Positron Source Update

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ASTeC & Cockcroft Institute
Daresbury Laboratory

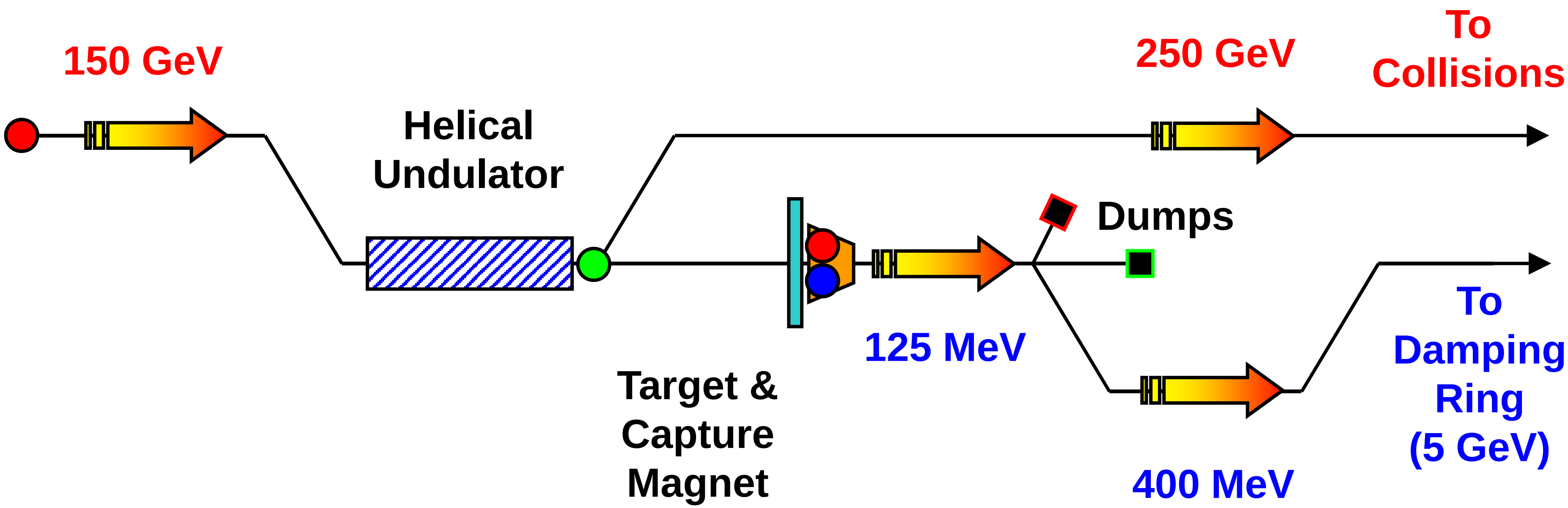
ILC 08, University of Illinois at Chicago,
17th November 2008

Overview

- General update on ILC positron source
- Many slides taken from Positron Source Workshop held at the Cockcroft Institute, Daresbury in October 2008 (http://www.ilcp.dl.ac.uk/home.html)
- The minimum machine
  - ➔ implications for the positron source

Positron Source Layout

Accelerator Science and Technology Centre



- **10MeV+ photon beam** generated in helical undulator by **150 GeV electrons**
- Photon beam travels ~400 m beyond undulator and then generates e^+e^- pairs in **titanium alloy target**
- Positrons captured and accelerated to 125 MeV
- Any electrons and remaining photons are then separated and dumped
- Positrons further accelerated to **400 MeV and transported for ~5km**
- Accelerated to 5 GeV and **injected into Damping Ring**

Undulator Details

- Several **short prototypes** have been tested
- Focus now on design, manufacture and testing of a **full cryomodule**
- Daresbury & Rutherford Appleton Laboratories have built a full scale **4m undulator** module
- Cornell have had a similar program of building short prototypes and intended to build a full cryomodule

Undulator Parameters	Symbol	Value	Units
Undulator period	λ	1.15	cm
Undulator strength	K	0.92	
Undulator type		helical	
Active undulator length	L_u	147	m
Field on axis	B	0.86	T
Beam aperture		5.85	mm
Photon energy (1st harmonic cutoff)	E_{c10}	10.06	MeV
Photon beam power	P_γ	131	kW

ASTeC

1.75m Undulator Fabrication

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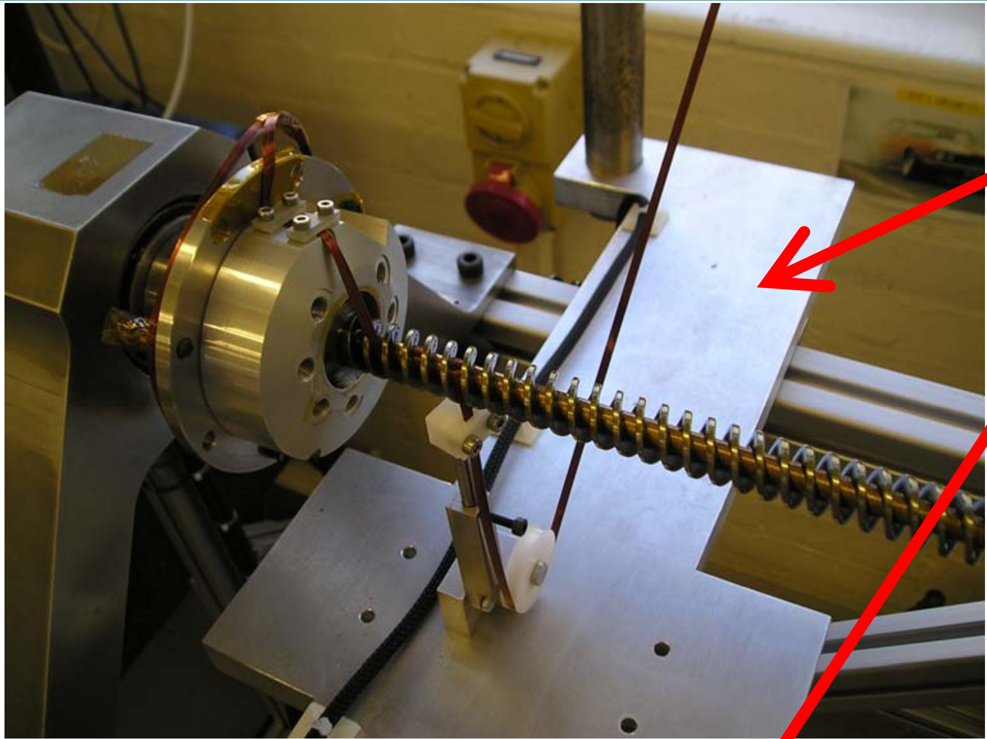
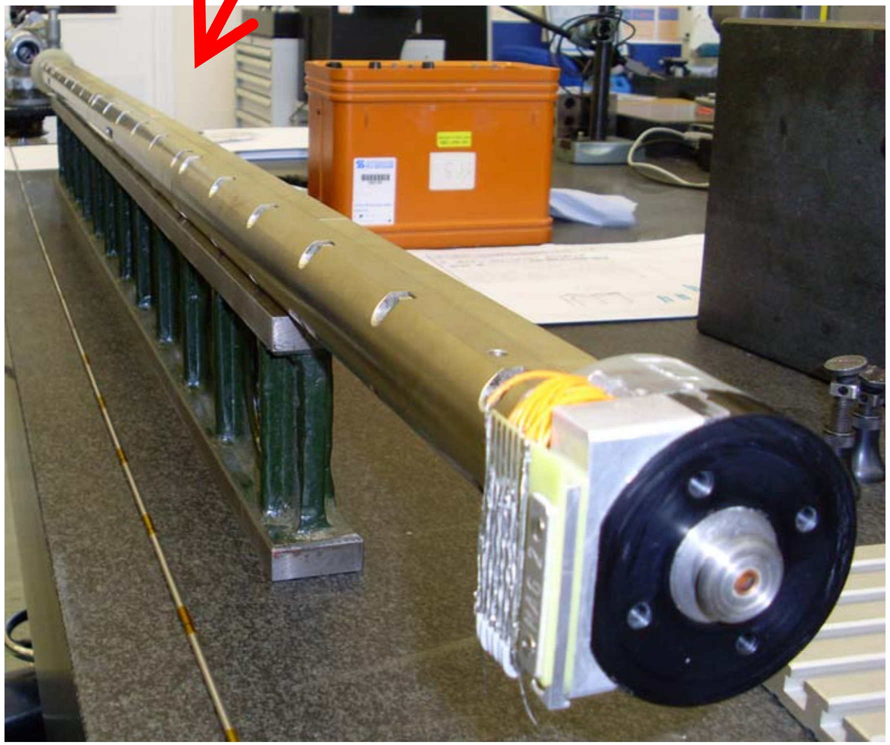


