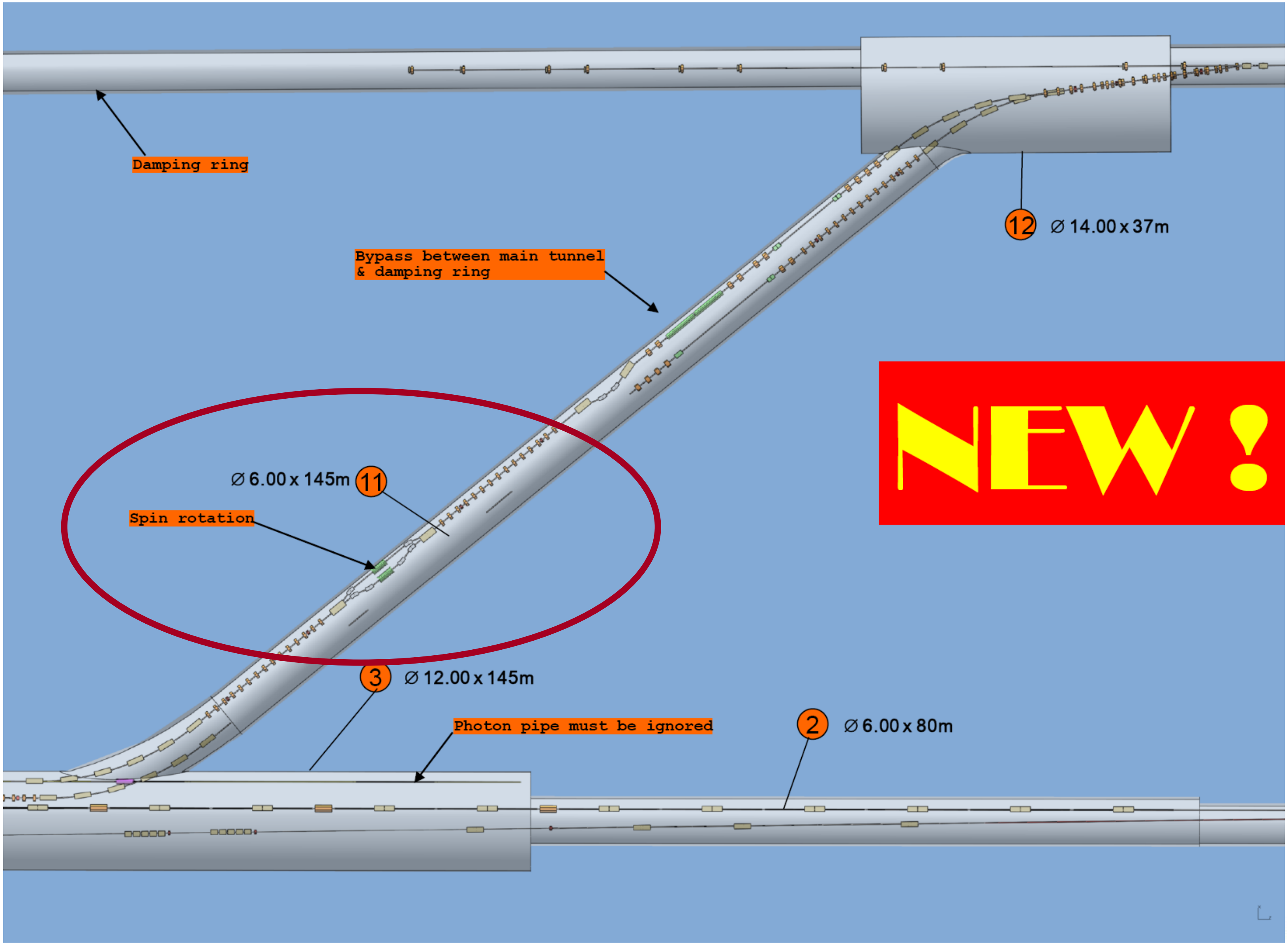
Ushakov

Summary Parameters

Parameter	RDR	SB2009	Units
e+ per bunch at IP	2 x 1010	1 to 2 x 1010	
Bunches per pulse	2525	1312	
e+ energy (DR injection)	5	5	GeV
DR transverse acceptance	0.09	0.09	m-rad
DR energy acceptance	±0.5	± 0.5	%
e- drive beam energy	150	125-250	GeV
e- energy loss in undulator	3.01	0.5-4.9	GeV
Undulator period	11.5	11.5	mm
Undulator strength	0.92	0.92	
Active undulator length	147 (210 after pol. Upgrade)	231 max.	m
Field on axis	0.86	0.86	T
Beam aperture	5.85	5.85	mm
Photon energy (1^{st} harm.)	10	1.1 (50 GeV) 28 (250 GeV)	MeV
Photon beam power	131	Max: 102 at 150 GeV	kW
Target material	Ti-6%Al-4%V	Ti-6%Al-4%V	
Target thickness	14	14	mm
Target power adsorption	8	8	%
PEDD in target			
Dist. Undulator center - target	500	500	m
e+ Polarization	34	22	%

