The ILC Baseline Positron Source Update

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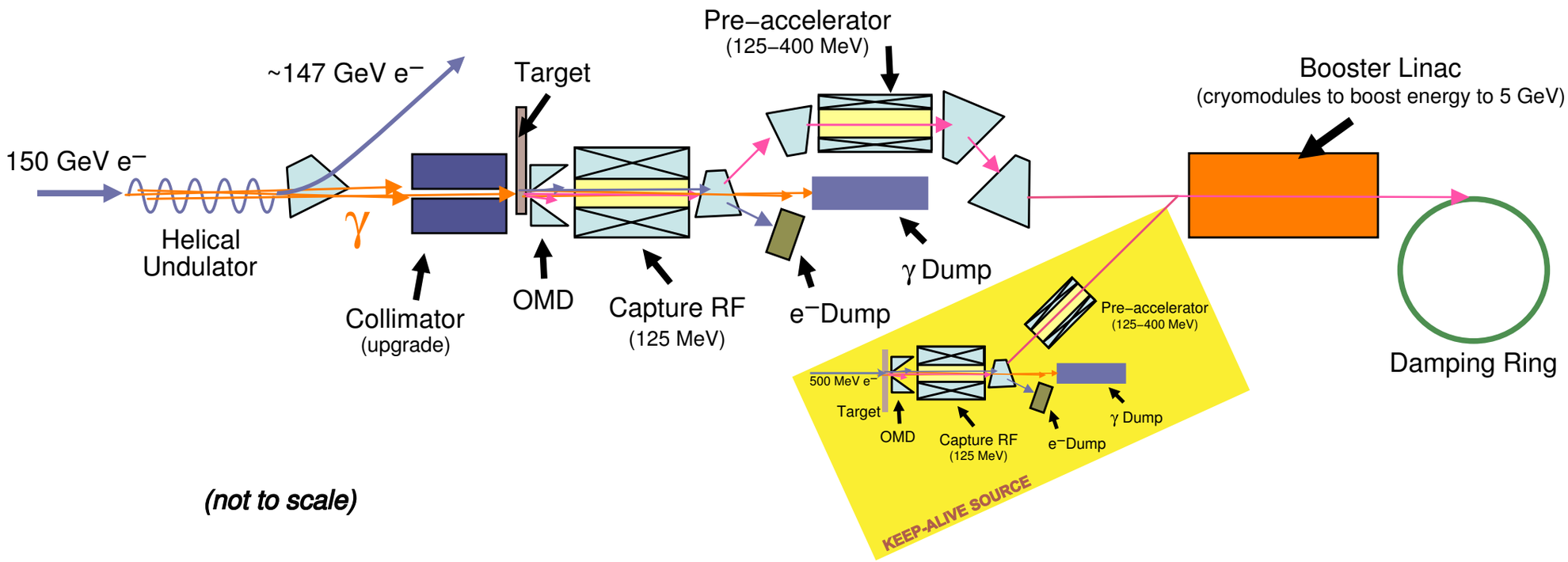
on behalf of the ILC Positron Source Collaboration

POSIPOL 2009, Lyon

Contents

- ILC Positron Source
- Undulator
  - full scale 4m undulator module
- Target
  - Eddy current experiment
  - Activation
  - Shielding
- Capture optics
- Gamma dump
- System integration
- Minimal Machine
- Conclusion/Next steps

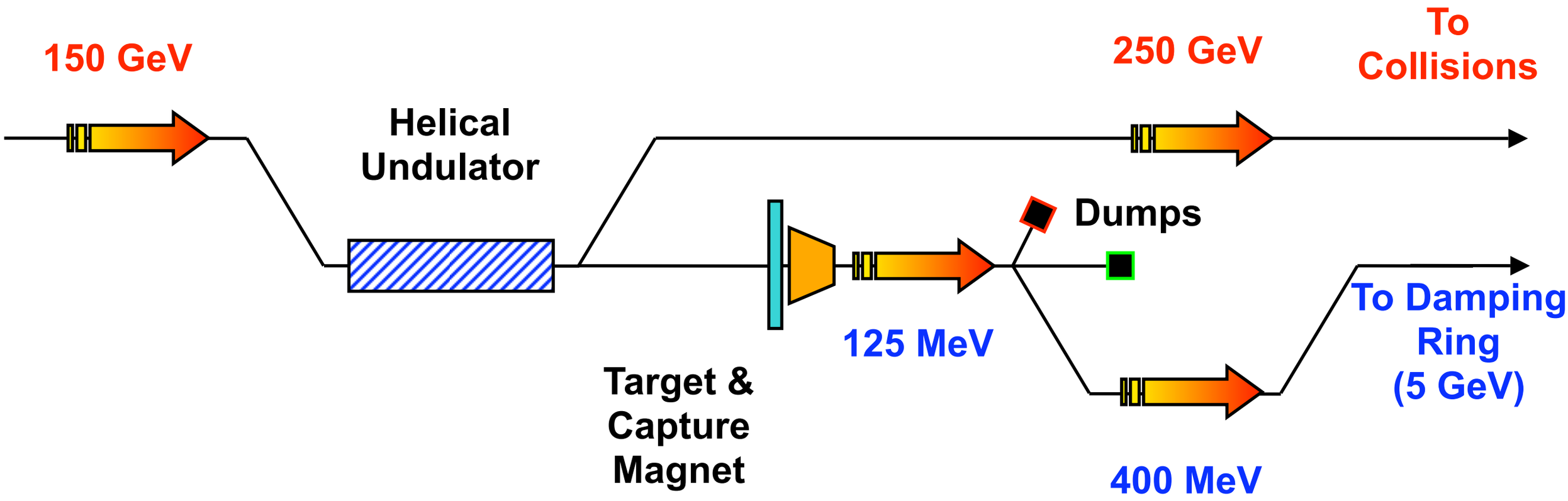
The Baseline Source



(not to scale)

	SLC	ILC
Positrons per Bunch	3.5×10^{10}	2×10^{10}
Bunches per Macropulse	1	2625
Macropulse Rep Rate (Hz)	120	5
Positrons per second	**4.2×10^{12}**	**2.6×10^{14}**

Positron Source Layout



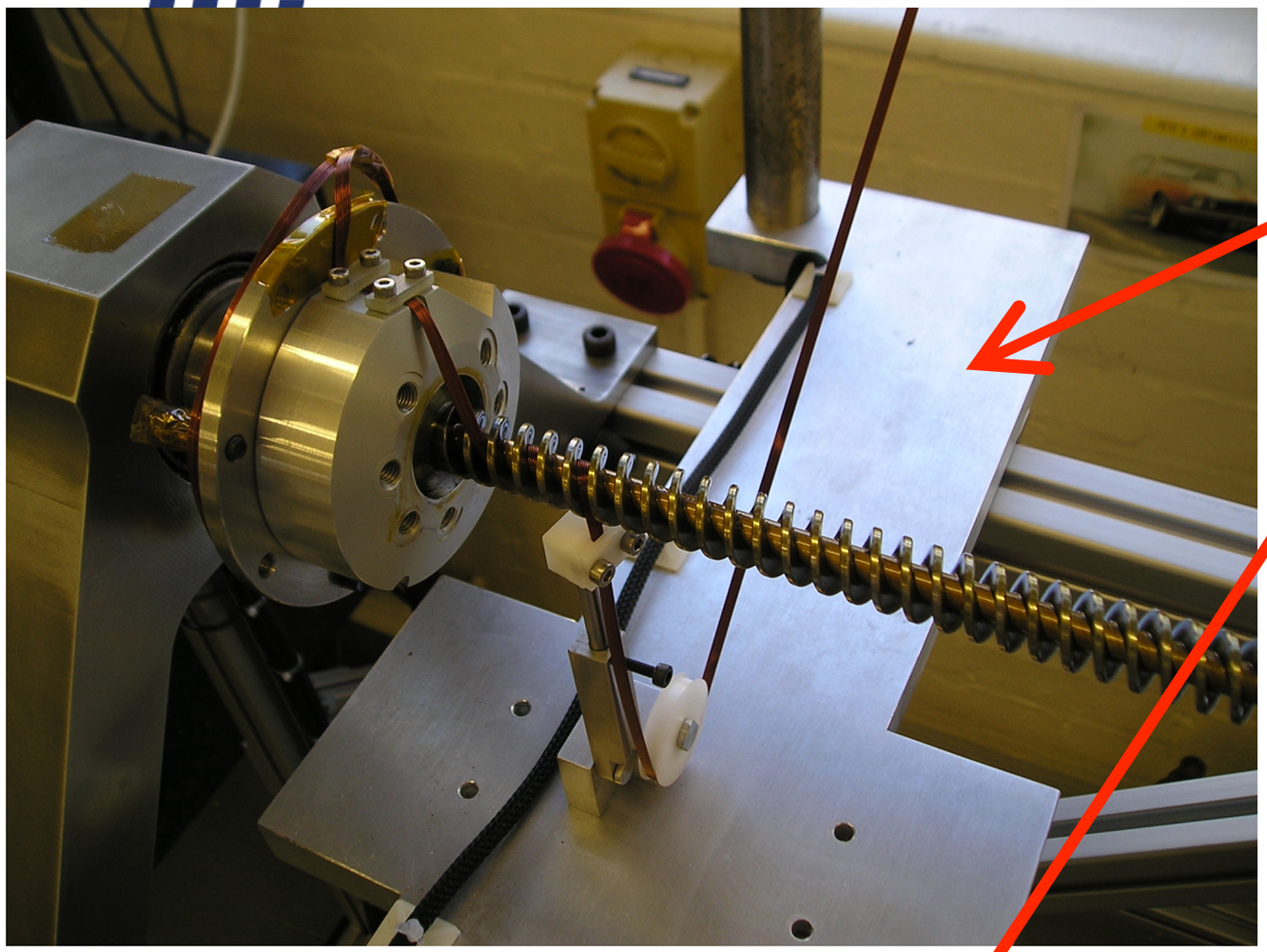
- **10MeV+ photon beam** generated in helical undulator by **150 GeV electrons**
- Photon beam travels ~400 m beyond undulator and then generates e^+e^- pairs in **titanium alloy target**
- Positrons captured and accelerated to 125 MeV
- Any electrons and remaining photons are then separated and dumped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

Undulator Parameters	Symbol	Value	Units
Undulator period	λ	1.15	cm
Undulator strenght	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 harmoinc cutoff)	E_{c10}	10.06	MeV
Photon beam power	P_γ	131	kW