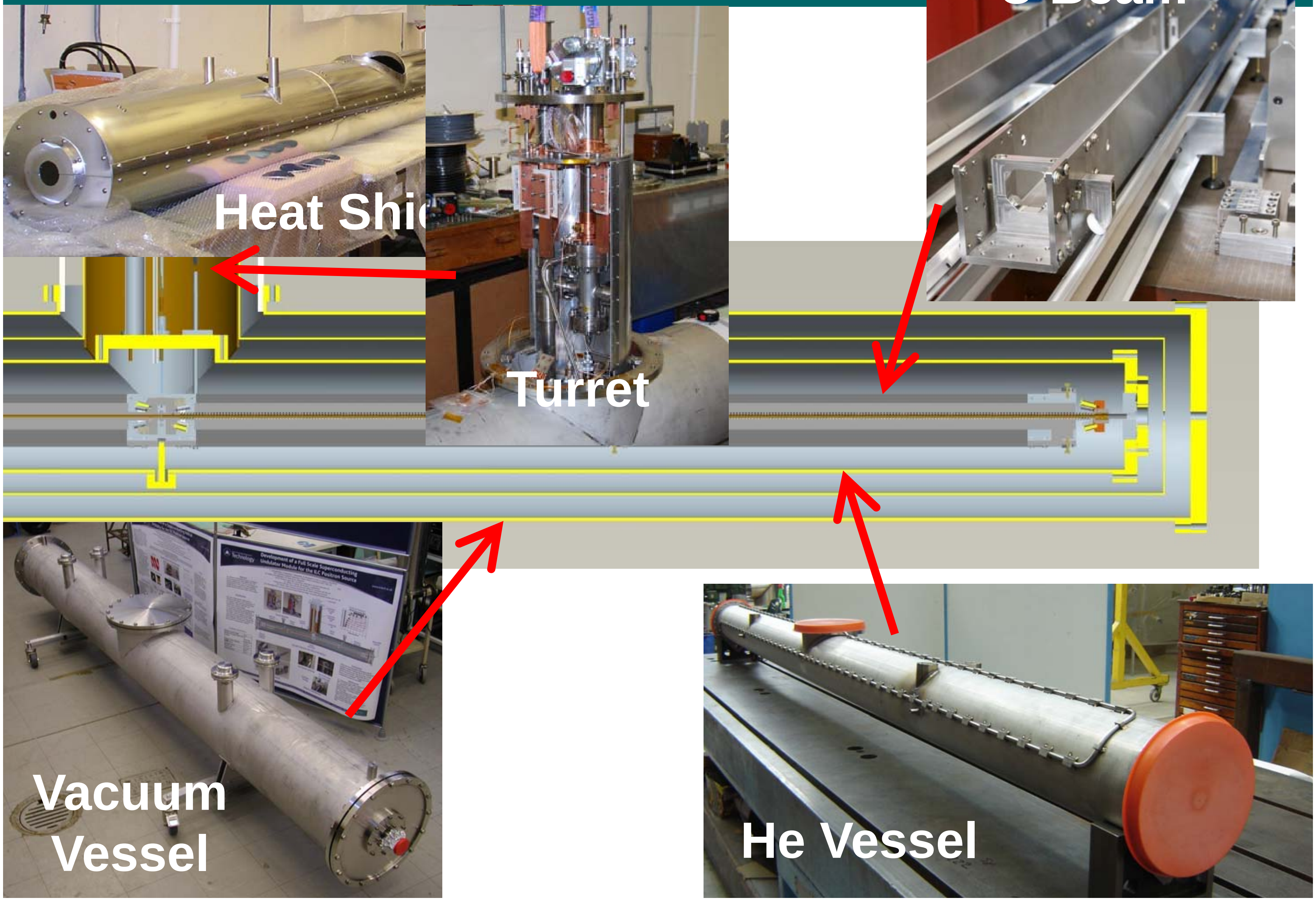
Winding

Potted and in one half of steel yoke

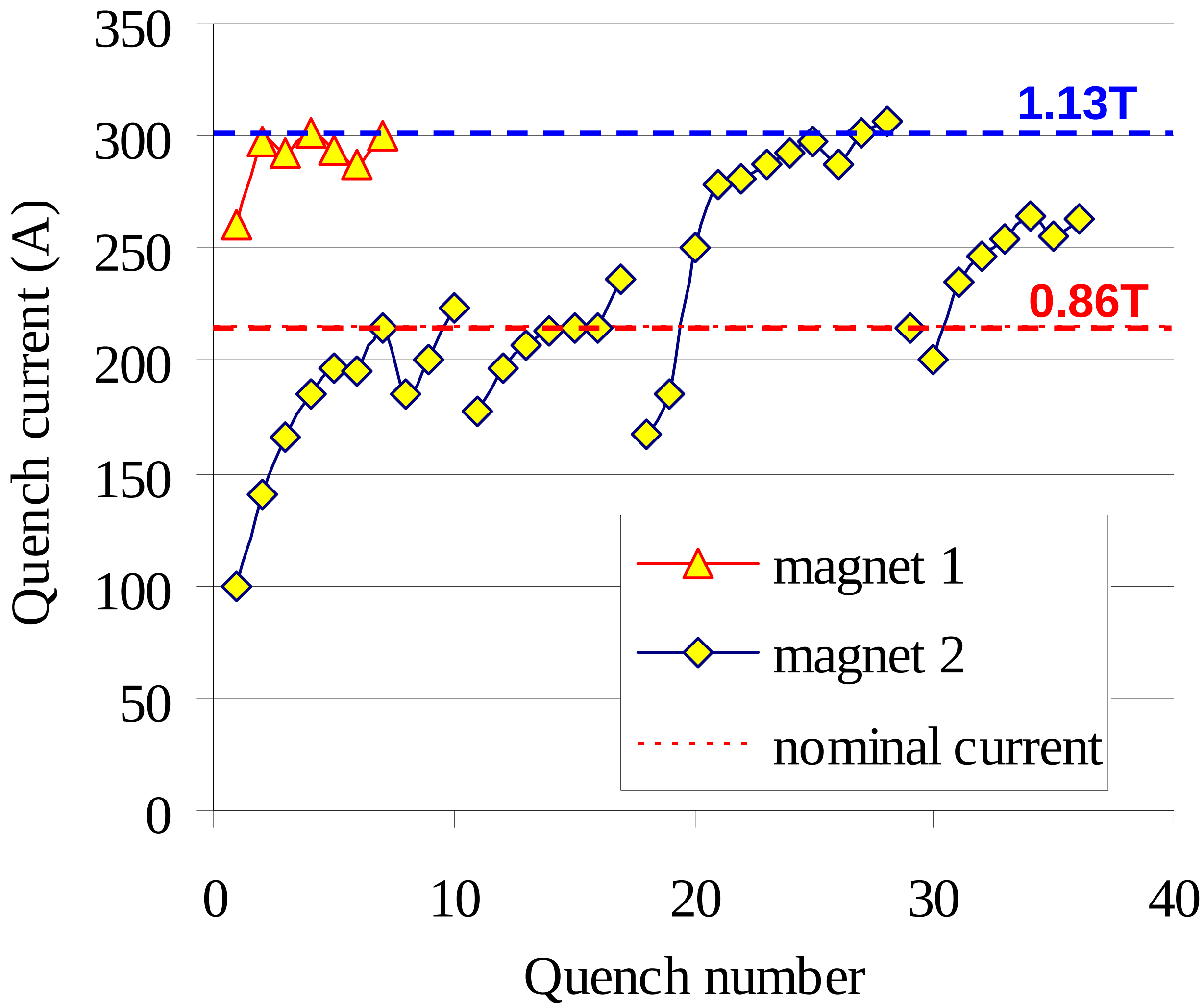
Complete magnet



4m Cryomodule Fabrication



Quench Training Data



Both long undulators have **exceeded the design current** (216 A) by **~40%.**

The two nominally identical magnets have quite different behaviours – the reason is **not understood.**

J.A. Clarke et al, EPAC 08

The Target

- Several materials have been considered for the conversion target
- **Titanium alloy** selected as has greatest safety margin
- Need to ***rotate*** target to reduce local radiation damage and thermal effects (**1m diameter** selected)
- Positron capture enhanced by magnetic field but **eddy current** effects limit field level
- **Rim & spokes** not solid disk to help mitigate these eddy current effects

Target Parameters	Symbol	Value	Units
Target material		Ti-6%Al-4%V	
Target thickness	L_t	0.4 / 1.4	r.l. / cm
Target power adsorption		8	%
Incident spot size on target	σ_i	> 1.7	mm, rms