Spin Rotation

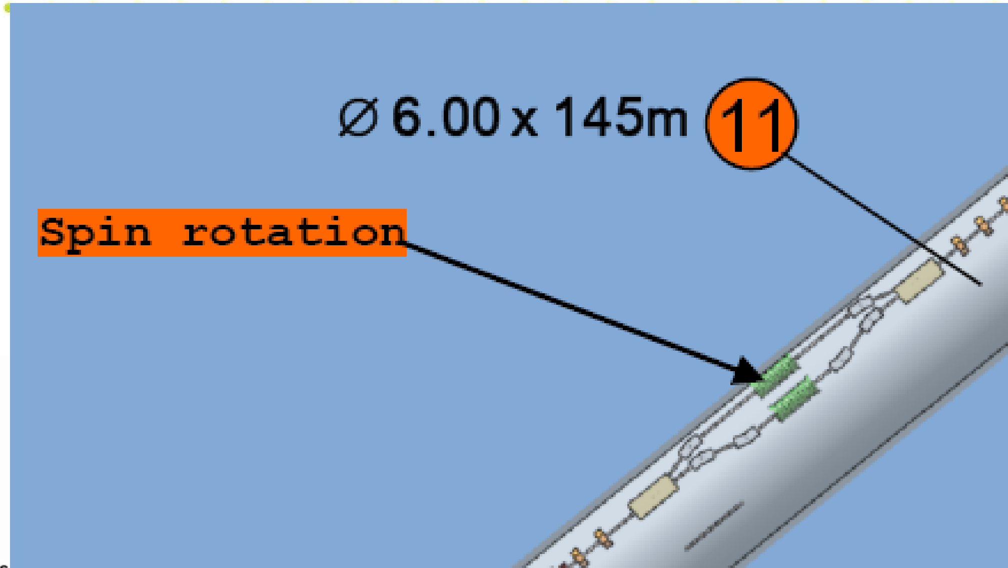
Spin Rotation

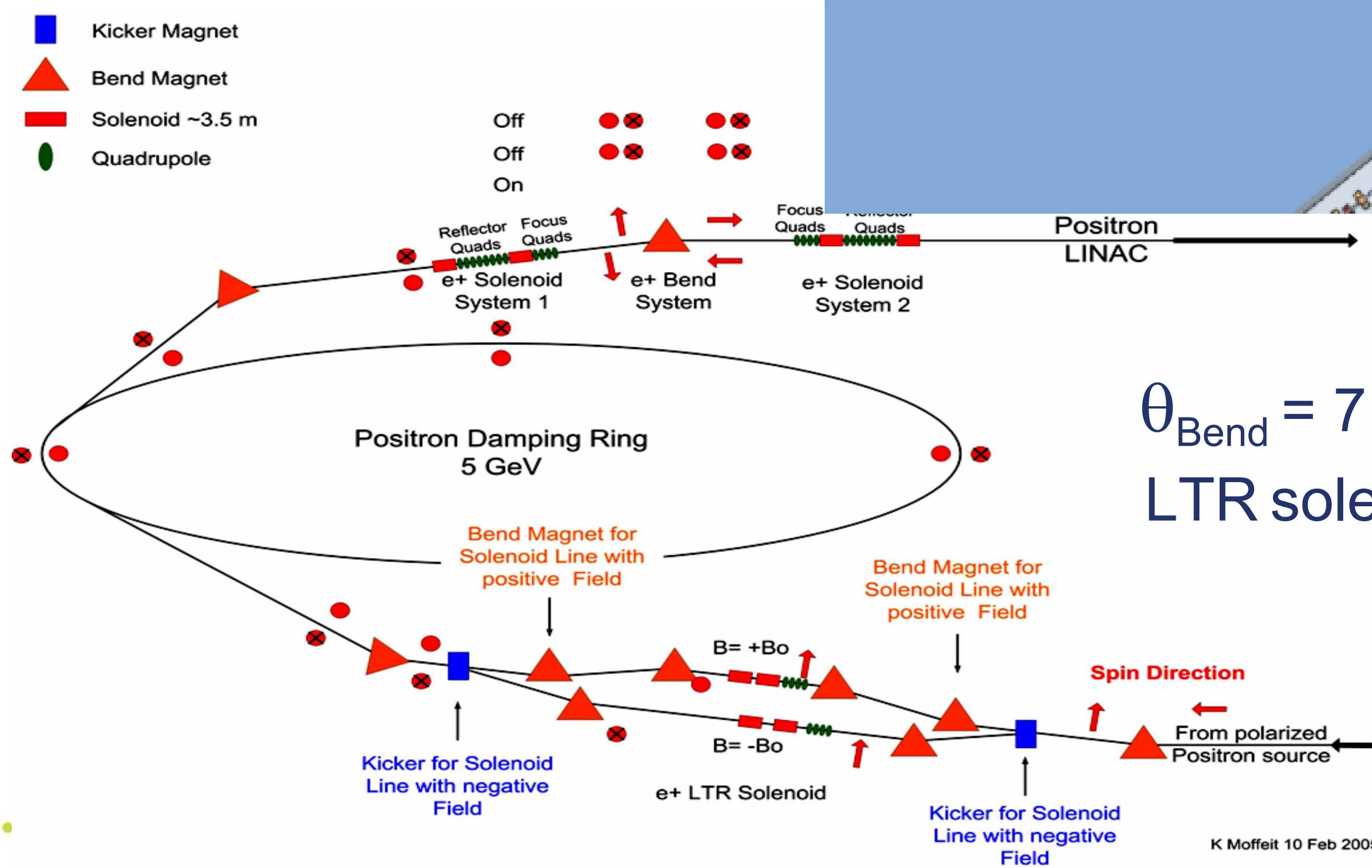


Spin Rotation

K. Moffeit et al., SLAC-TN-05-045

→ Spin rotation and fast reversal before DR (5 GeV)





$\theta_{Bend} = 7.93^{o}$

LTR solenoid: 26.2 Tm

Accelerator elements

- RDR:

TABLE 2.3-3
Total number of components in the Positron Source.

Magnets	#	Instrumentation	#
Dipoles	157	BPM x,y pairs	922
NC quads	871	BPM readout channels	922
SC quads	51	Wire scanners	29
Sextupoles	32	Beam length monitors	2
NC solenoids	38	Profile monitors	7
SC solenoids	2	Photon profile monitors	3
NC correctors	871		
SC correctors	102	RF	#
Kickers	15	NC L-band structures	30
Septa	4	1.3 GHz SC cavities	200
SC undulator cryomodules	42	1.3 GHz cryomodules	26
OMD	2	1.3 GHz klystrons/modulators	37

- And SB2009 ???