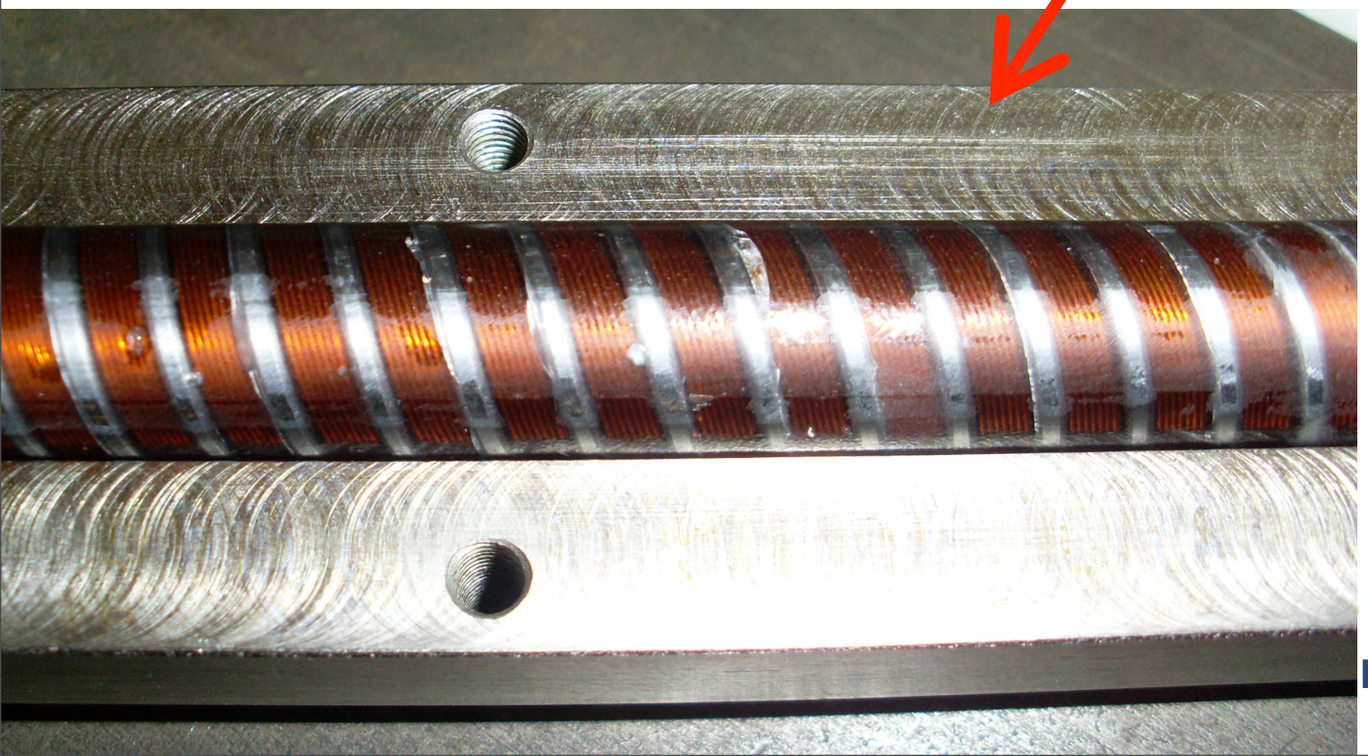
1.75m Undulator Fabrication

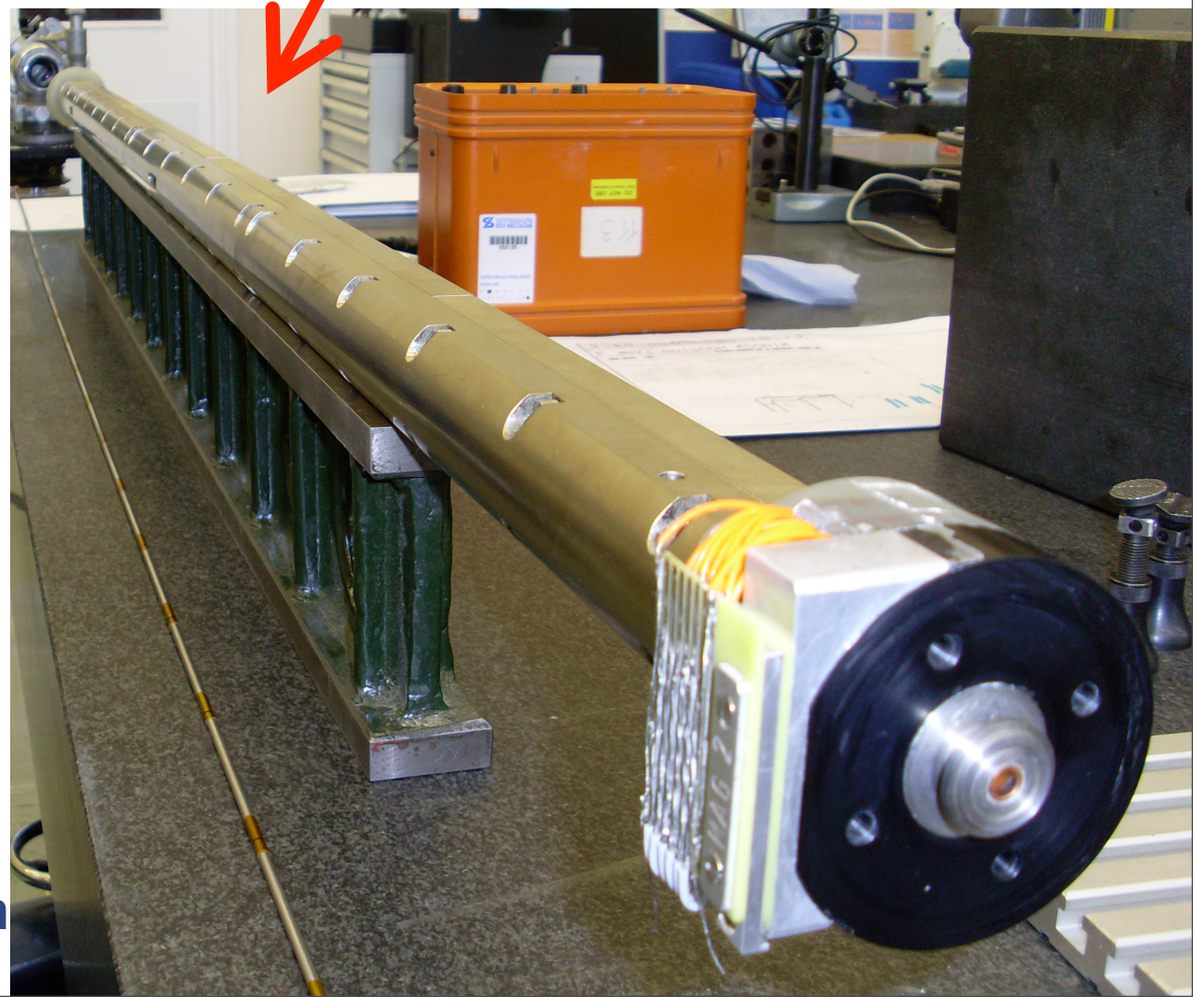


Winding

Potted and in one half of steel yoke

Complete magnet





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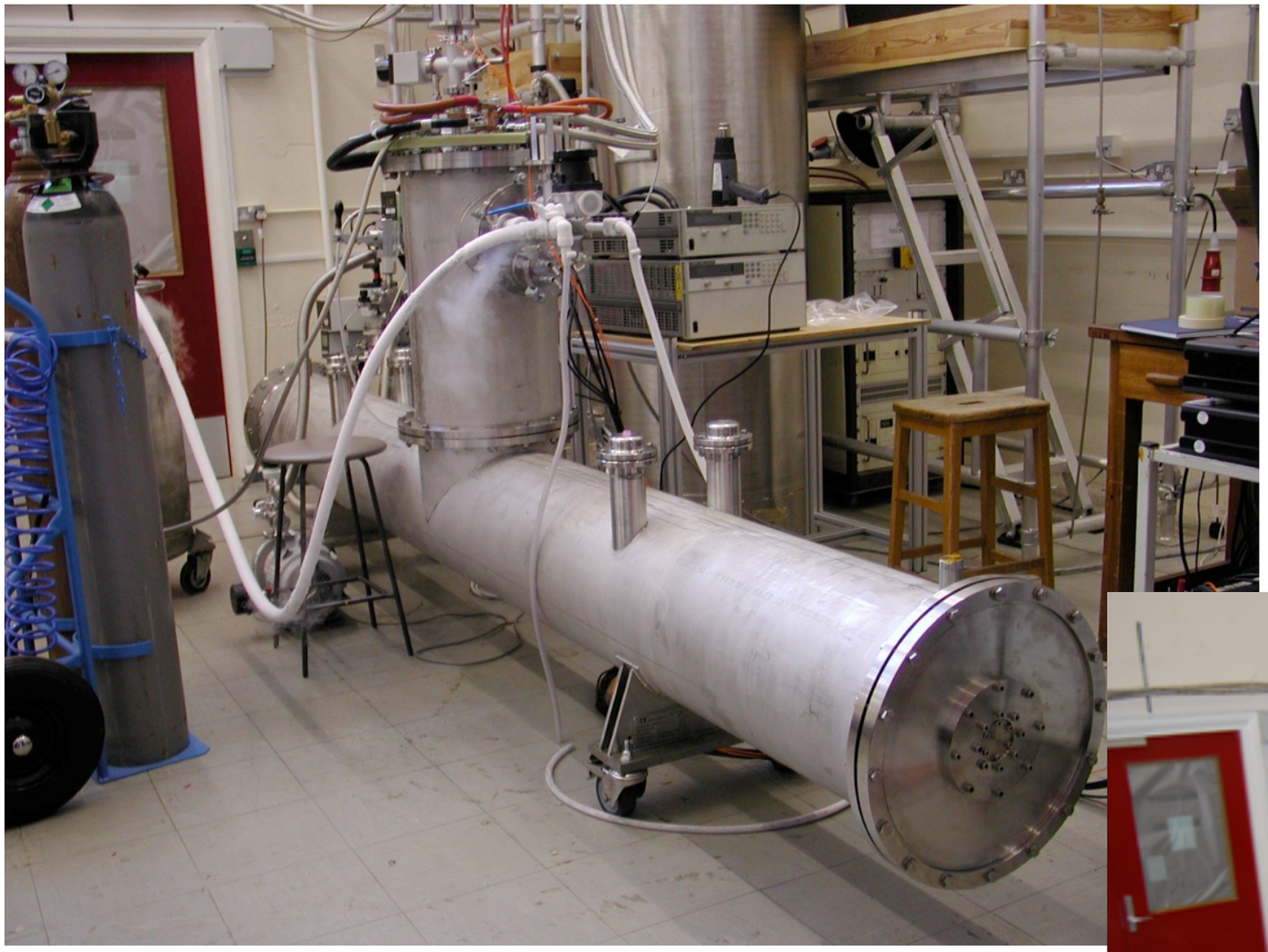
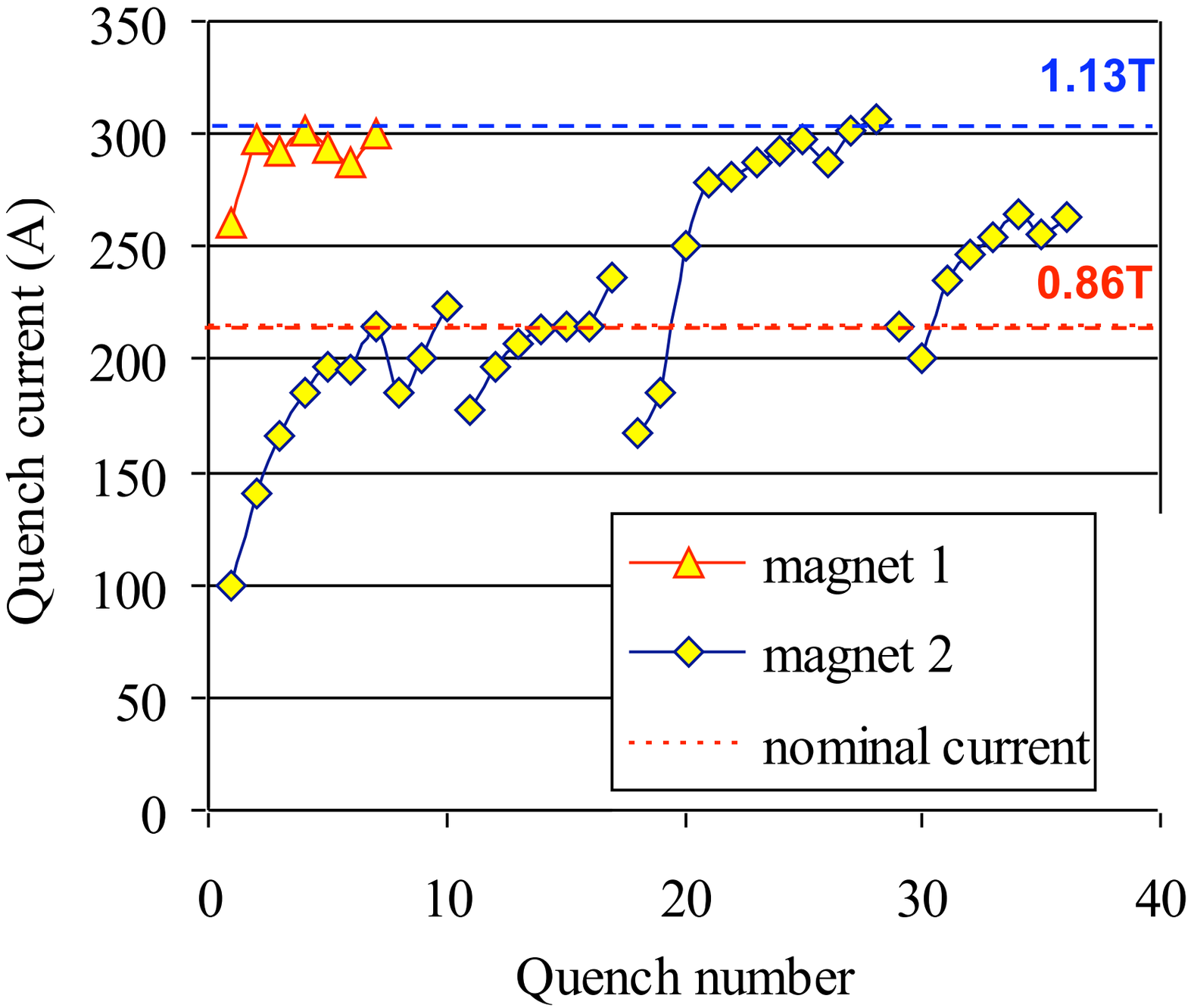
Module Under Test



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

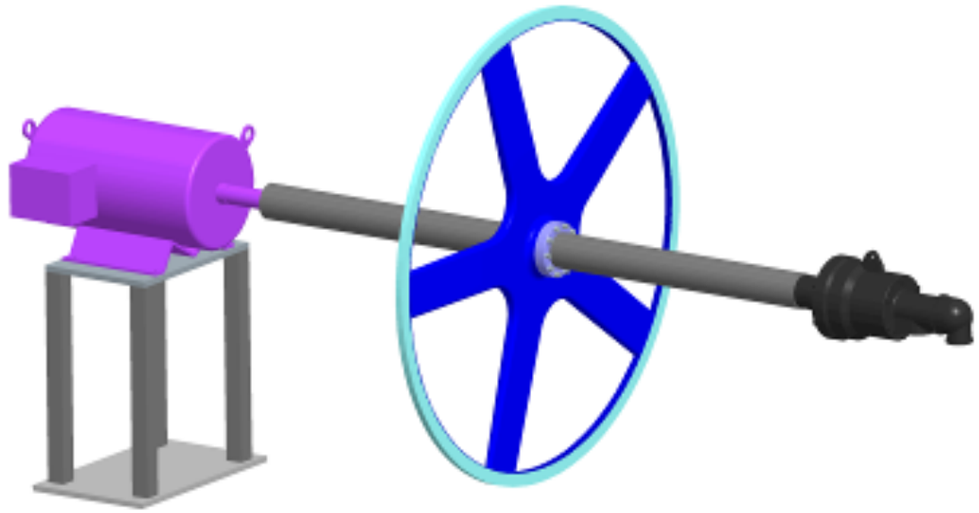
The Target

- 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

RDR Target Design

- Wheel rim speed (100m/s) fixed by **thermal load** (~8% of photon beam power)
- Rotation reduces pulse energy density (averaged over beam spot) from ~900 J/g to ~24 J/g
- Cooled by internal **water-cooling** channel
- Wheel diameter (~1m) fixed by **radiation damage** and capture optics
- Materials fixed by thermal and mechanical properties and pair-production cross-section (Ti6%Al4%V)
- Wheel geometry (~30mm radial width) constrained by **eddy currents**.
- 20cm between target and rf cavity.
- Axial thickness ~0.4 radiation lengths.