Eddy Current Experiment

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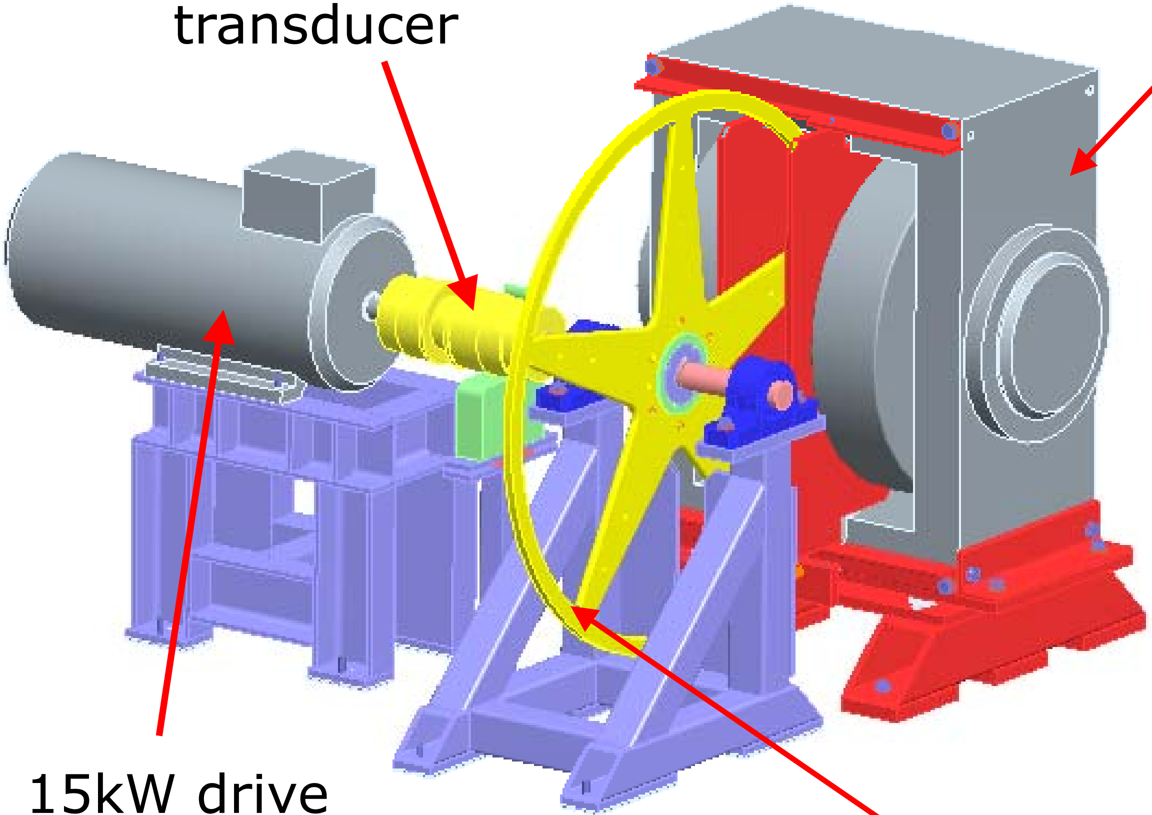
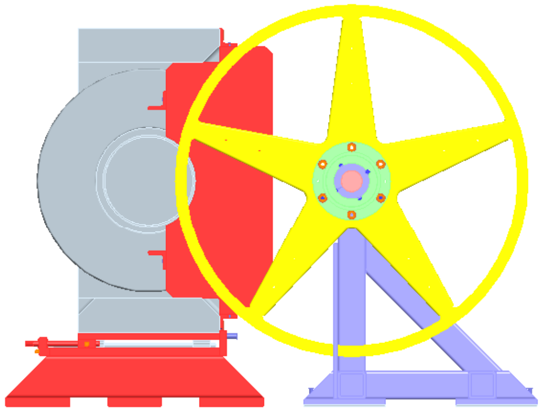
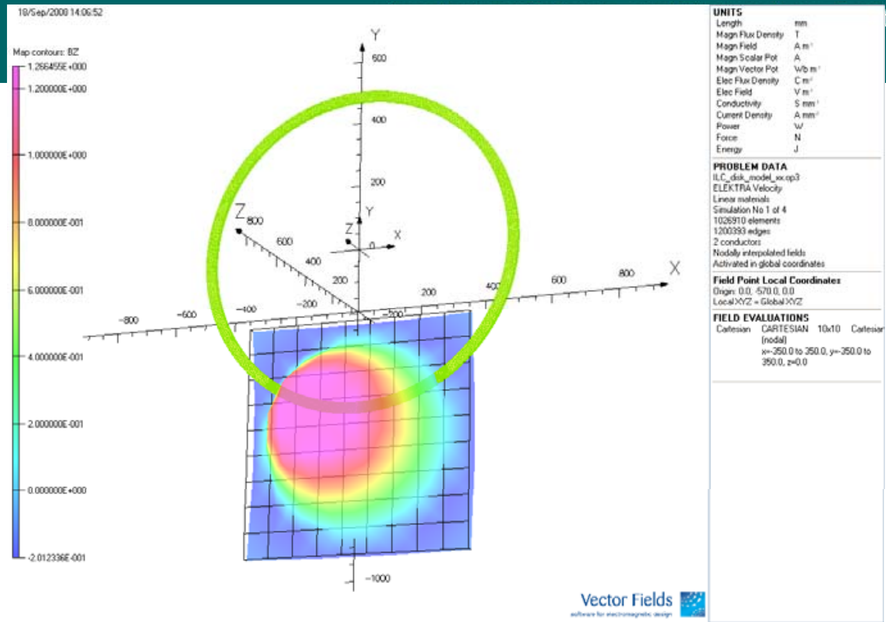
Experiment initiated at Cockcroft Institute/Daresbury Laboratory to monitor ***eddy current*** effects and ***mechanical stability*** of full size wheel at design velocity

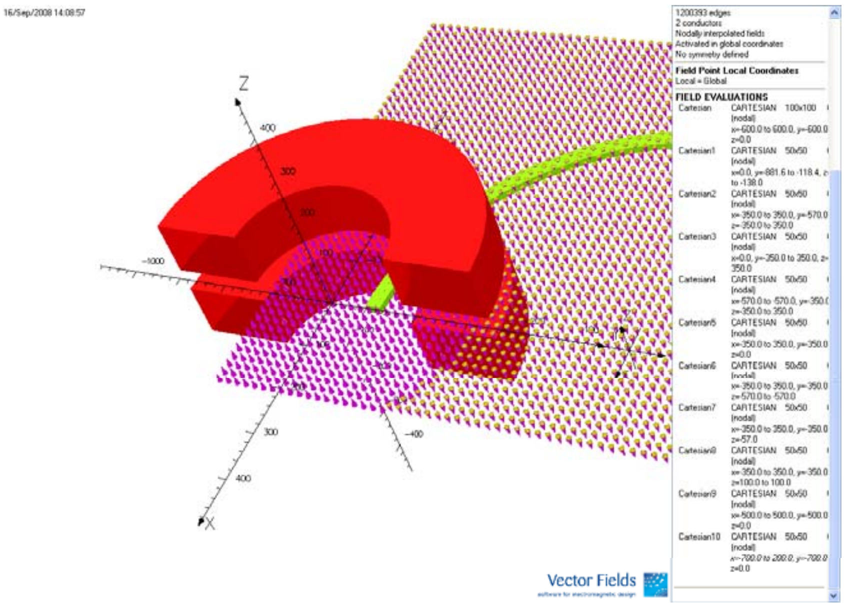


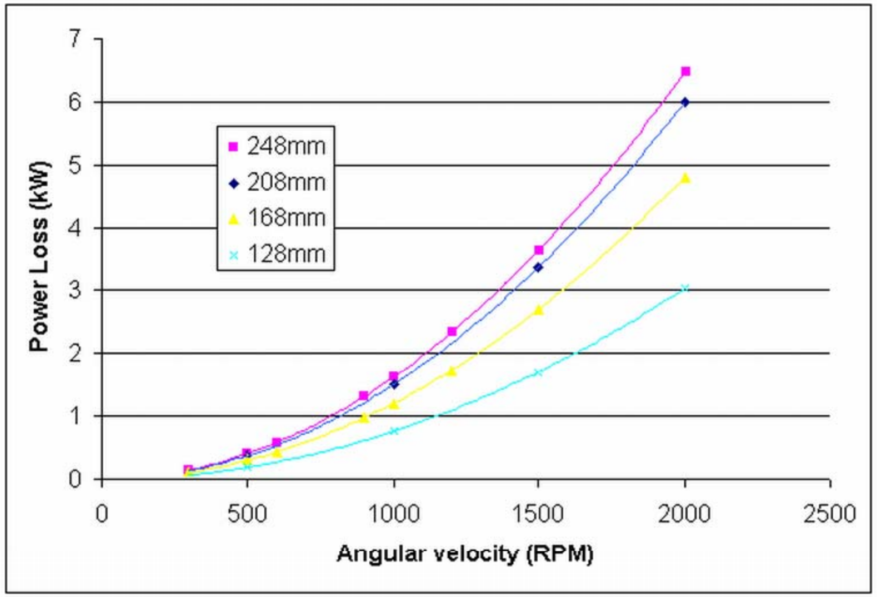


I Bailey et al, EPAC 08

- Magnetic simulations at DL
- Opera (Vector Fields) with Elektra rotation solver
- Magnet modelled as two coils
- **Eddy current power losses and reactive forces are calculated**
- Superceded by work at RAL…



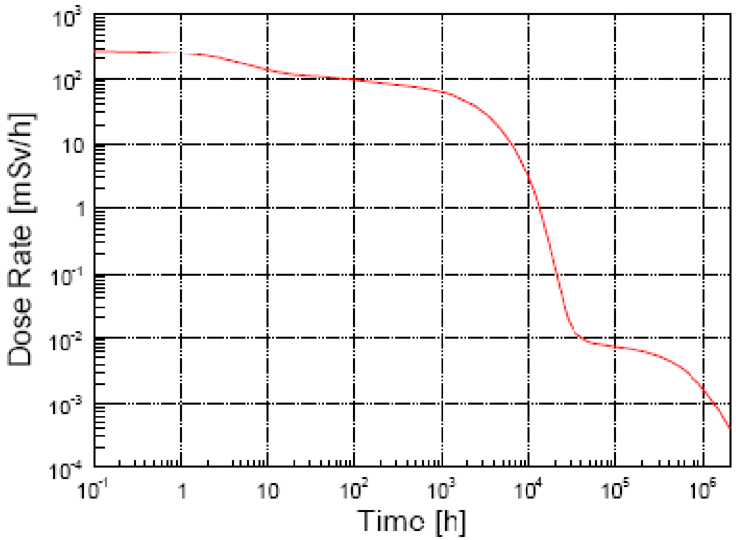




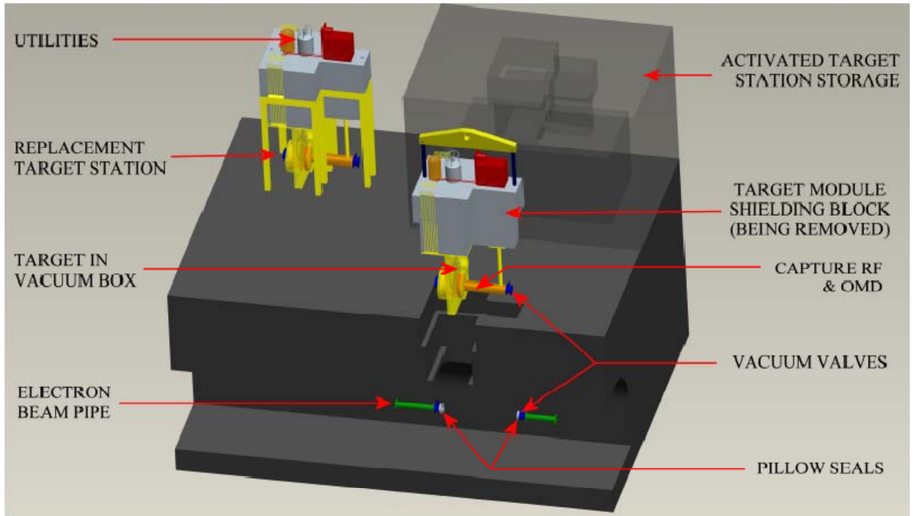
L Jenner

Target Activation

- Equivalent dose rate calculated after **5000 hours** of operation at **1m** from the source
- **Remote handling** required so can exchange target modules rapidly
- No intention to make in-situ repairs of the target