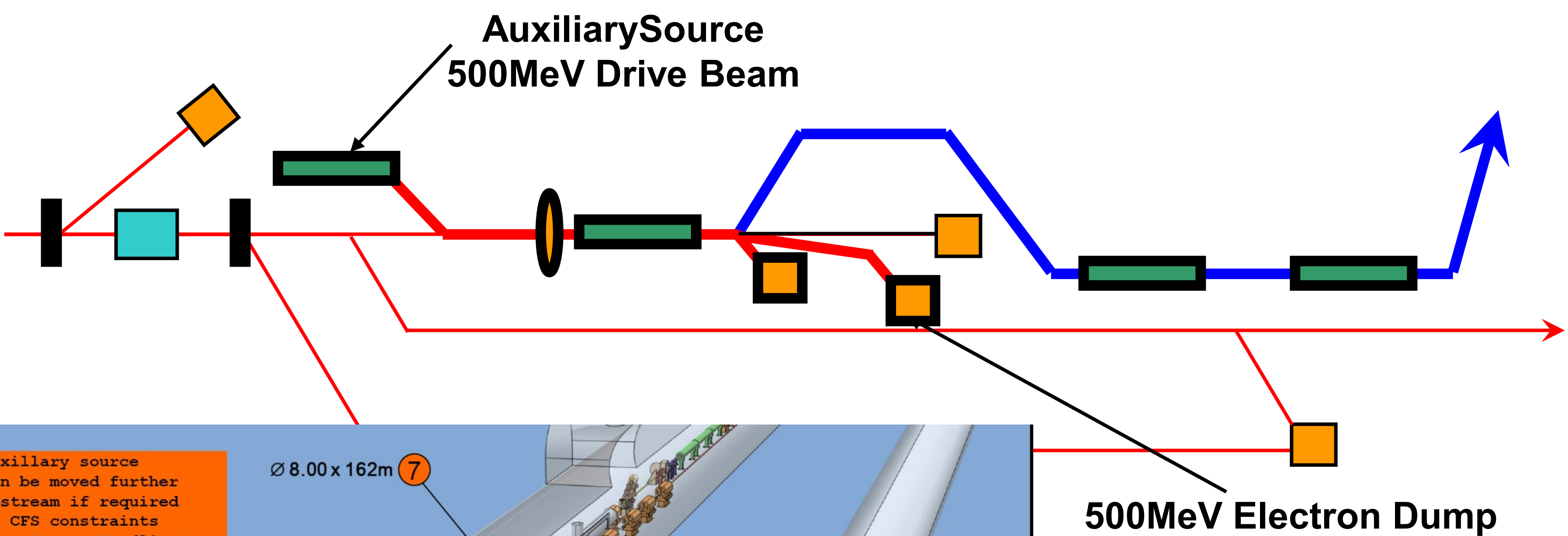
- Y. Batygin: Spin rotation and energy compression in the ILC Linac-to-Ring positron beamline

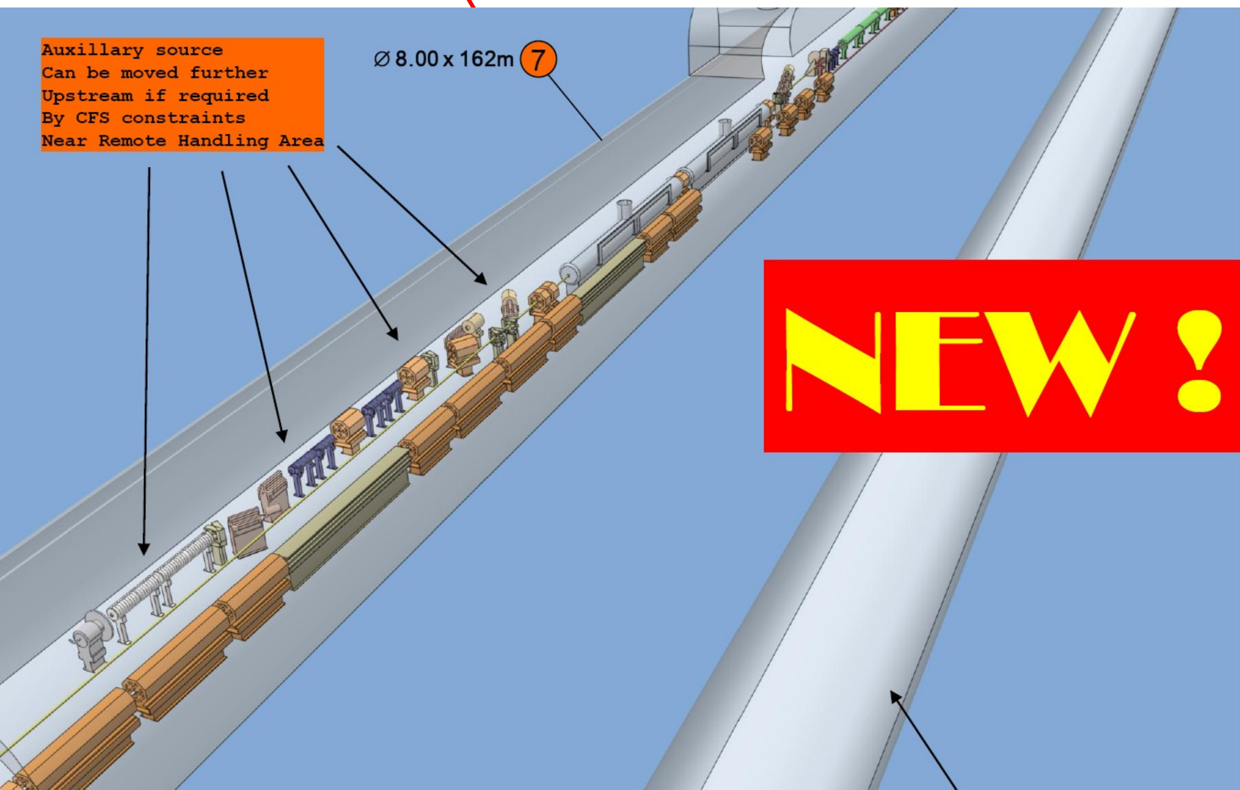
  Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 570, Issue 3, 21 January 2007, Pages 365-373, http://www.sciencedirect.com/science/article/B6TJM-4MBJX10-3/2/668bf016f9f824104547b5f6d723adda