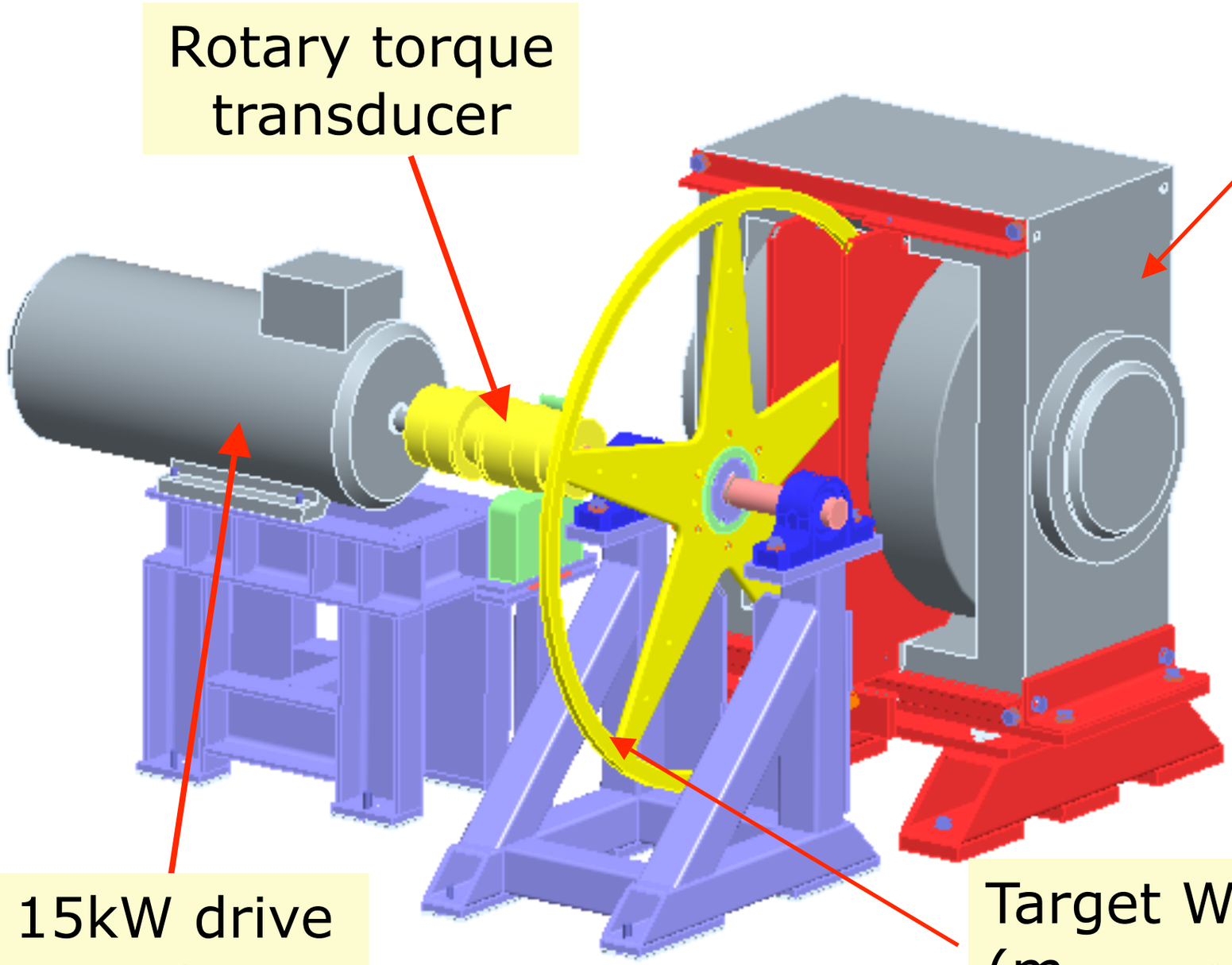


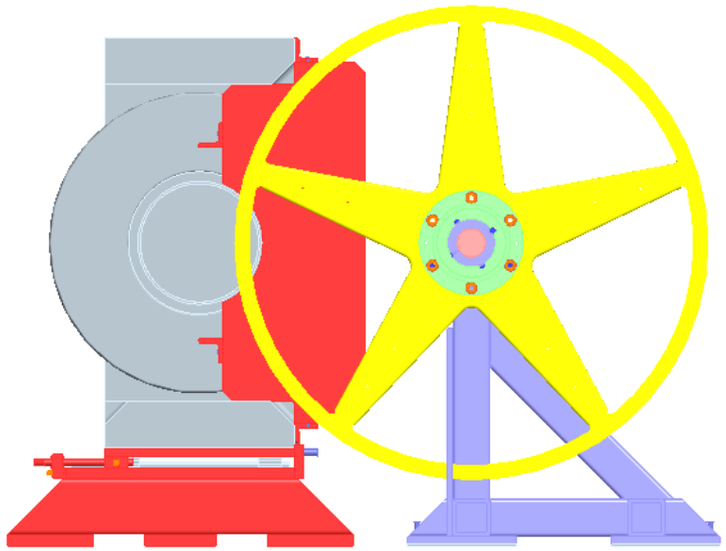
T. Piggott, LLNL

Drive motor and water union are mounted on opposite ends of through-shaft.

Eddy Current Experiment

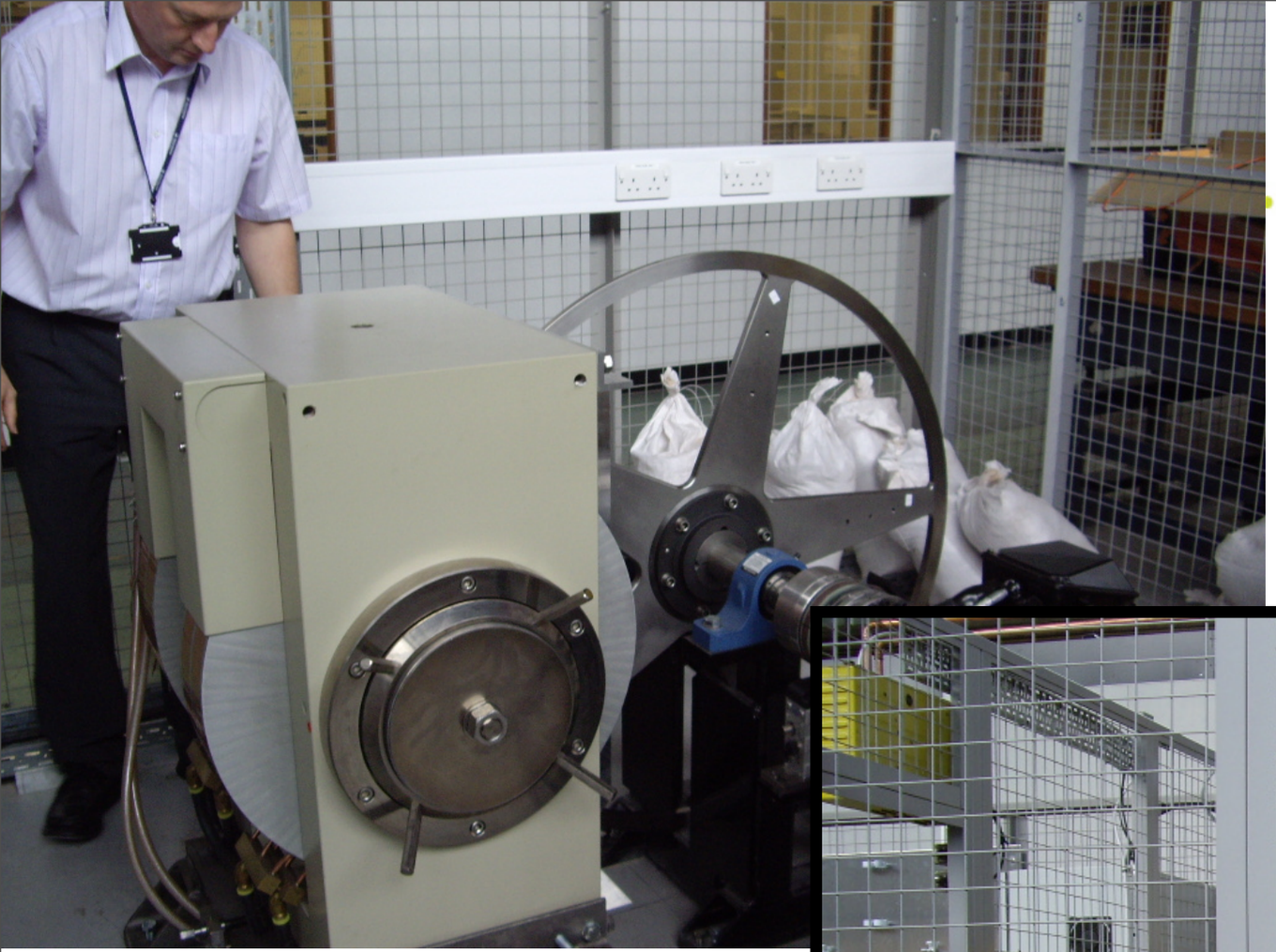
Experiment initiated at Cockcroft Institute/Daresbury Laboratory to monitor *eddy current* effects and *mechanical stability* of full size wheel at design velocity