	Conventional	Undulator Based
after Source Switch-Off	700	280
after 1 hour	628	248
after 1 day	574	111
after 1 week	469	86



A. Ushakov, EPAC 08

Shielding around Target

Modification of Model:

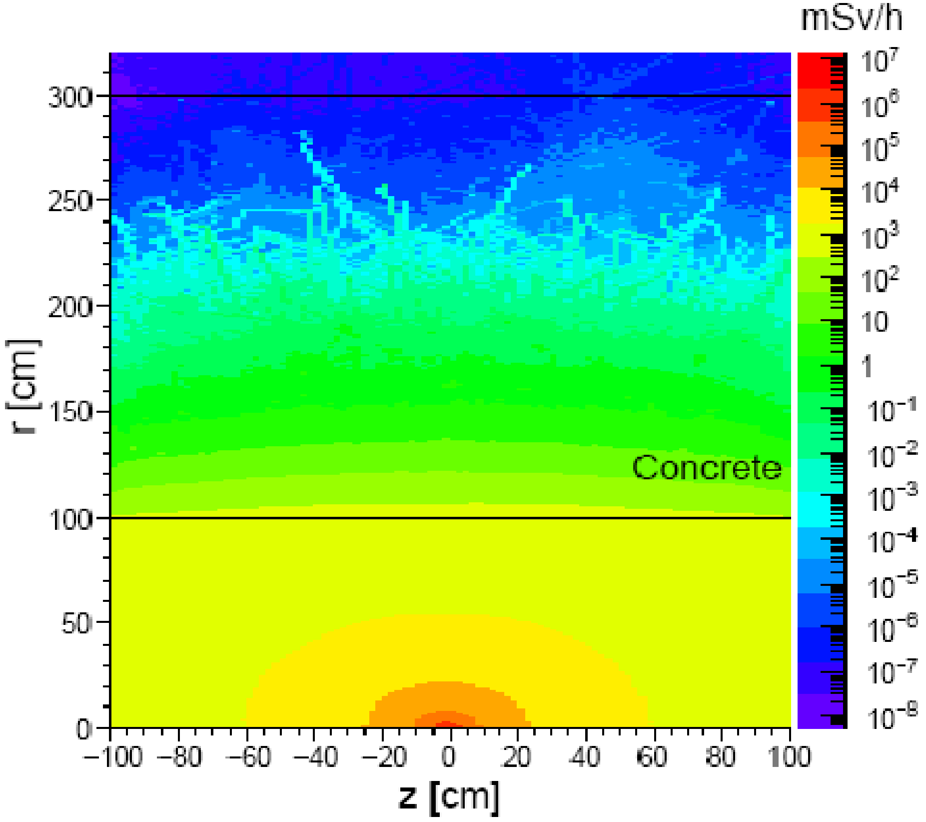
- 2m concrete wall has been added
- Target rim has been changed to the disk with radius of 1.5 cm
- Cooling water channel has been removed

Composition of Concrete ($2.34\ g/cm^3$)

El.	Frac. %
H	10
C	23
O	40
Mg	2
Si	12
Ca	12

Dose Rate

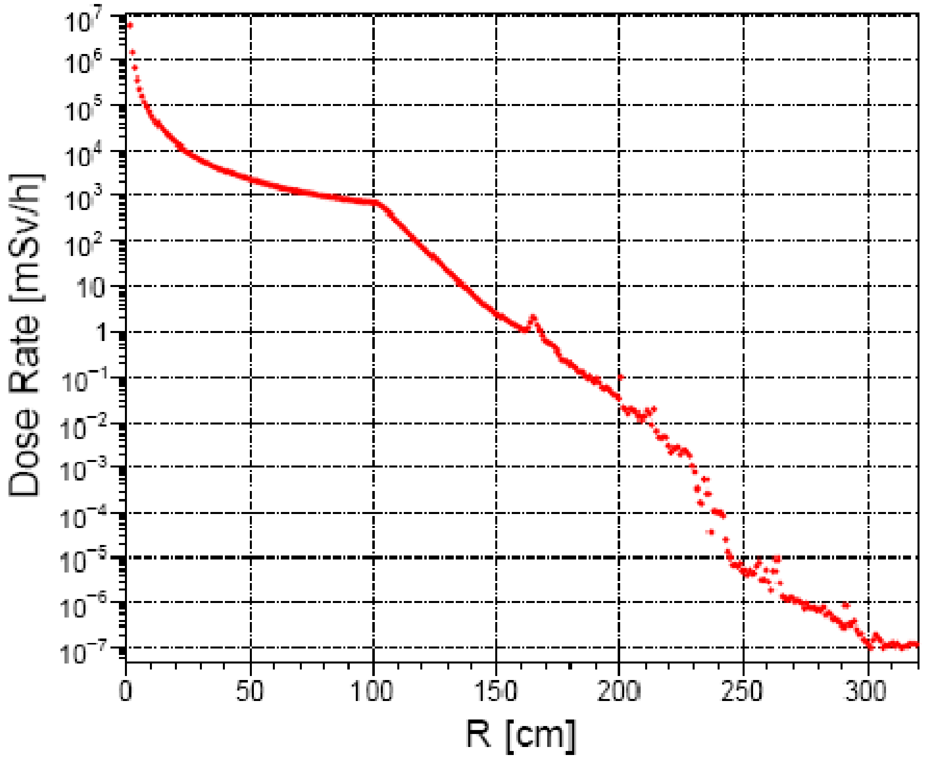
after 5000 h of irradiation and 0 s of cooling time

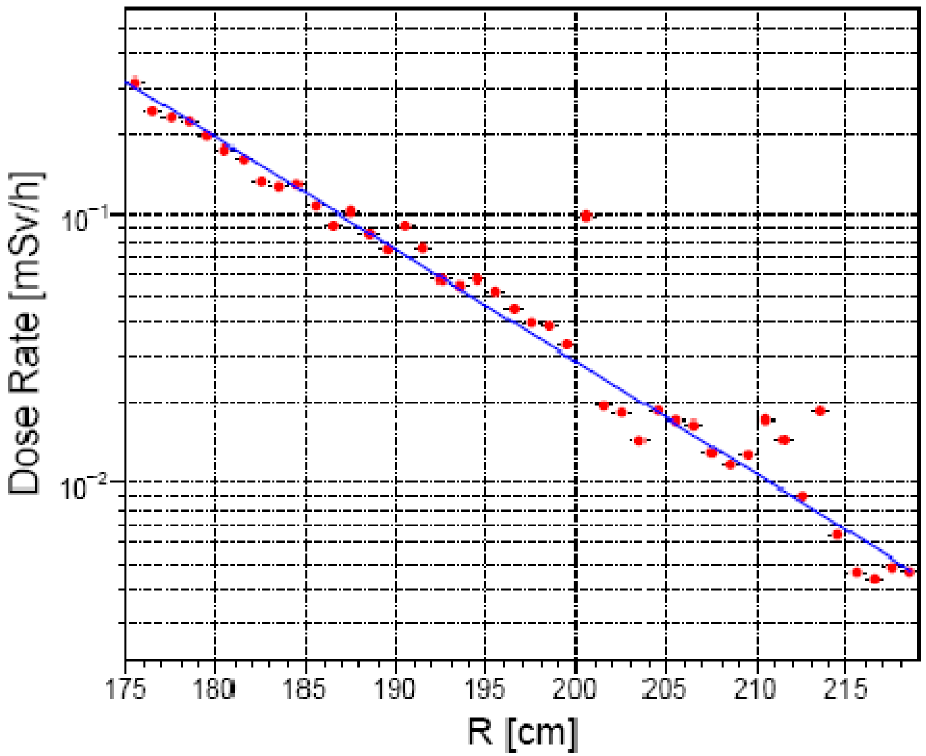


Required Thickness of Shielding

Personal dose: 20 mSv/year; 2000 h/year $\mapsto$ $\dot{D}_{max}$ = 0.01 mSv/h

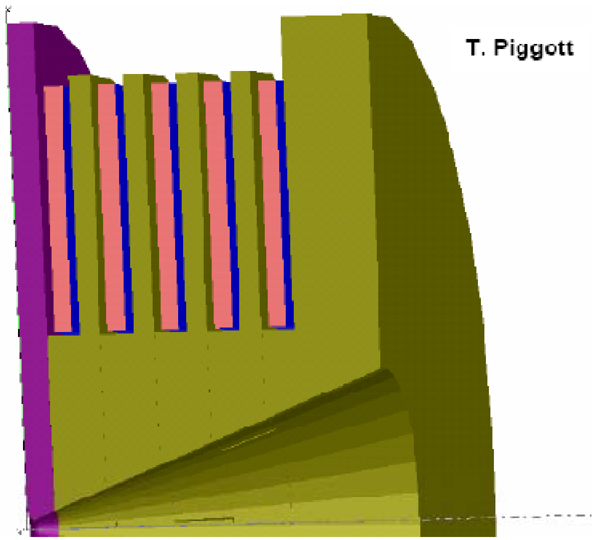
1.1m of concrete looks conservative





Capturing the Positrons

- If a linac is placed directly after the target then **~10% of the positrons are captured**
- Using an appropriate magnetic field can **enhance** the capture significantly
  - ➔ Simple solenoid (but no field on target) **~15%**
  - ➔ Flux concentrator **~21%**
  - ➔ Lithium lens **~30 - 40%**



- Flux concentrator is an *established* technique
- Needs to be scaled up from **μs to ms** pulse lengths
- Further study needed to prove feasibility
- Would need a prototype
- **Presently assumed solution**

Similar devices have been built before ….