- Zhou, Batygin, Nosochkov, Sheppard, Woodley; Start-to-end beam optics development and multi-particle tracking for the ILC undulator-based positron source. SLAC-PUB-12239. http://www-public.slac.stanford.edu/sciDoc/docMeta.aspx?slacPubNumber=slac-pub-12239

- Auxilary Source
- Beam Dumps
- Radiation Aspects

Auxiliary Source Mode





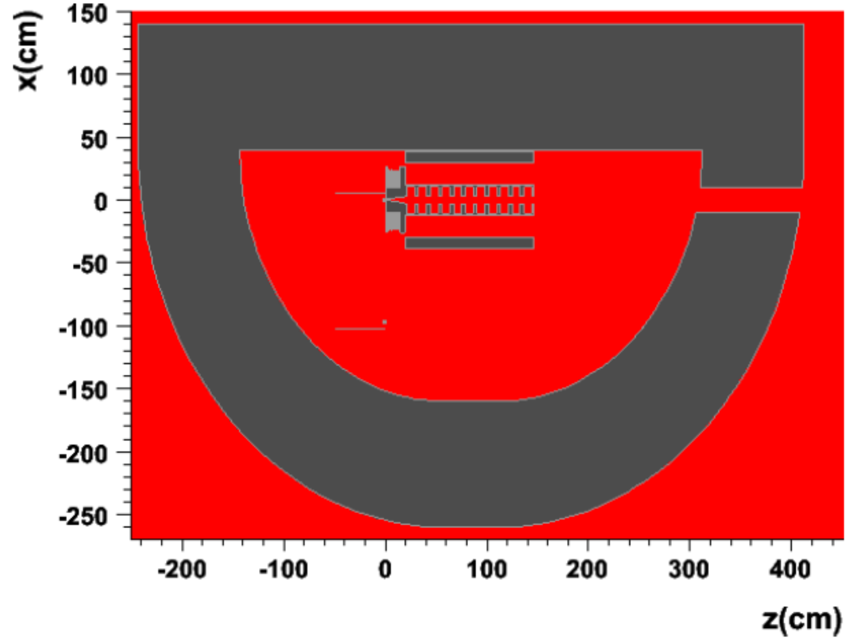
Beam dumps in Central Region

- Abort dump upstream undulator
- Photon beam dump
- Low energy e- dump
- 500MeV e- dump (aux. source)
- High energy beam dump