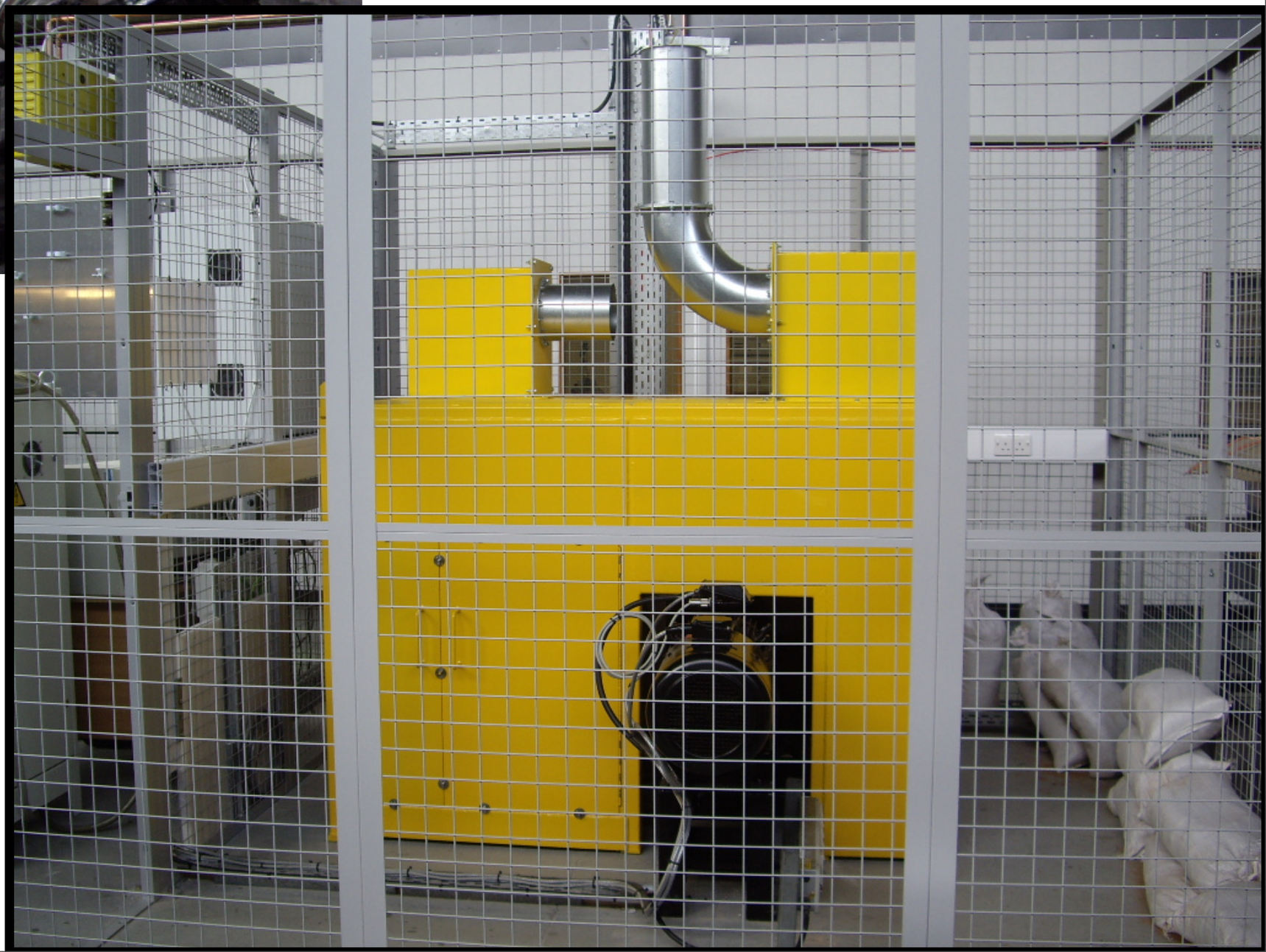




Global Design Effort

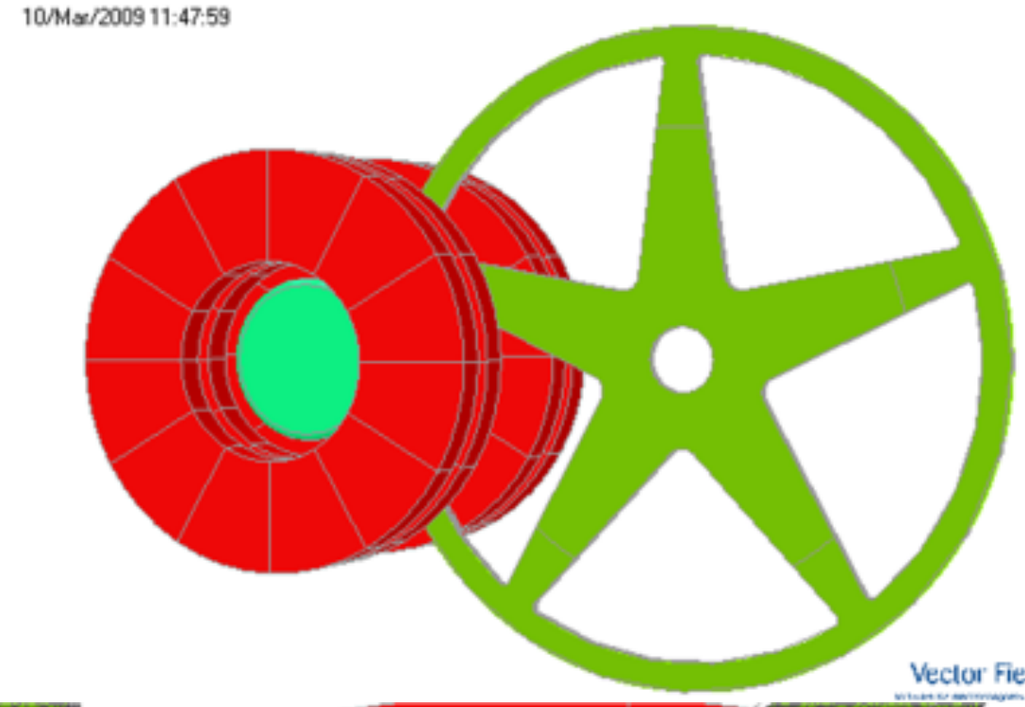
I Bailey et al, EPAC 08

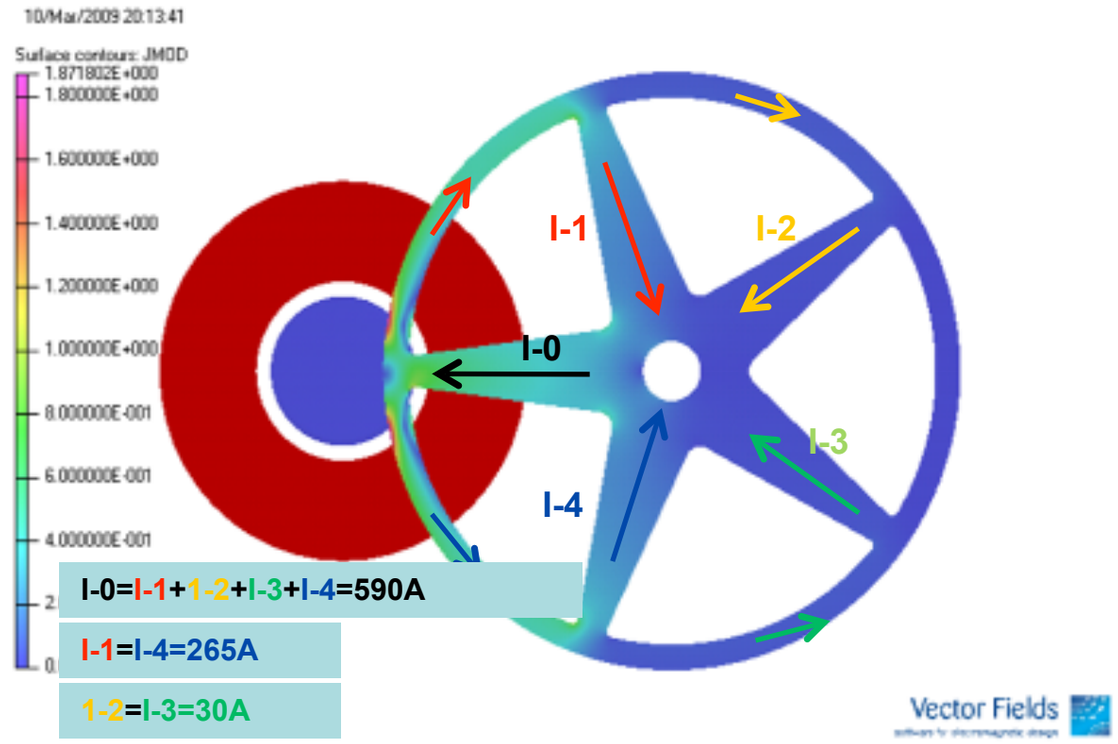


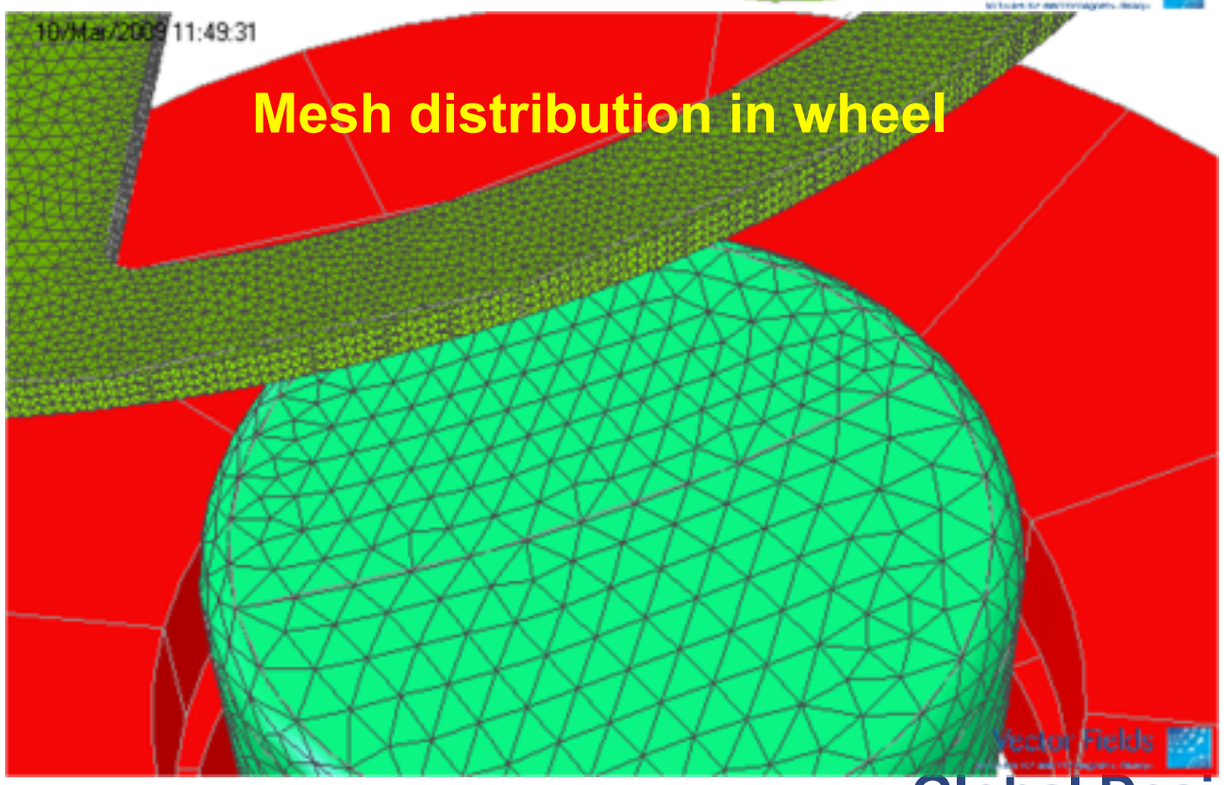


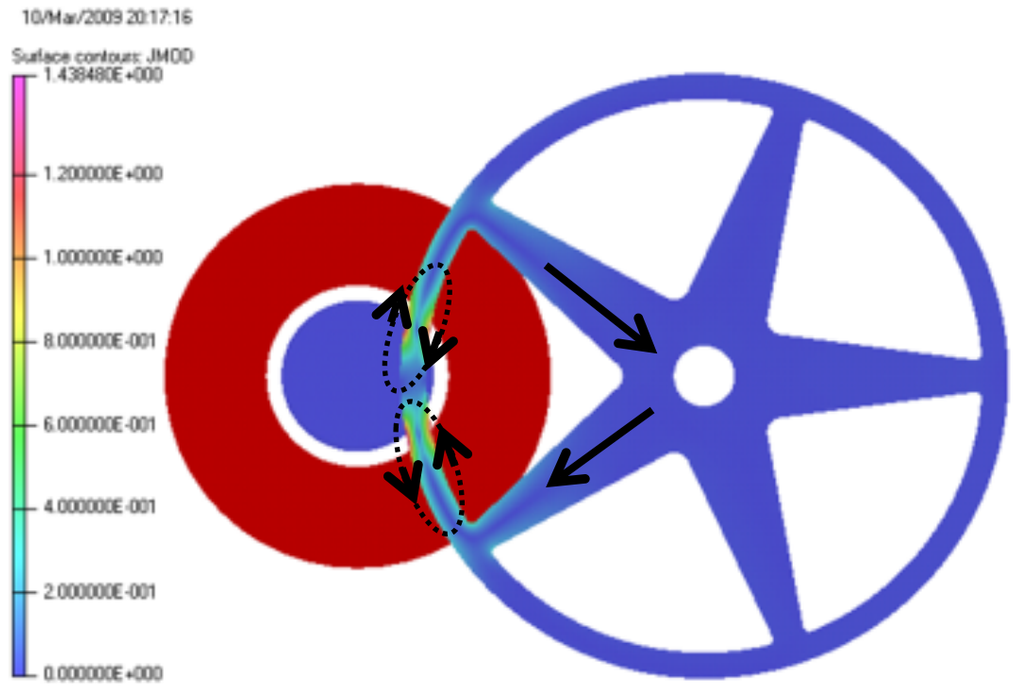
L Jenner

Carmen (spoke) Model



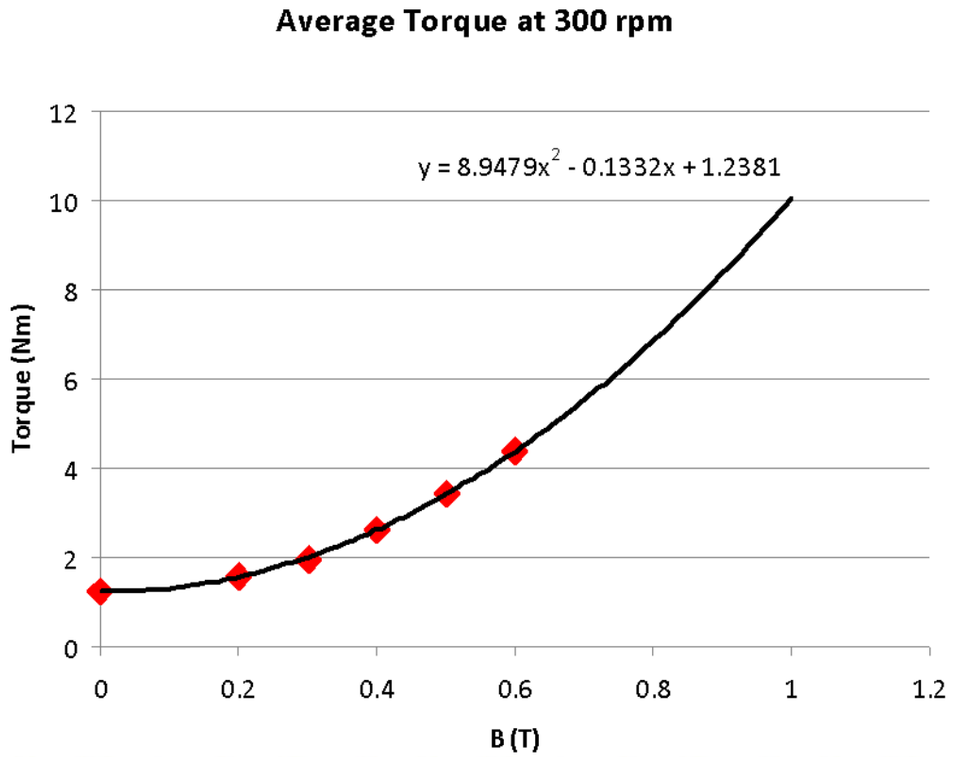


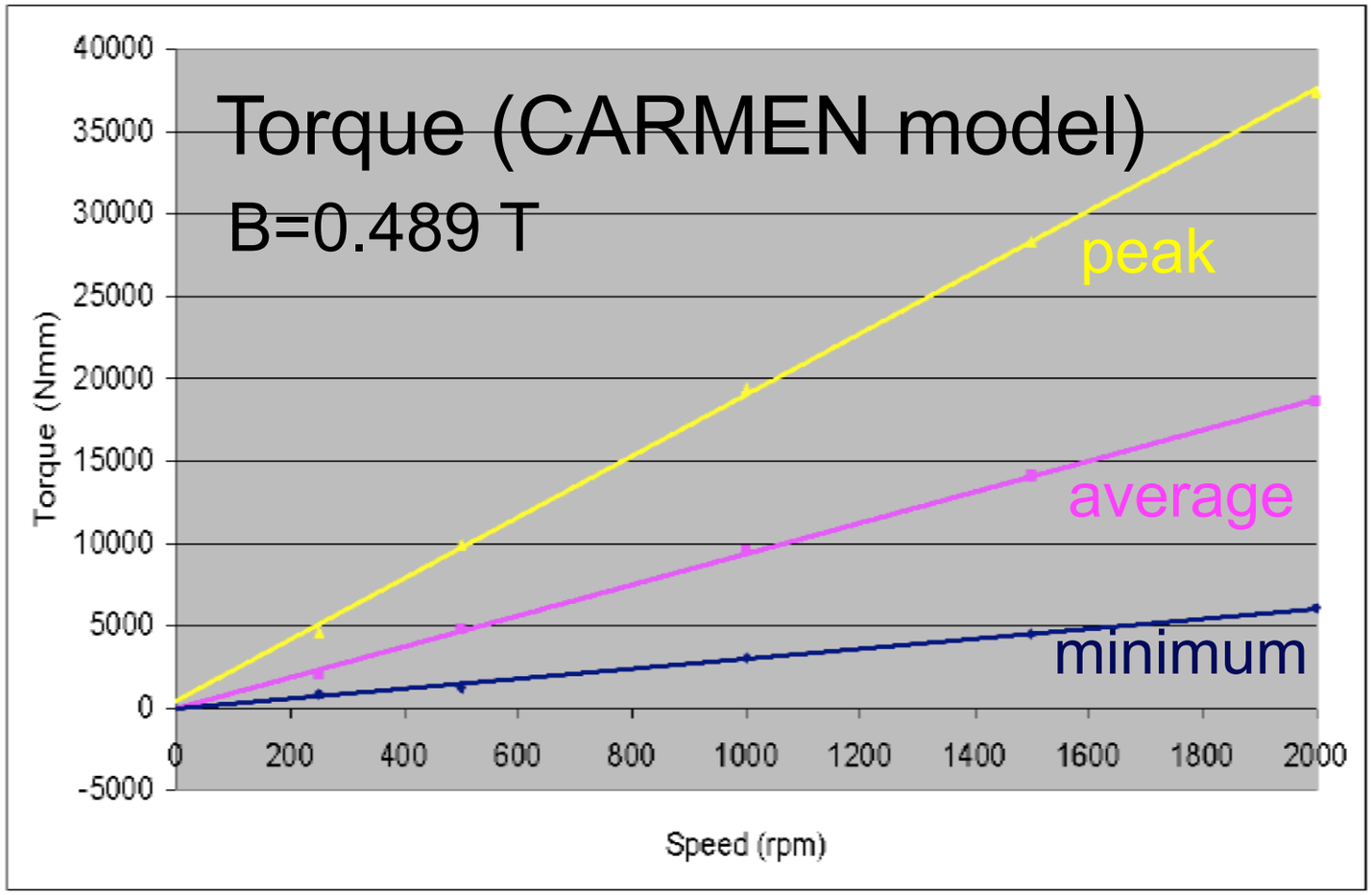




Eddy Current measurements

- Data taking ongoing
  - Wheel operated up to 1.45 T @ 1000 rpm and up to 0.485 T @ 1500 rpm
  - preliminary extrapolation to 1T @ 2000 rpm give ~5 kW





Target Activation

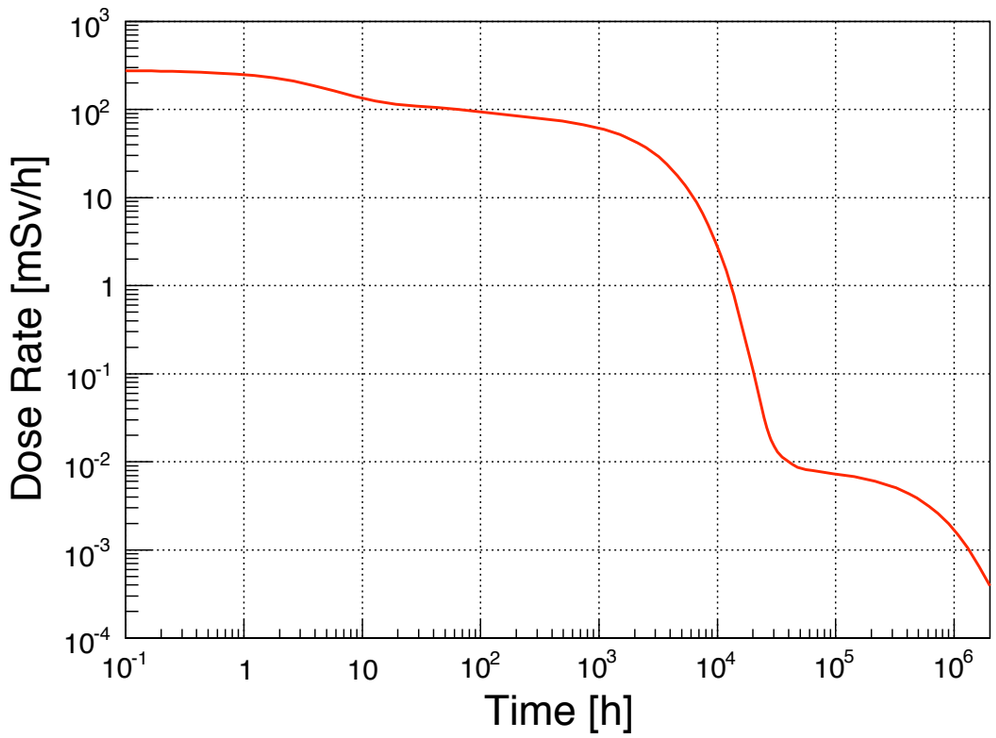