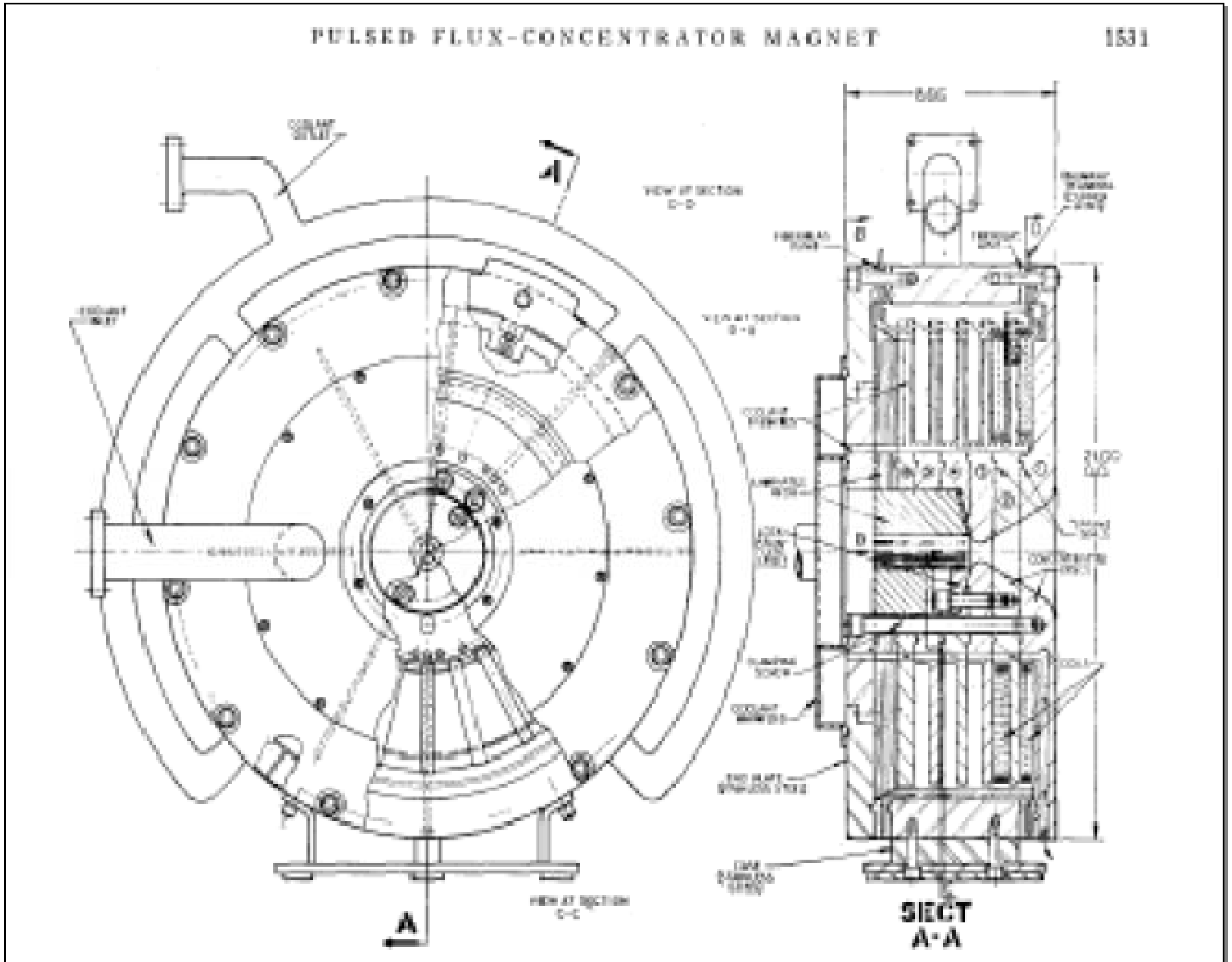


FIG. 4. End view and side section of flux concentrator final design.

- Brechna, et al.
  - **1965**
  - **Hyperon experiment**
- Very preliminary ANL and LLNL simulations do not indicate showstoppers
- No one has stepped up to claim this is "doable"

J Gronberg

ILC Parameters are close to Brechna

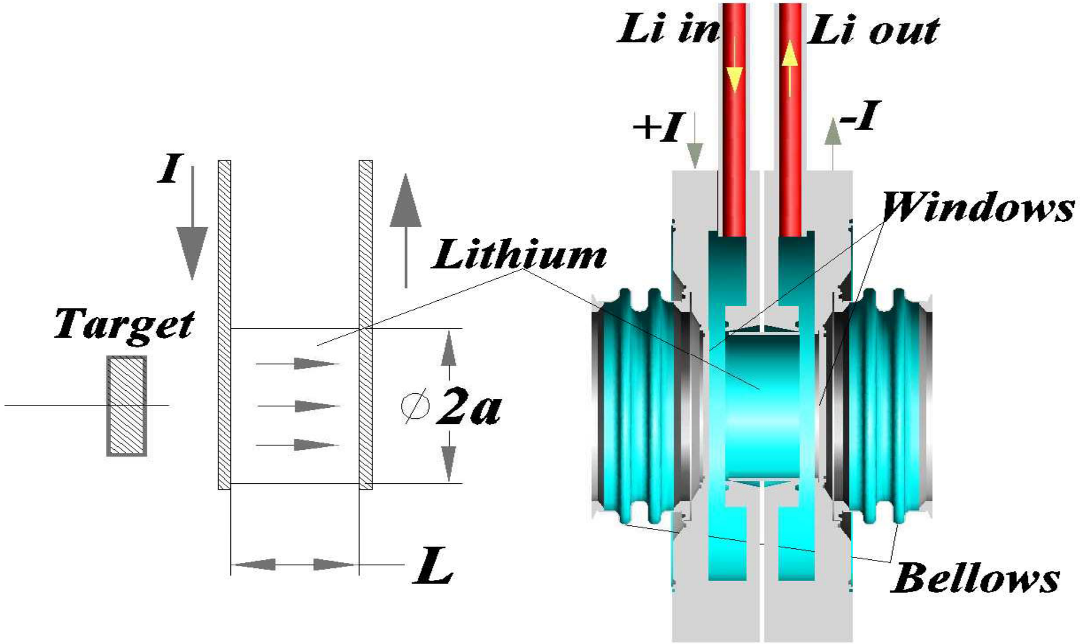
Parameter	Brechna	ILC	Units
Field Strength	10	7	T
Pulse Length	40	1	ms
Repetition Rate	1/3	5	Hz

J. Sheppard

- Extrapolation from Brechna to ILC is not large
  - Lower field
  - Lower pulse length
  - Pulse length x repetition rate is similar
- Requires significant design and prototyping effort

Lithium Lens Capture System

- Current flows co-linearly with positrons
- Induced magnetic field gives **focussing**
- Lithium will be liquid with flow of ~1m/s
- Capture up to **~40%** of positrons
- Would also need ***prototype***

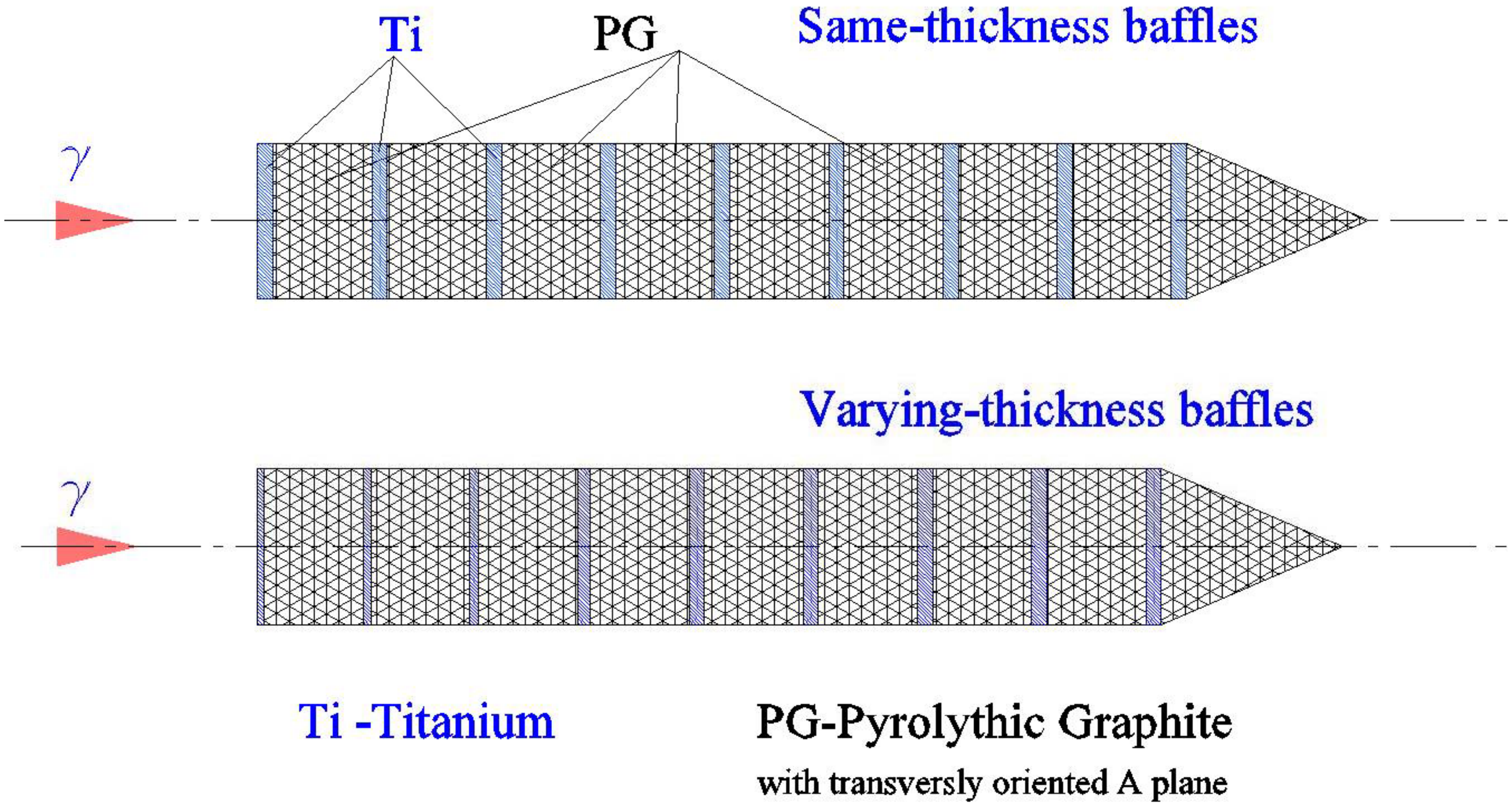


- Concerns mainly about *survivability* of windows
- Radiation damage
- Thermal shock & cycling
- Cavitation of the lithium