Beam dumps for e+ source: nothing new since RDR

Radiation

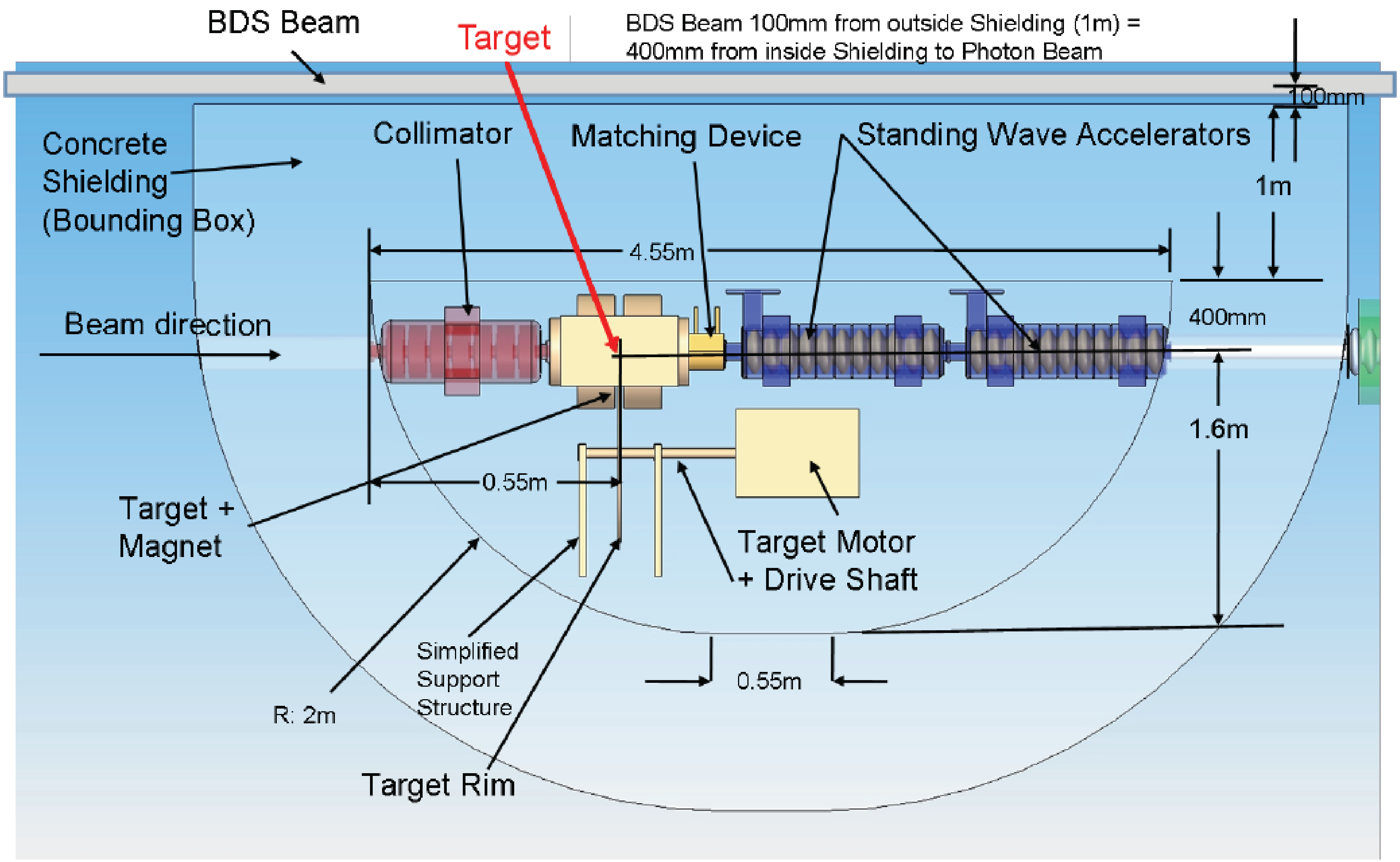
Positron Source Meeting, Daresbury, Oct. 2009



- Estimations of dose rates for different OMD options give similar results (the highest rate is for QWT)
- Residual dose rates have been calculated for ordinary and heavy concretes:
  - 1 m thick ordinary concrete shielding is not sufficient,
  - heavy concrete shielding with thickness $\sim$80 cm should be enough

Concrete Shielding Sketch

provided by Norbert Collomb, Neil Bliss (Science & Technology Facilities Council)



Summary

- Undulator:
  - **ok, except new improved parameter considerations**
- Collimator
  - **Final design missing**
  - **Problem: heat load (shock waves?)**
- Target
  - **Vacuum seal tests**
  - **Shock wave studies**
  - **Remote handling – update?**
- OMD
  - **FC design ⇔ LLNL**
- Accelerating structures
- Spin rotation and helicity reversal
- Radiation aspects, remote handing
- Dumps

Backup

Positron System Schematic Layout (SB2009)