- Equivalent dose rate calculated after **5000 hours** of operation at **1m** from the source
- **Remote handling** required so can exchange target modules rapidly
- No intention to make in-situ repairs

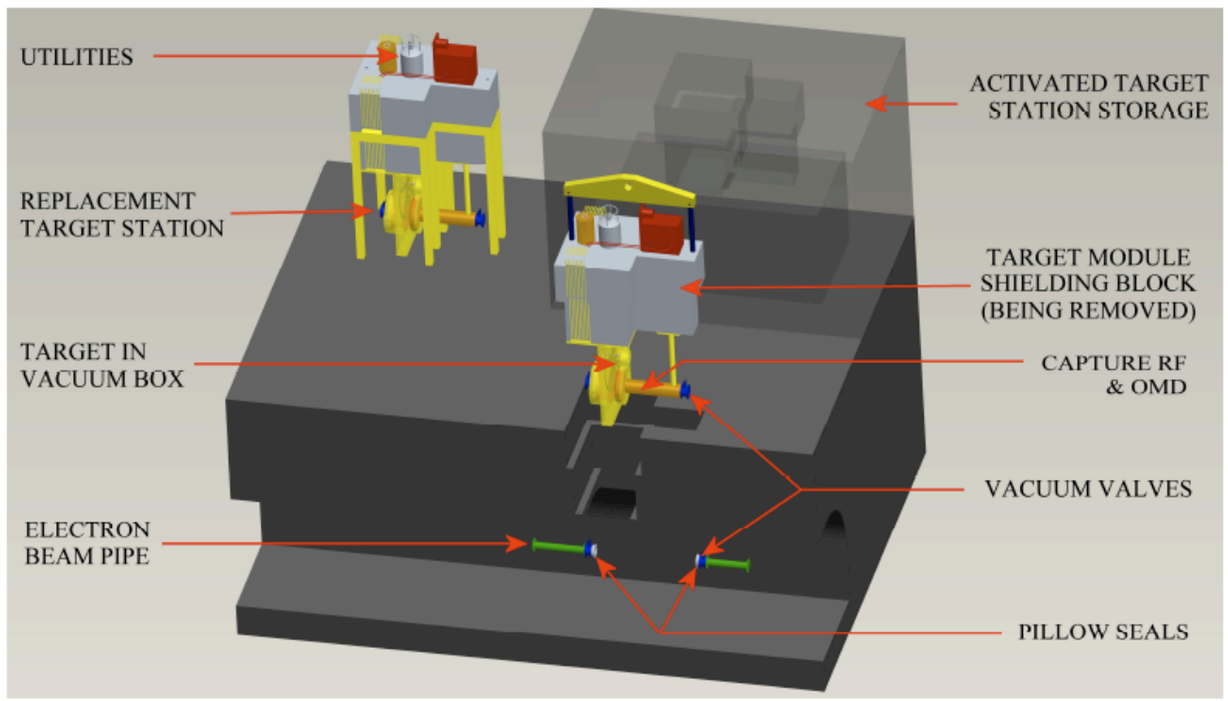
Dose Rate [mSv/h]

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

Undulator Based Source

0.4 X_0, Ti6Al4V Target; R_{col} = 2.3 mm





A. Ushakov, EPAC 08

Global

Shielding around Target

Modification of Model:

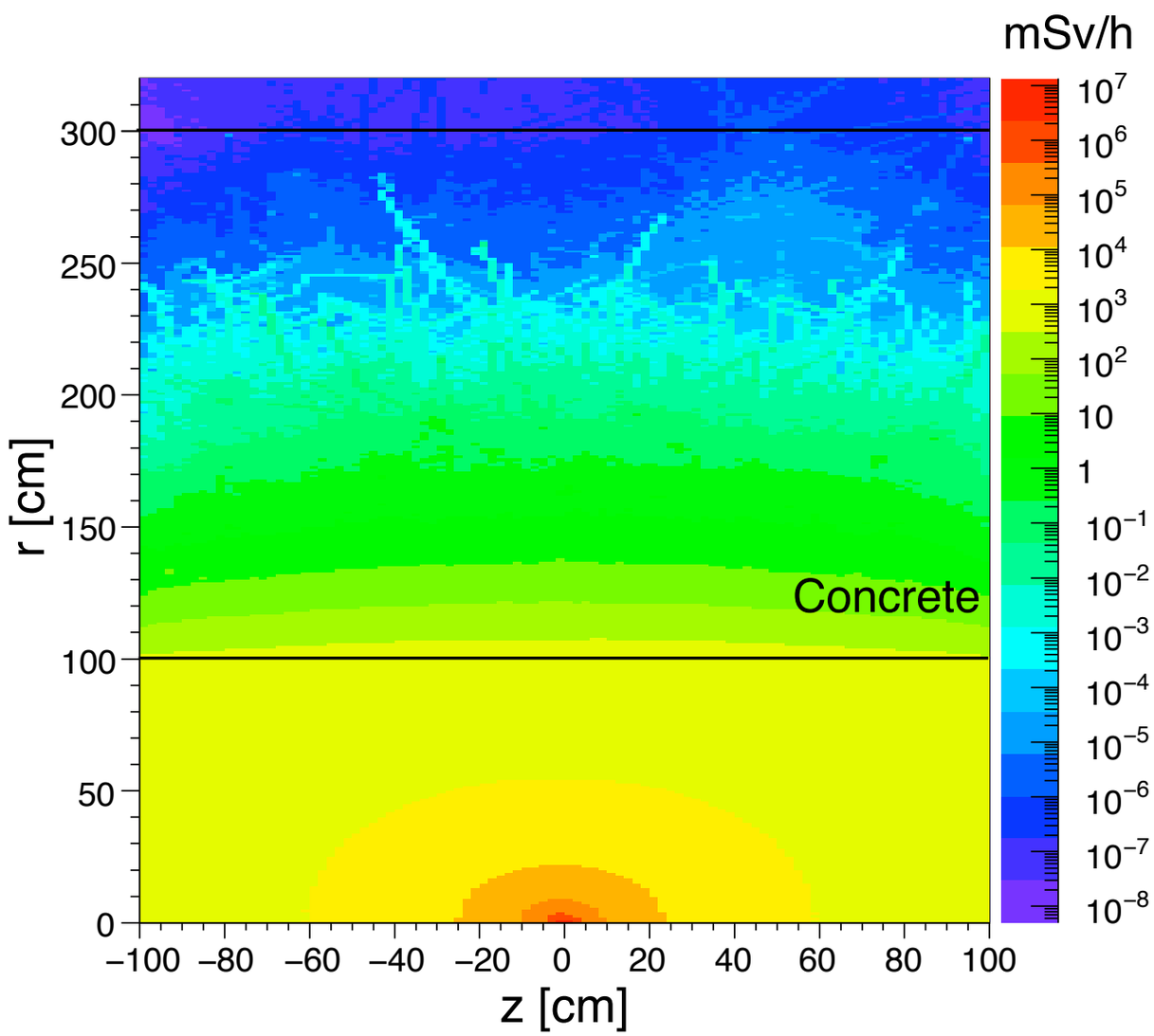
- 2m concrete wall has been added
- Target rim has been changed to the disk with radius of 1.5 cm
- Cooling water channel has been removed