A Mikhailichenko, EPAC 08

Gamma Dump

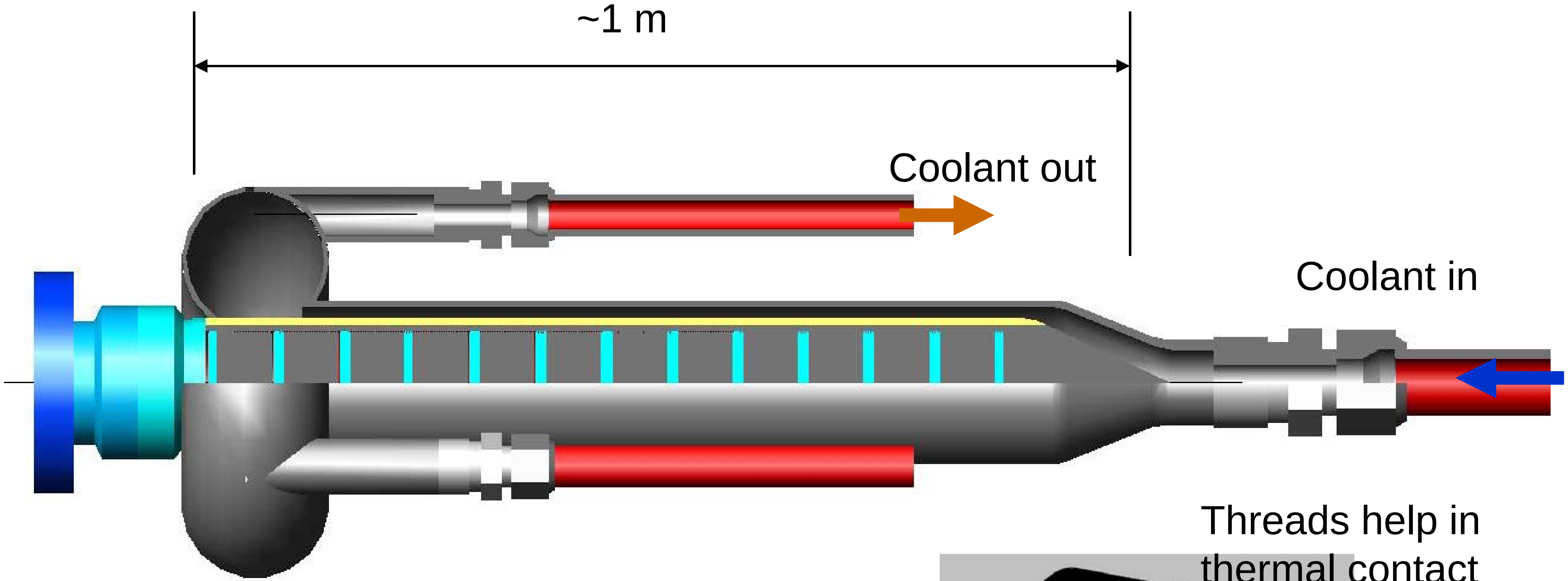
Concept: controllably transform gammas into electron/positron pairs, which deposit theirs energy by ionization losses in low Z media

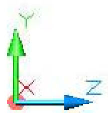


As the critical energy in Carbon is high (84 MeV) ionization losses are dominant

A Mikhailichenko

Gamma Dump with PG and Ti baffles

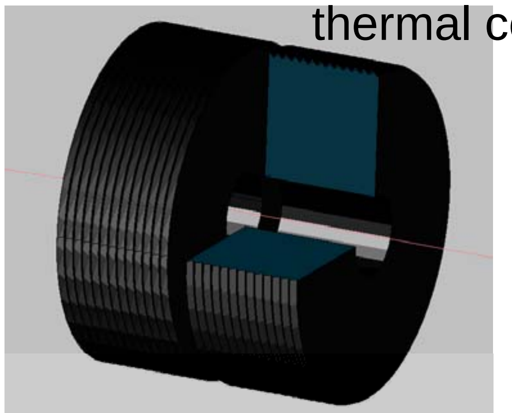




Power 200kW requires coolant flow rate for temperature jump 20^{o}C

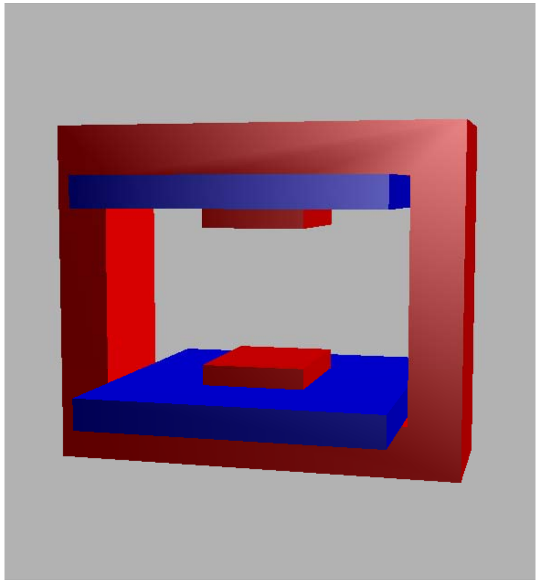
$$\dot{m} \cong \frac{E_{tot}}{\Delta T C_p} \cong \frac{2 \cdot 10^5}{20 \cdot 4.18 \cdot 10^3} \cong 2.4 L/\sec$$

Threads help in thermal contact

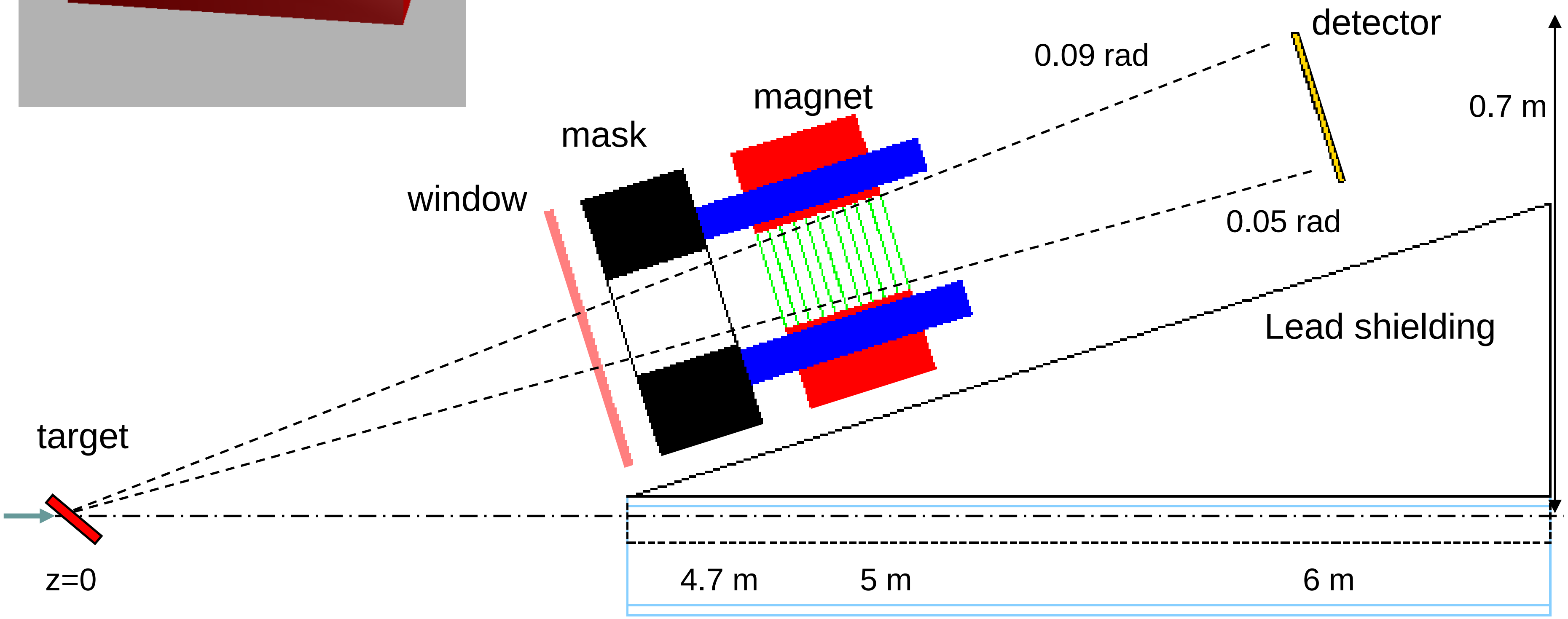


A Mikhailichenko

Low Energy Polarimeter - Geometry improved



- "realistic" magnet design
- magnetic field inclined
- distances adapted
- target inclination
- eff. Taret Polarization
- improved shielding
- beam parameters from undulator simulation