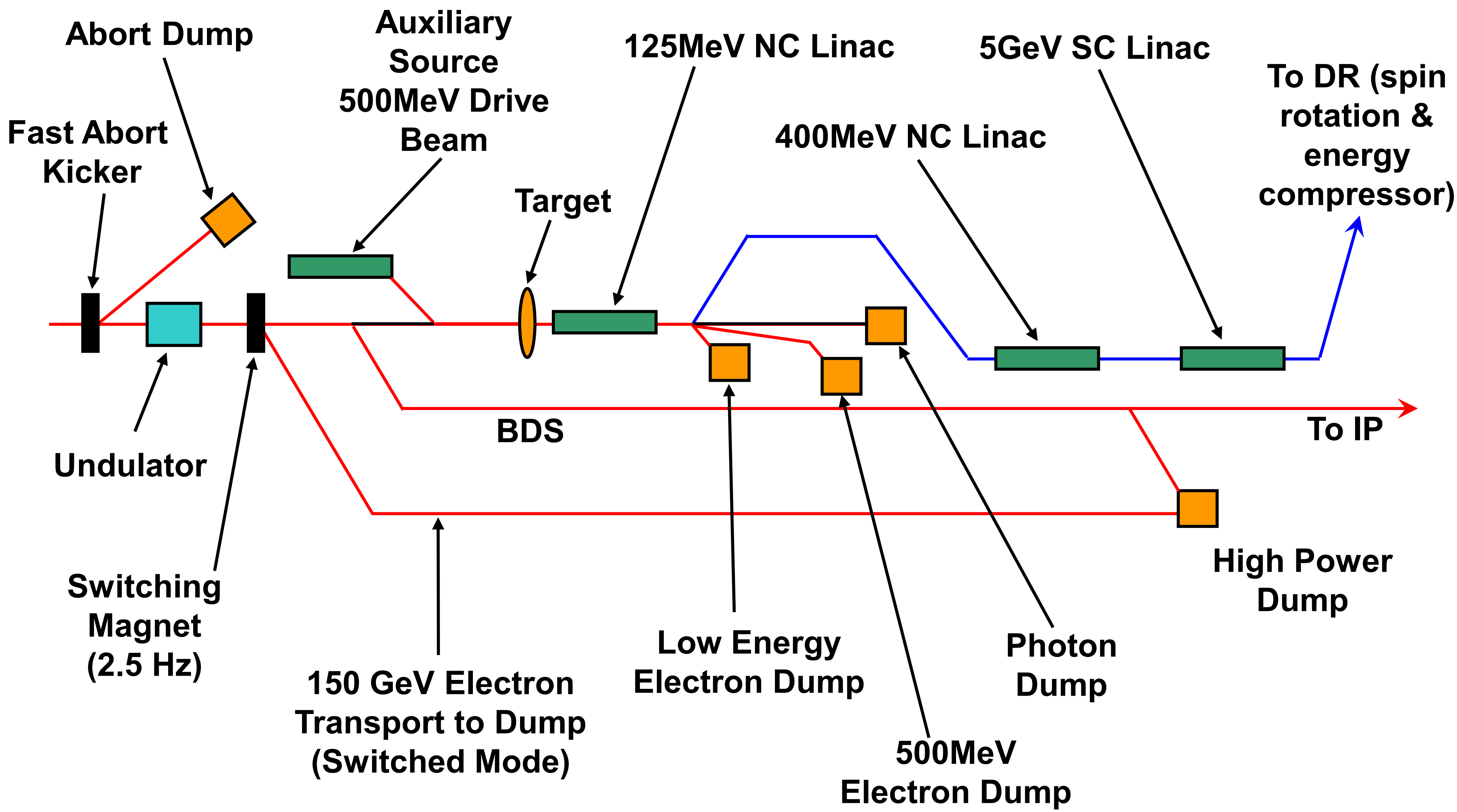


Table 4.7.1: RDR parameter plane ranges compared to SB2009 specifications (TF refers to Travelling Focus). This table is reproduced from Section 2.4.

		RDR			SB2009	
		min	nominal	max	no TF	with TF
Bunch population	$\times 10^{10}$	1	2	2	2	2
Number of bunches		1260	2625	5340	1312	1312
Linac bunch interval	ns	180	369	500	530	530
RM bunch length	µm	200	300	500	300	300
Normalized horizontal emittance at IP	mm-mr	10	10	12	10	10
Normalized vertical emittance at IP	mm-mr	0.02	0.04	0.08	0.035	0.035
Horizontal beta function at IP	mm	10	20	20	11	11
Vertical beta function at IP	mm	0.2	0.4	0.6	0.48	0.2
RMS horizontal beam size at IP	nm	474	640	640	470	470
RMS vertical beam size at IP	nm	3.5	5.7	9.9	5.8	3.8
Vertical disruption parameter		14	19.4	26.1	25	38
Fractional RMS energy loss to beamstrahlung	%	1.7	2.4	5.5	4	3.6
Luminosity	$\times 10^{34}$ cm^{-2}s^{-1}	2			1.5	2