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

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

Dose Rate

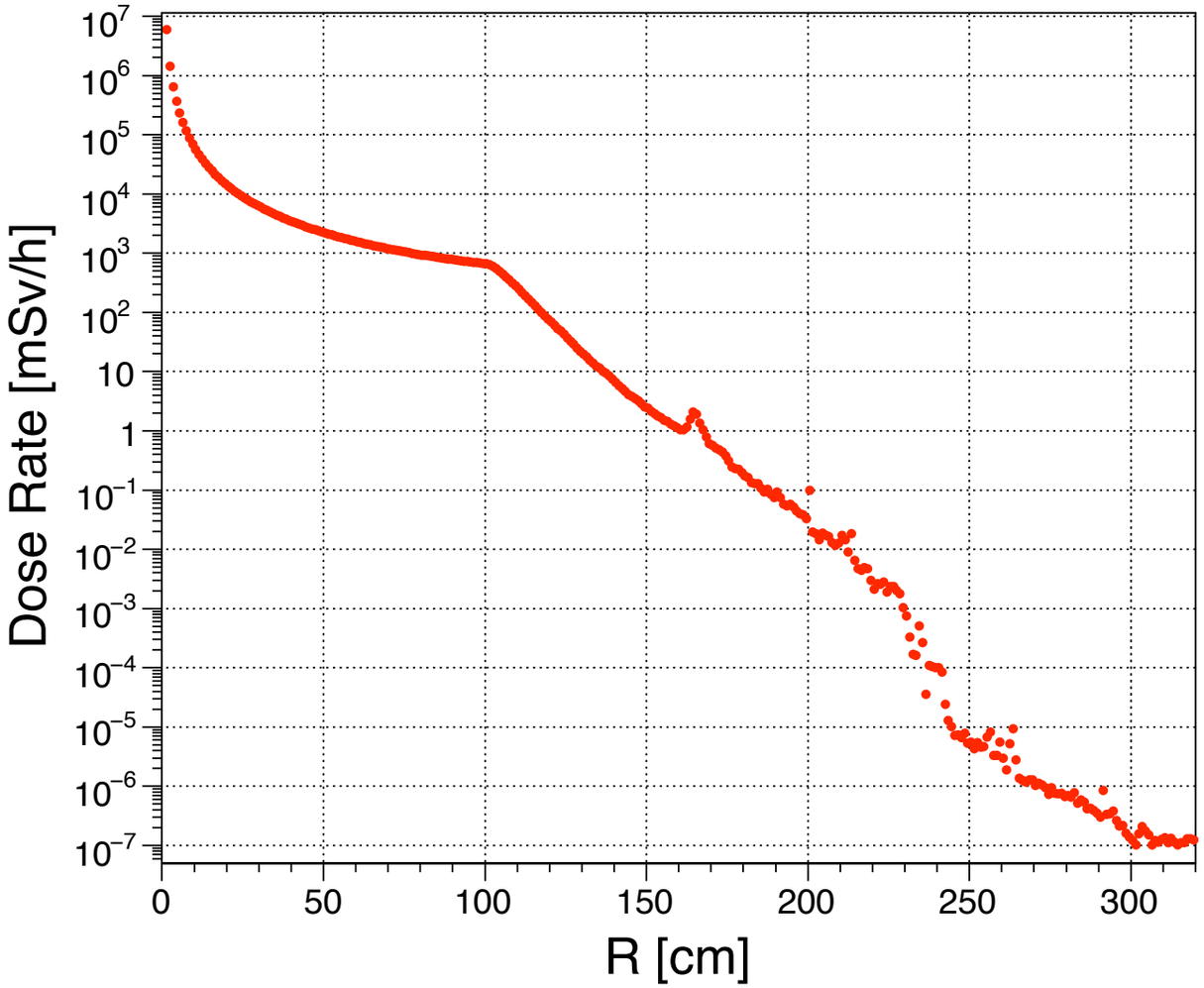
after 5000 h of irradiation and 0 s of cooling time

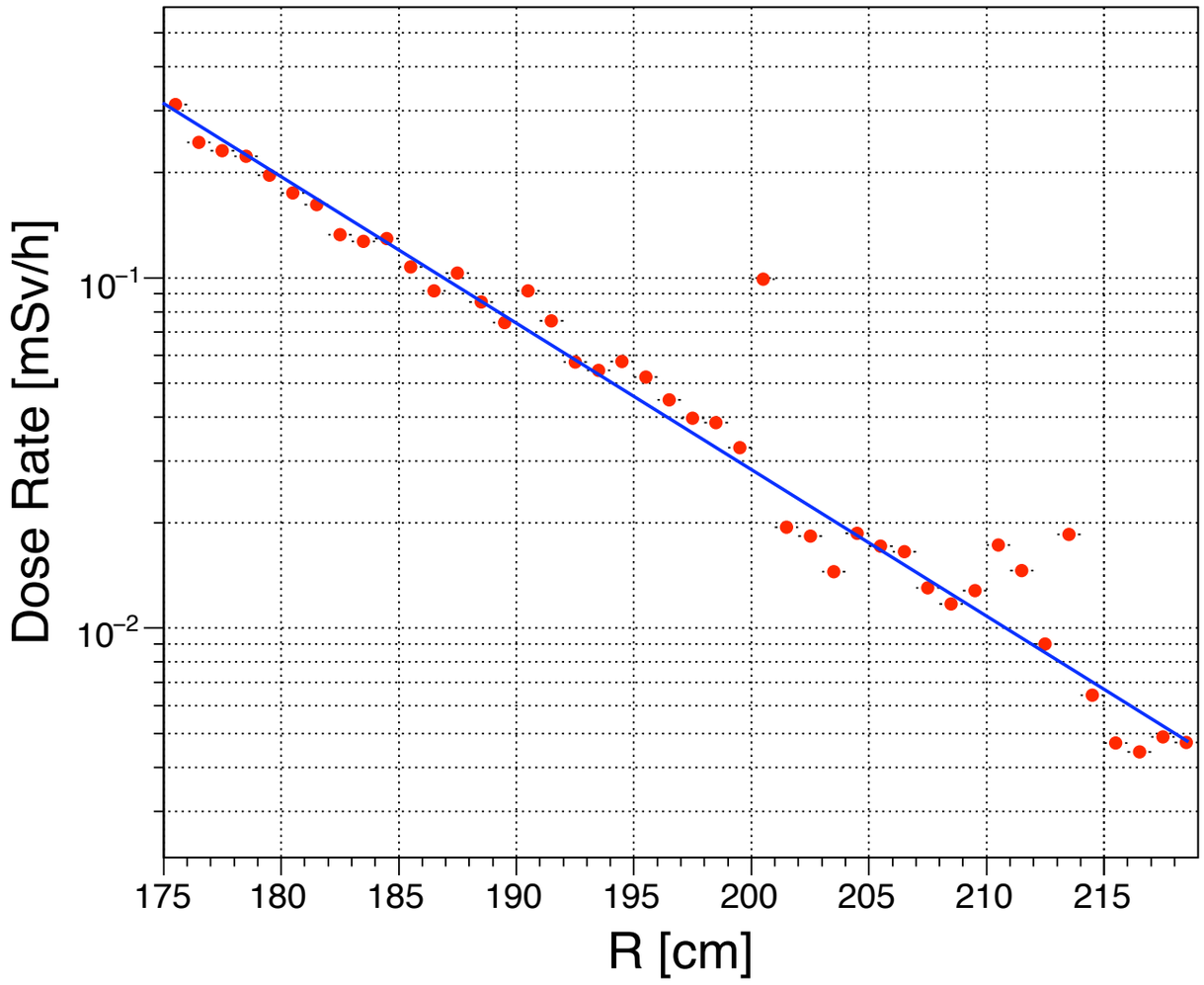


Required Thickness of Shielding

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

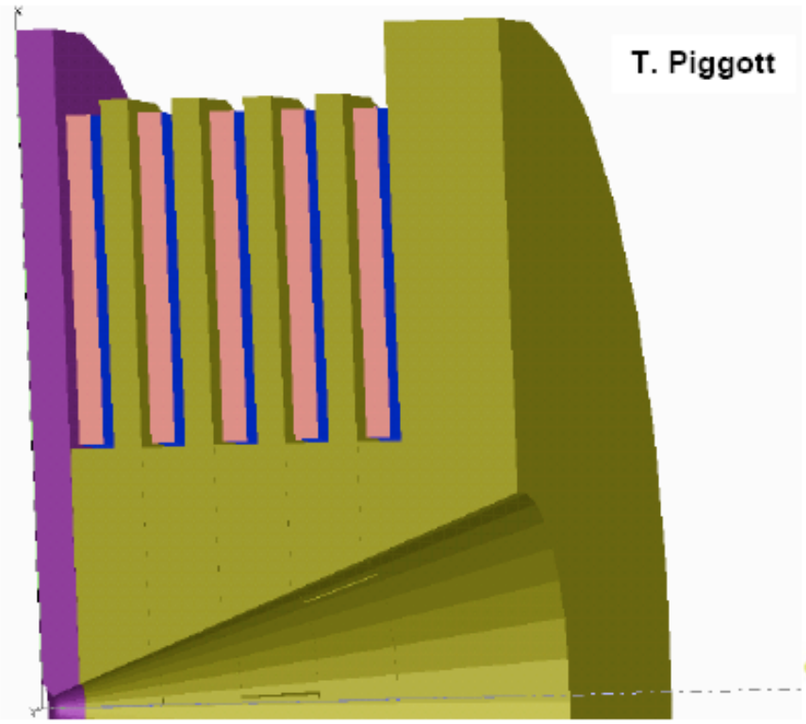
1.1m of concrete looks conservative





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 μ**s to ms** pulse lengths
- Further study needed to prove feasibility
- Would need a prototype

Flux Concentrator

- Long pulse length
- High field (field on target)
- Power supply
- Engineering to handle Cooling & forces
- Previous example suggests should be feasible
- Little active design so far for ILC

but ramping up now at LLNL

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

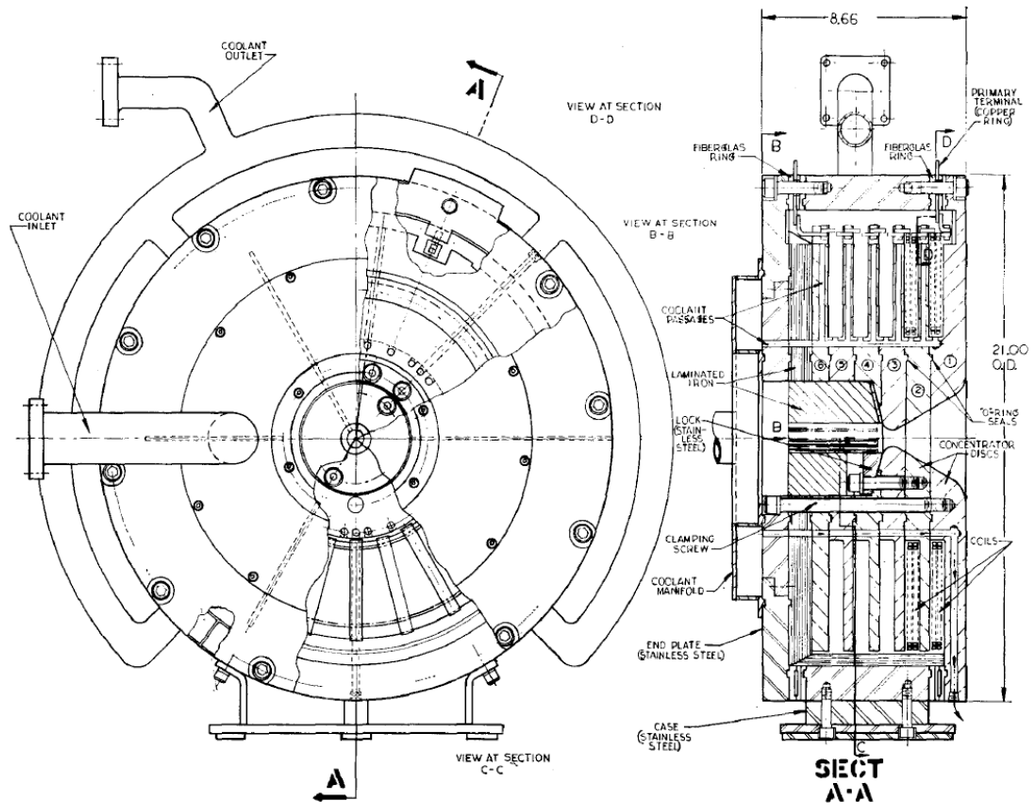
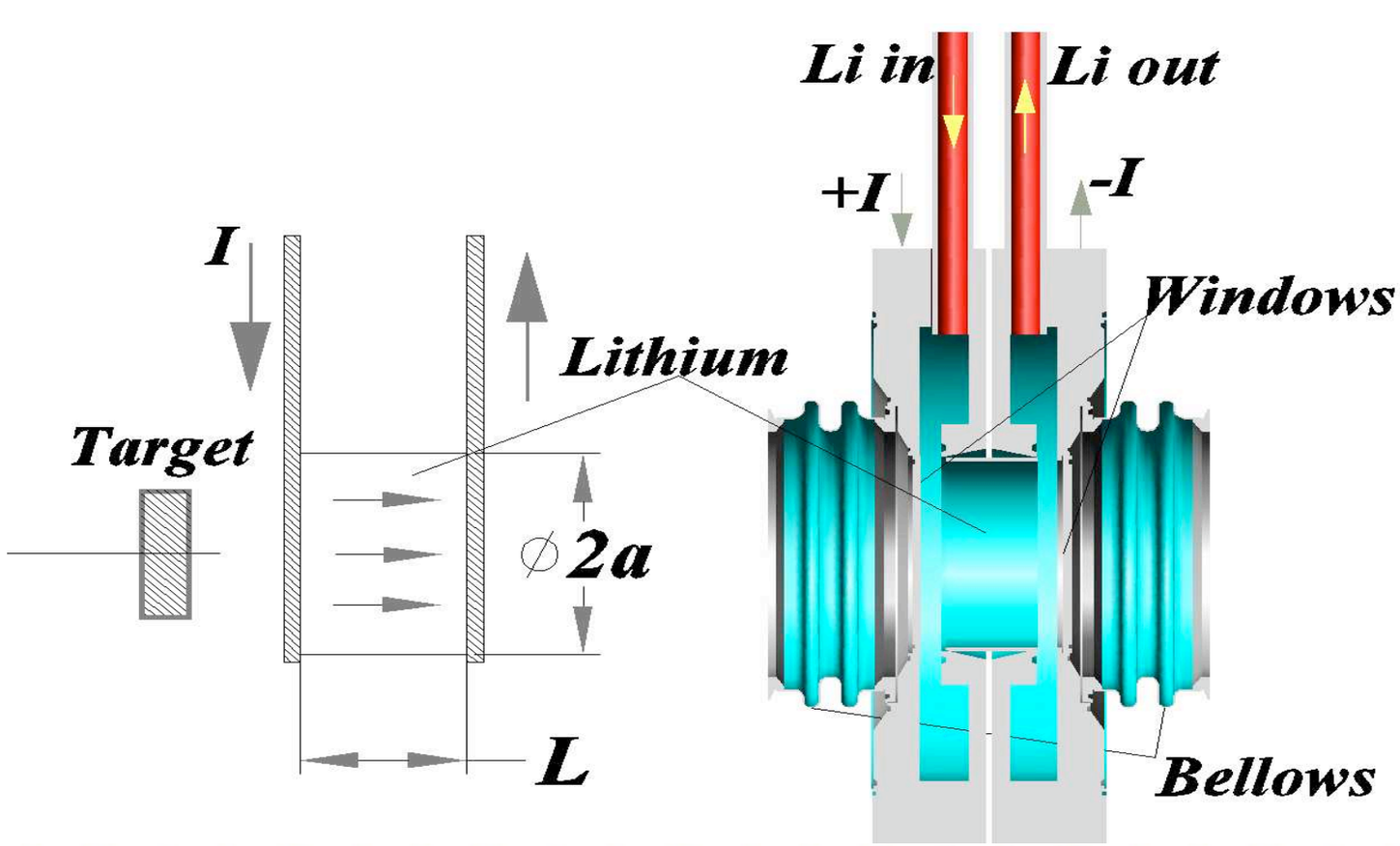