R Dollan

Bhabha results

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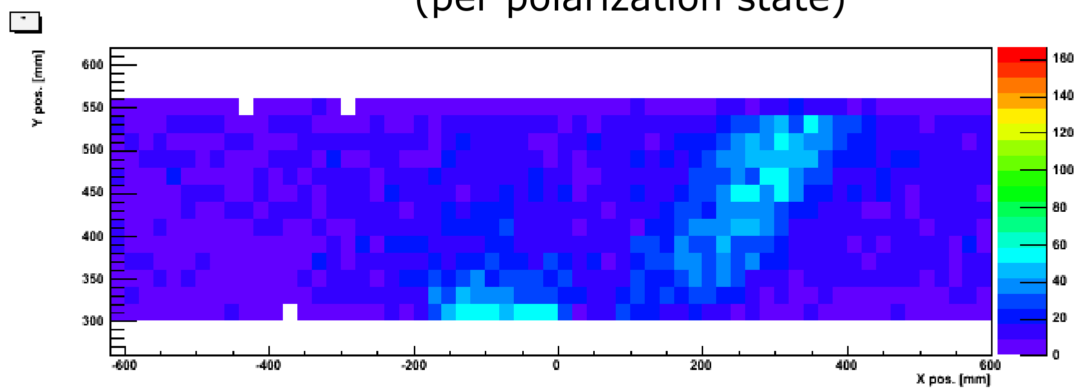
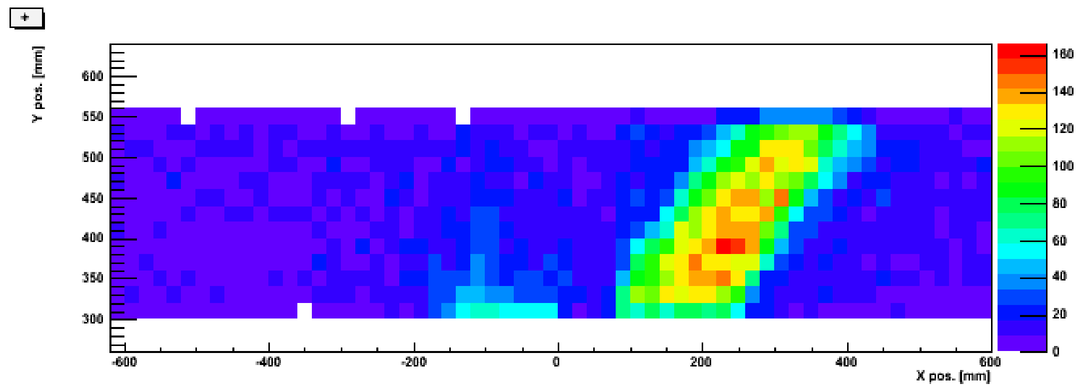
Beam parameters: (from source simulation!)

E [MeV]	400 (± 3.5 %)
σ_x ,σ_y [mm]	5.78, 5.76
ε_x ,ε_y [mm mrad]	5.67,5.65
P(beam)	-100%

- Target: 30 μm Fe
  90°
  P ±100%
- Spectrometer: BdL 0.1 Tm
- Detector charge sensitive
  2x2 cm pads
- 2 x 10^{10} positrons on target
  (per polarization state)

Example:
distribution of scattered
Bhabha electrons for
opposite polarization states
of the target:





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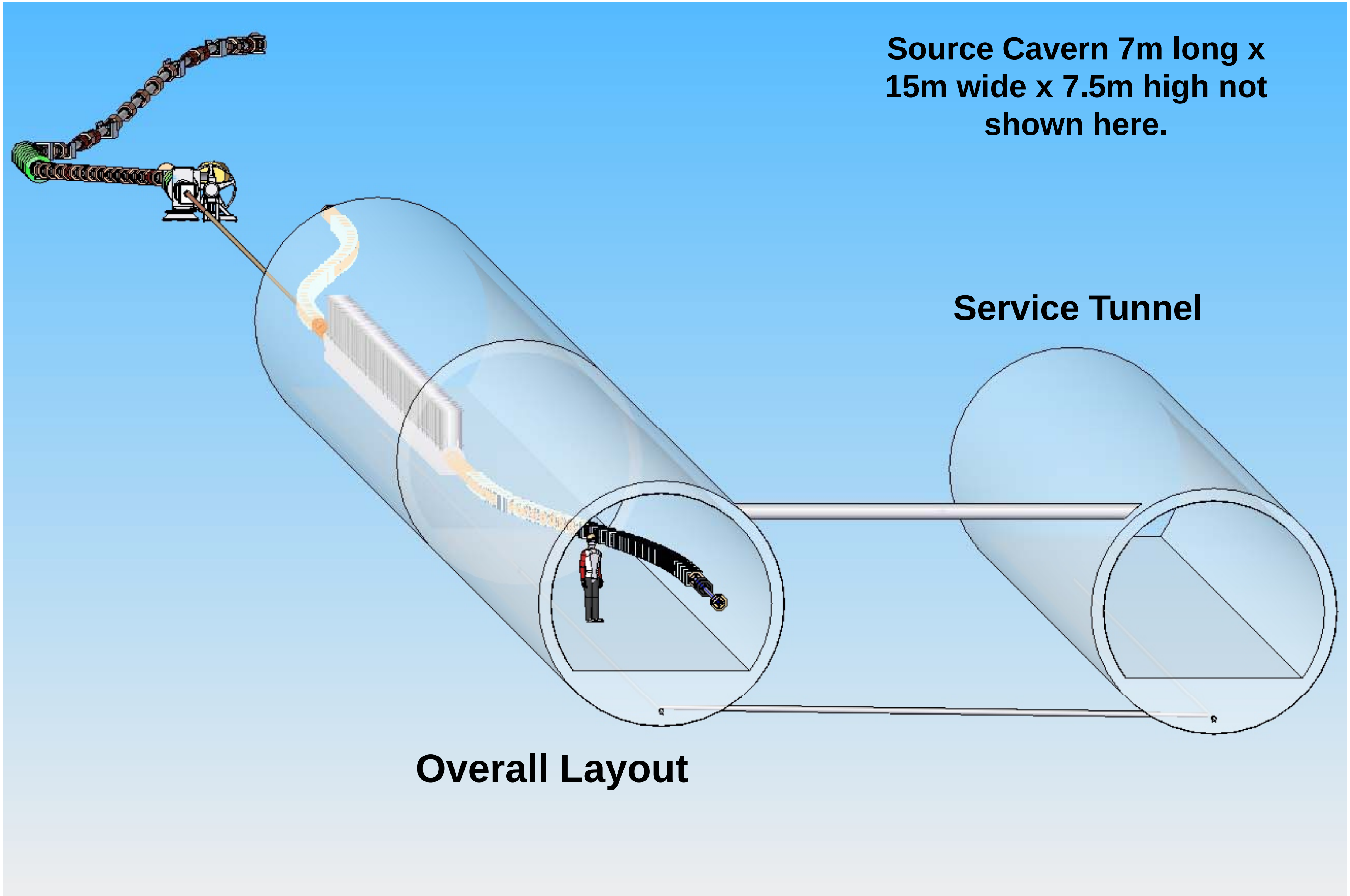
Integration Studies