FIG. 4. End view and side section of flux concentrator final design.

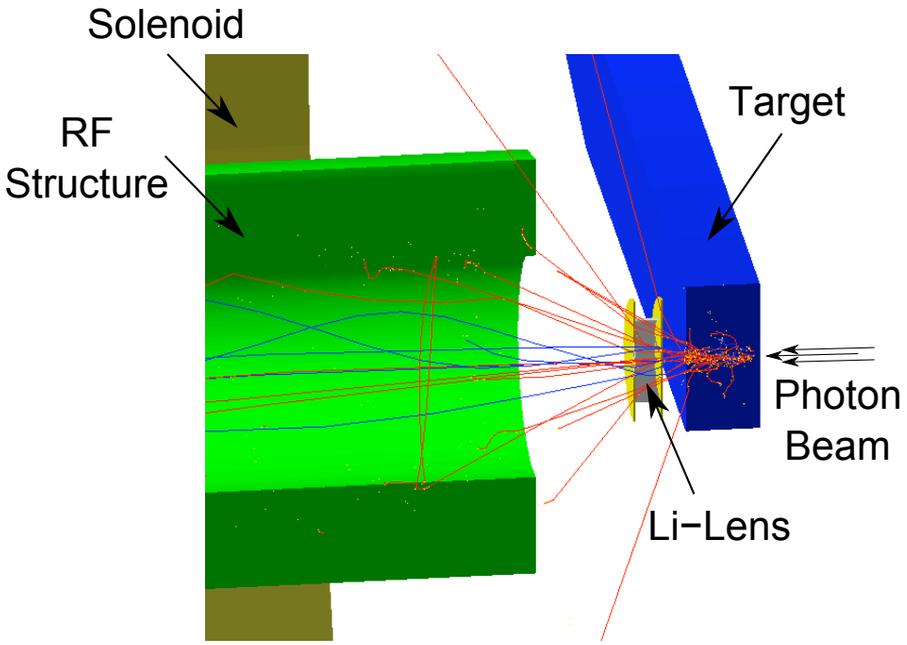
Lithium Lens Capture System

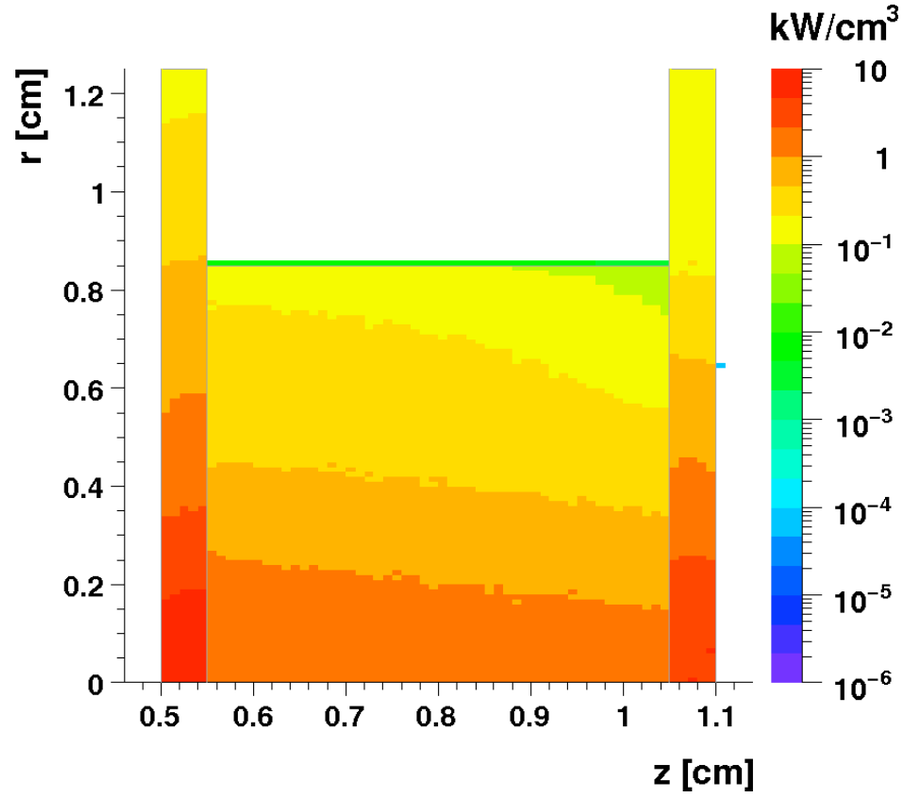
- Current flows co-linearly with positrons
- Induced magnetic field gives **focussing**
- Lithium will be liquid with flow of ~1m/s
- Capture up to **~40%** of positrons
- Would also need ***prototype***

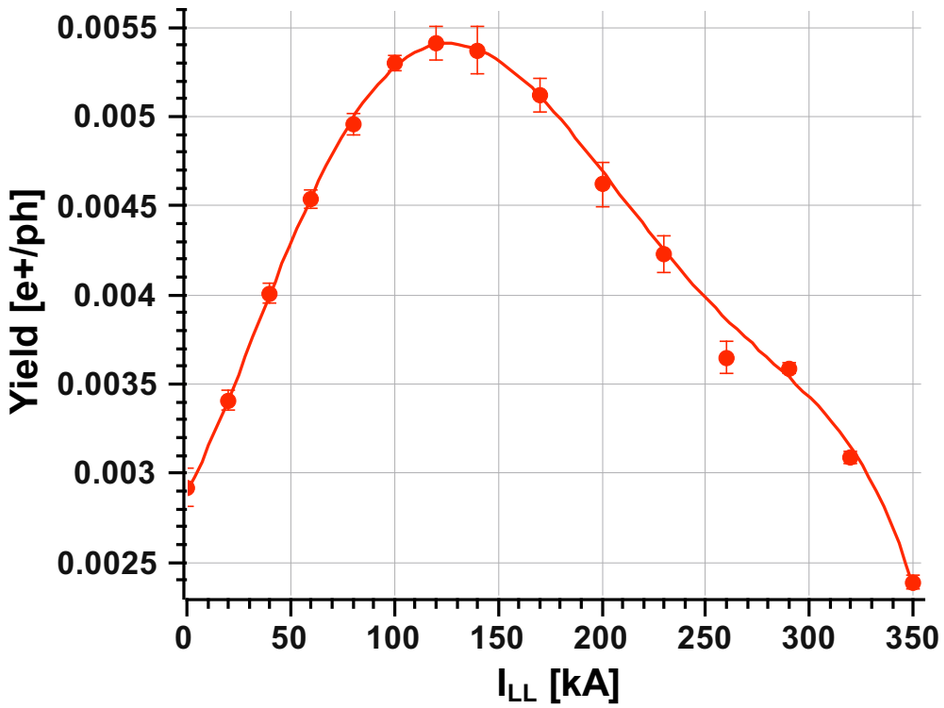


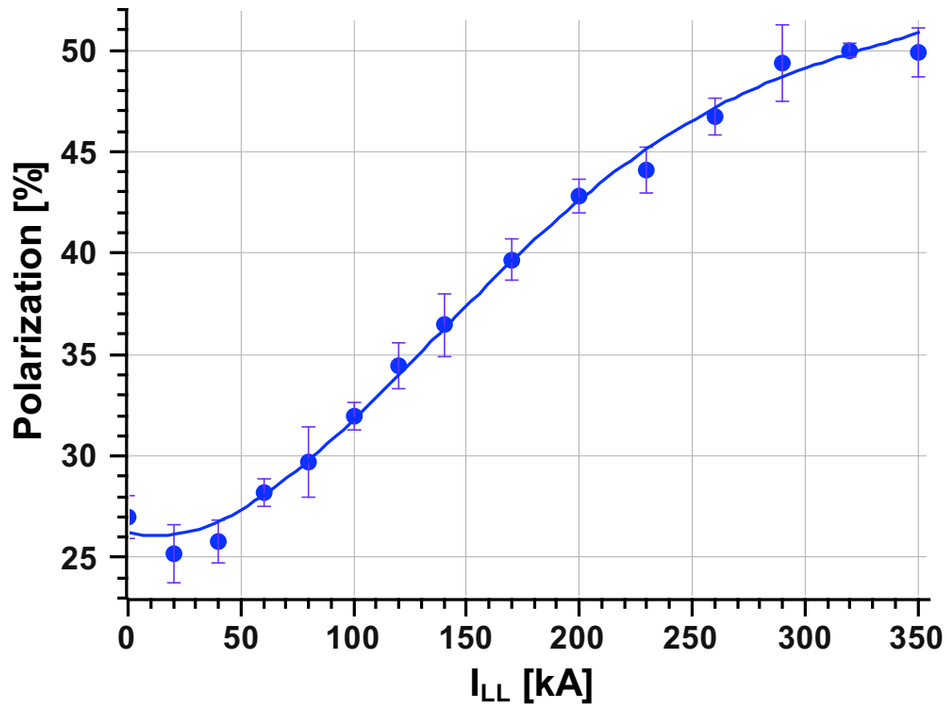
- Concerns mainly about *survivability* of windows
  - Radiation damage
  - Thermal shock & cycling
- Cavitation of the lithium
- **More detailed studies now ramping up at Cornell**