N Collomb

ILC Undulator Section

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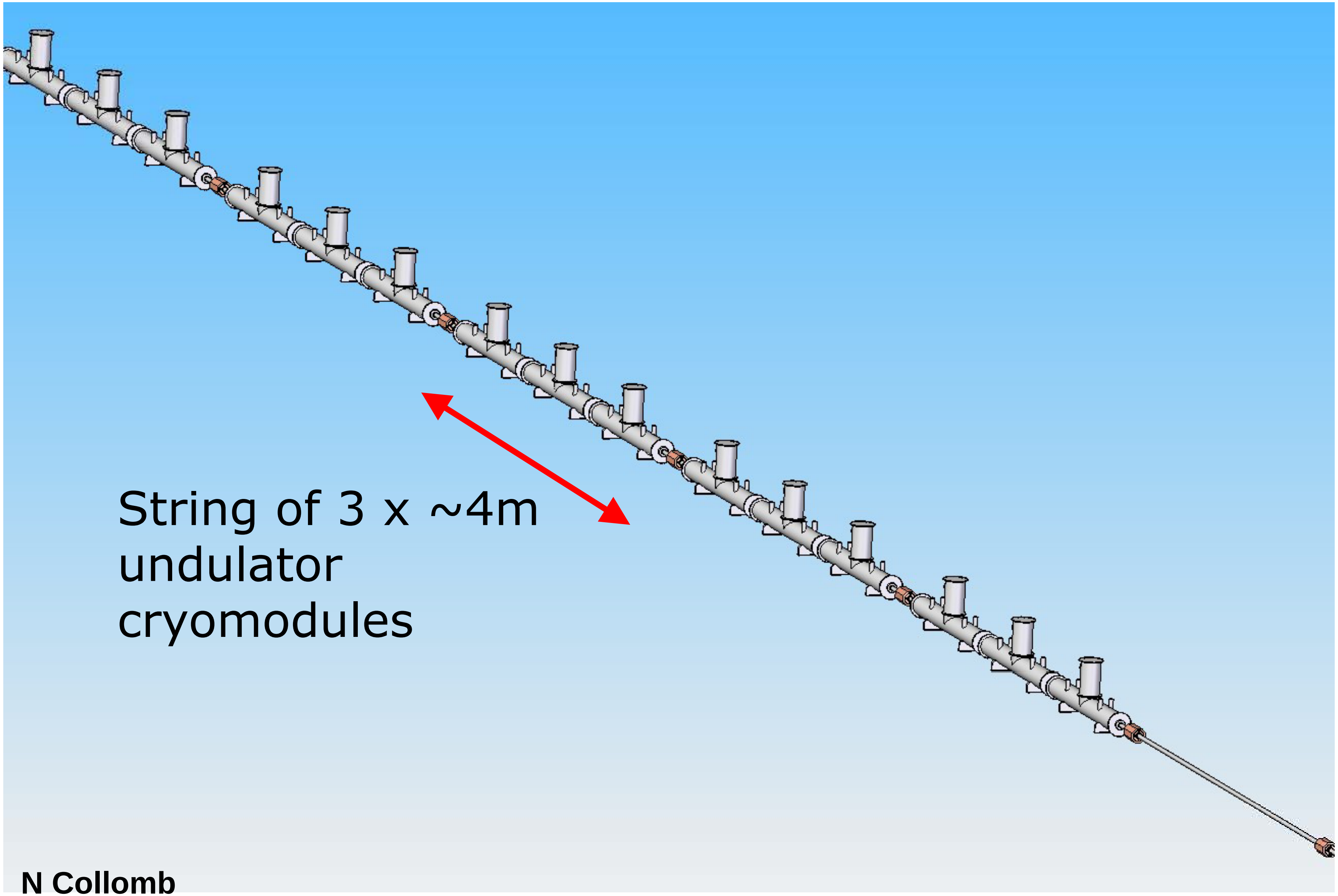
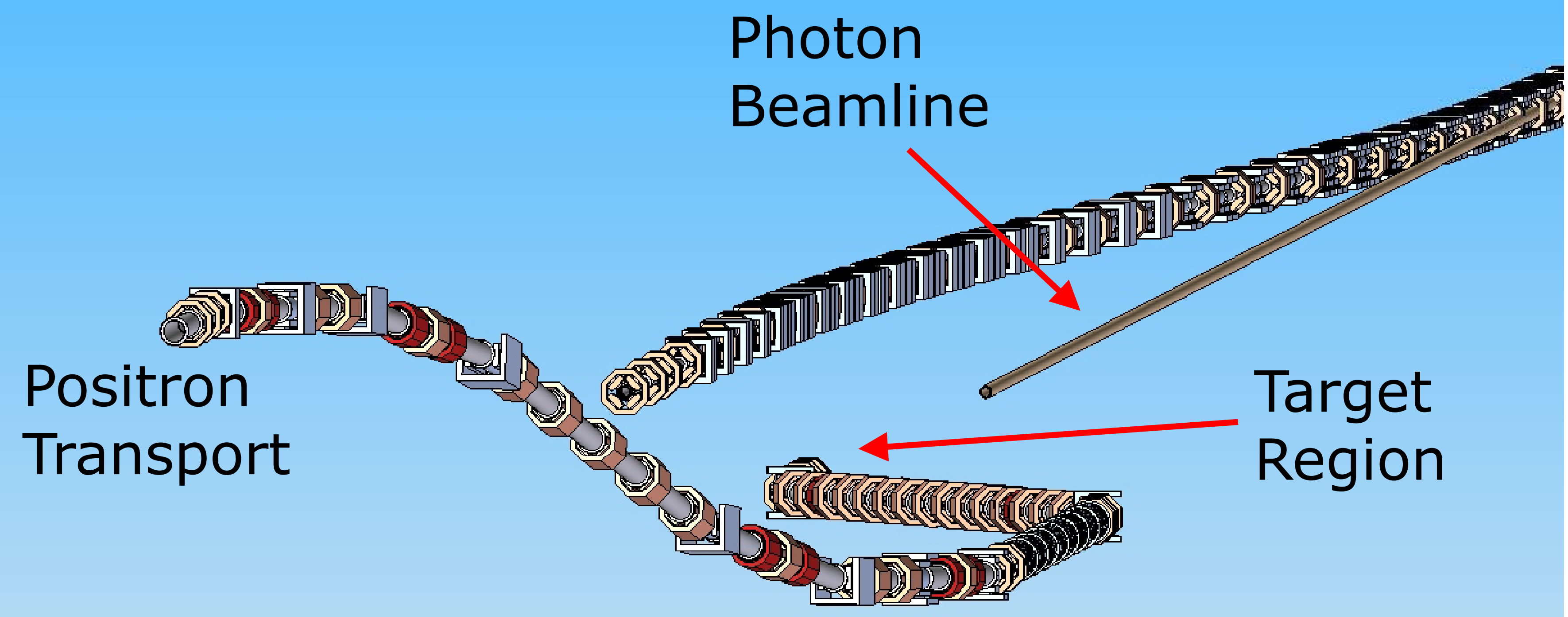


ILC Photons to Target



N Collomb

ILC Requirements

ILCSC Parameters group

- E_{cm} adjustable from 200 – 500 GeV
- Luminosity: $\int Ldt$ = 500 fb^{-1} in 4 years
  - Peak at max. energy of $2\times10^{34}cm^{-2}s^{-1}$
  - Assume $1/\gamma$ L scaling for <500 GeV
- Energy stability and precision below 0.1%
- Electron polarization of at least 80%
- The machine must be upgradeable to 1 TeV
- Two detectors
  - Single IR in push-pull configuration
  - Detector change-over in not more than 1 week

Minimum Machine: Central Region Integration

- Undulator-based positron source moved to end of linac (250 GeV point)

- e+ and e- sources share same tunnel as BDS
  - ➔ upstream BDS (optimised integration)
  - ➔ Including 5GeV injector linacs

- Removal of RDR "Keep Alive Source"
  - ➔ replace by few % 'auxiliary' source using main (photon) target
  - ➔ 500 MeV warm linac, also in same tunnel

- Damping Rings
  - ➔ in BDS plane but horizontally displaced to avoid IR Hall
  - ➔ Injection/Ejection in same straight section
  - ➔ Circumference
    - 6.4 km (current RDR baseline)
    - 3.2 km (possible low-P option)

    } **alternative options**

N Walker

Positron Source & BDS integration

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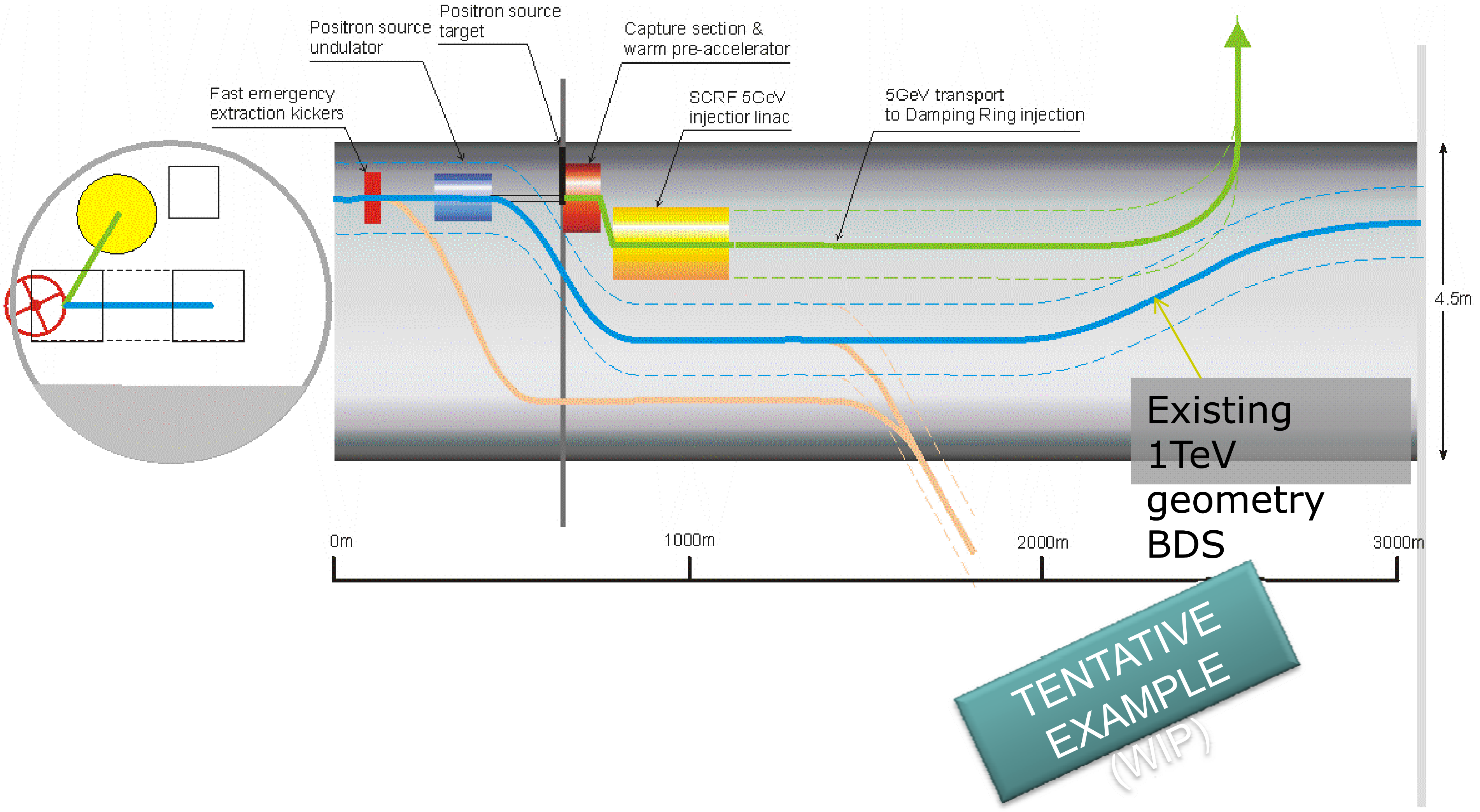

N Walker

Particular Issues for e+ Source

- General integration into post-LINAC / BDS region
  - ➔ Treat as a single design problem
  - ➔ Move away from modular design concept (for Area Systems)
  - ➔ Central region "team" must now work closely together
- Operational issues & physics impact
  - ➔ Operation no longer at constant e- beam energy
  - ➔ (Re-)optimisation of parameters & layout
    - Additional constraints
  - ➔ Low energy running (low Ecm) issues
- Availability / Reliability
  - ➔ Removal of 10% KAS