Lithium Lens - Simulations



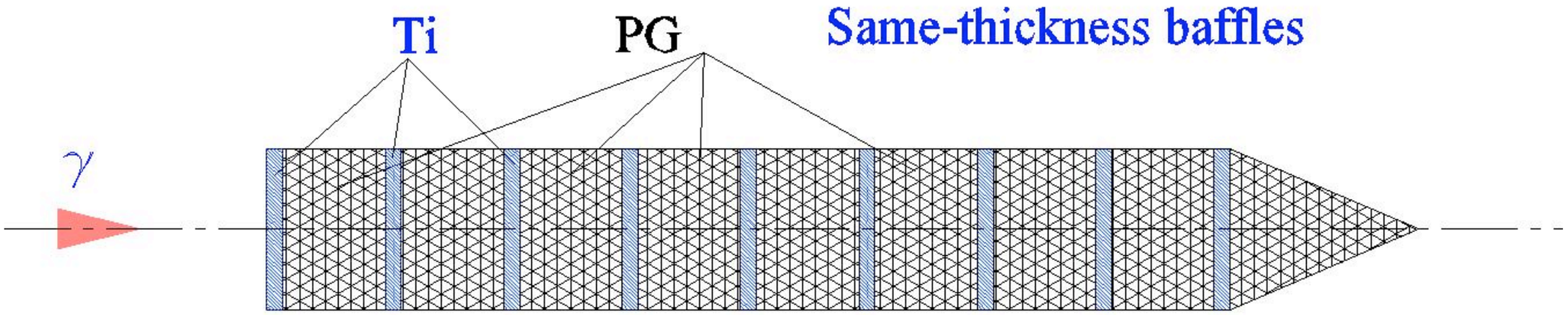


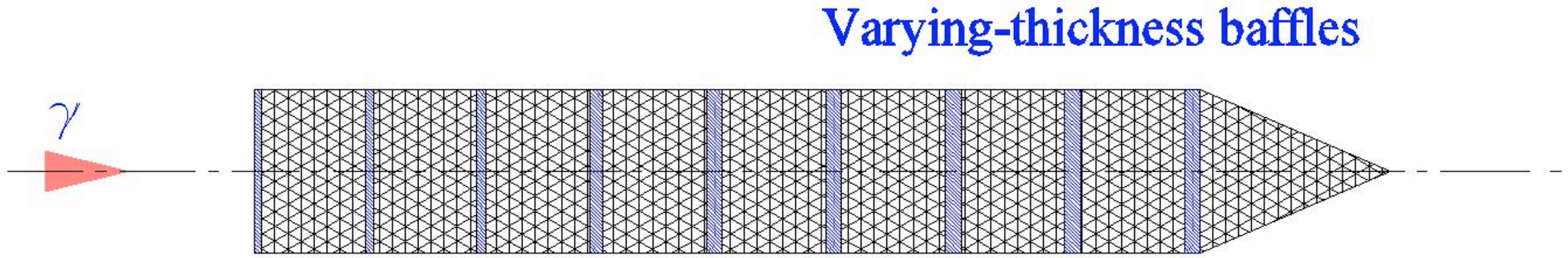




Gamma Dump

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



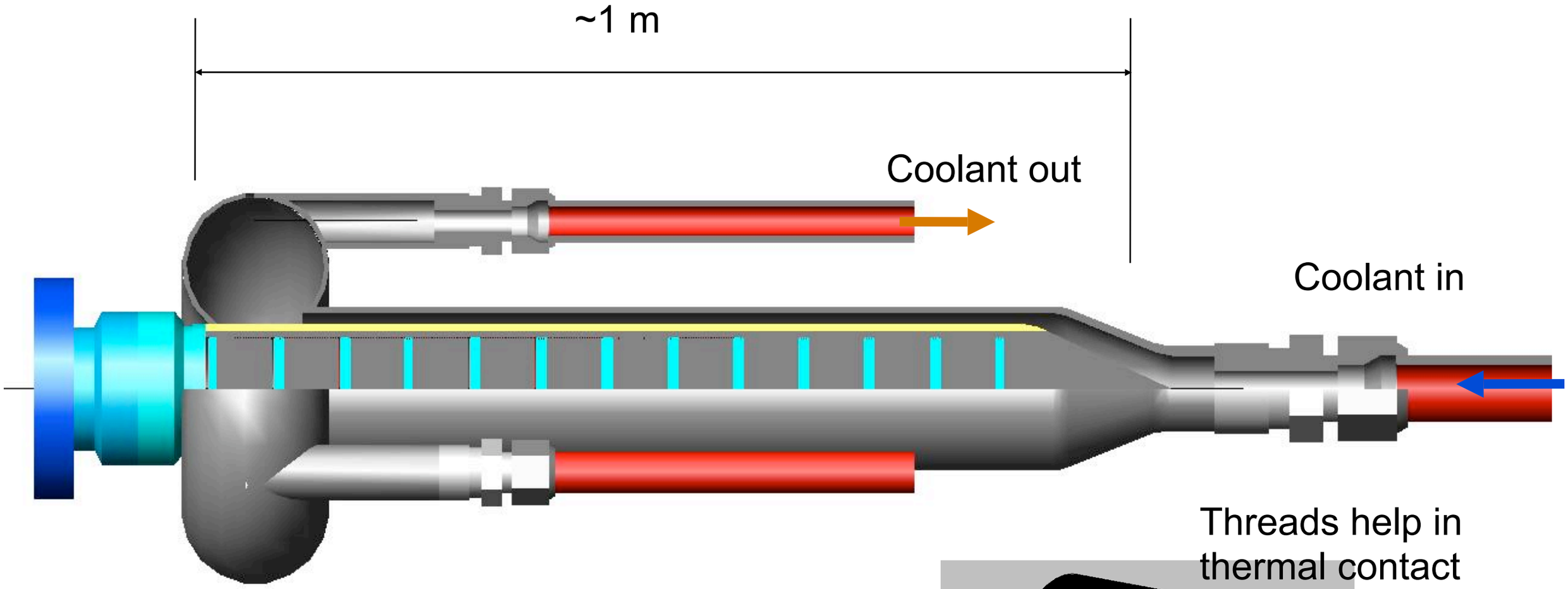


Ti -Titanium

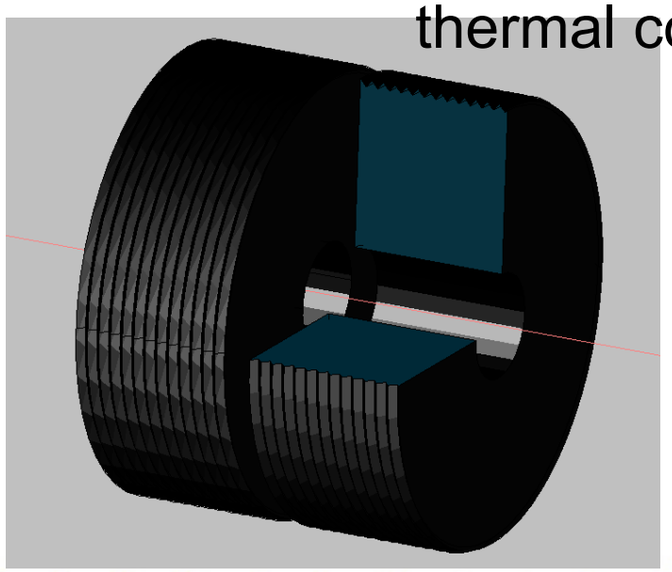
PG-Pyrolythic Graphite
with transversly oriented A plane

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

Gamma Dump with PG and Ti baffles



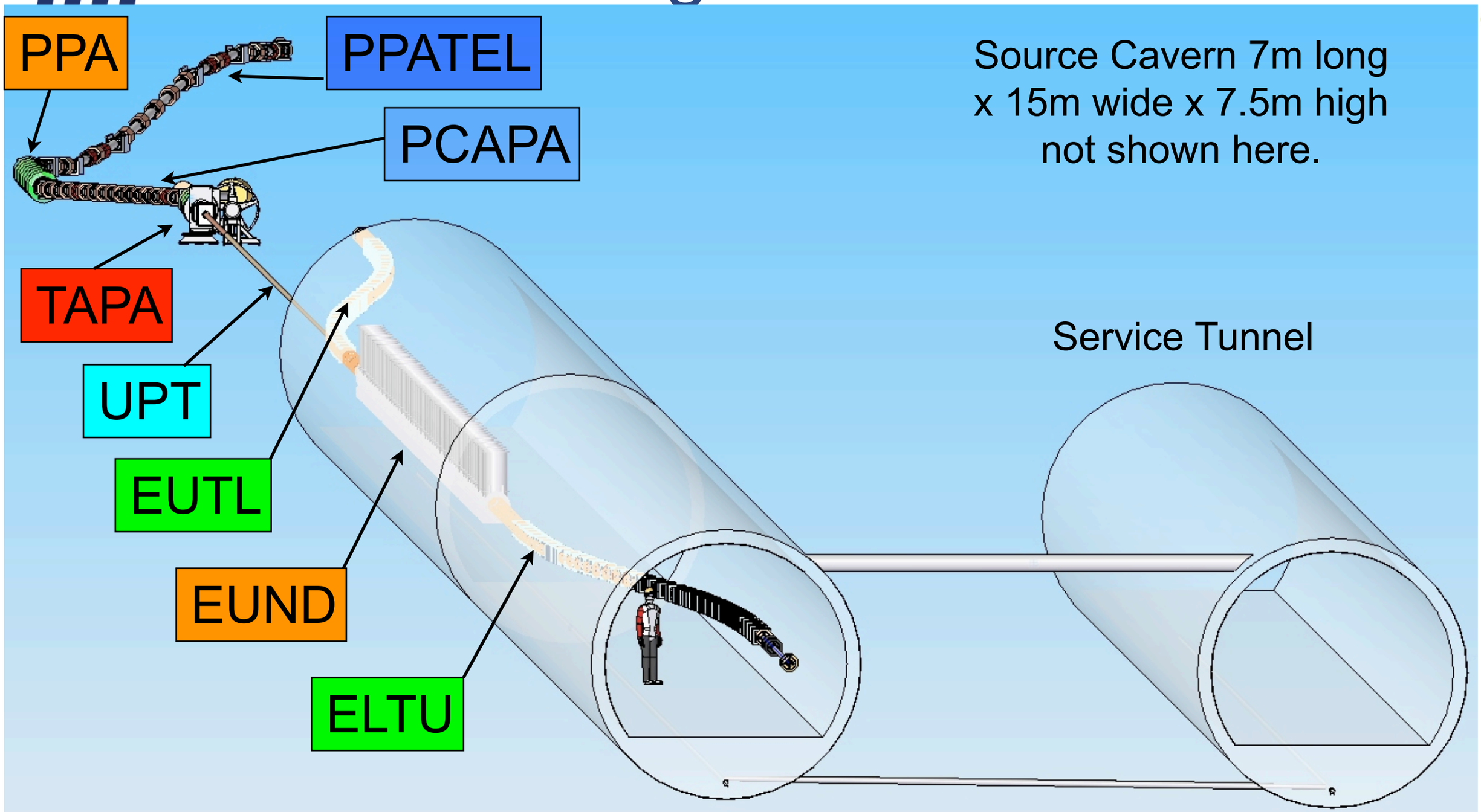
Threads help in thermal contact



Power 200kW requires coolant flow rate for temperature jump 20°C

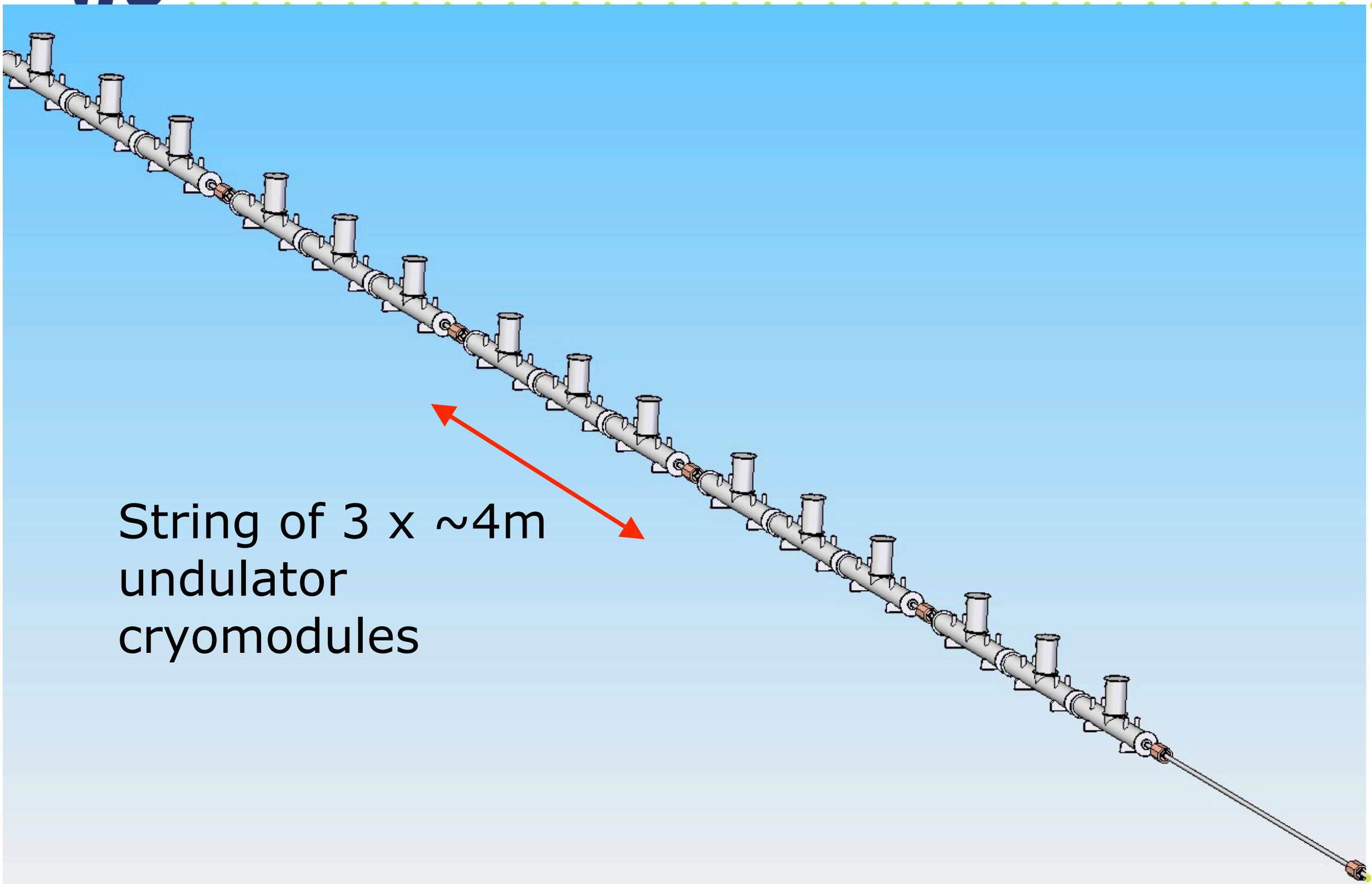
$$\dot{m} \cong \frac{E_{tot}}{\Delta T C_p} \cong \frac{2 \times 10^5}{20 \times 4.18 \times 10^3} \cong 2.4 L/\sec$$

RDR Integration Studies



Overall Layout

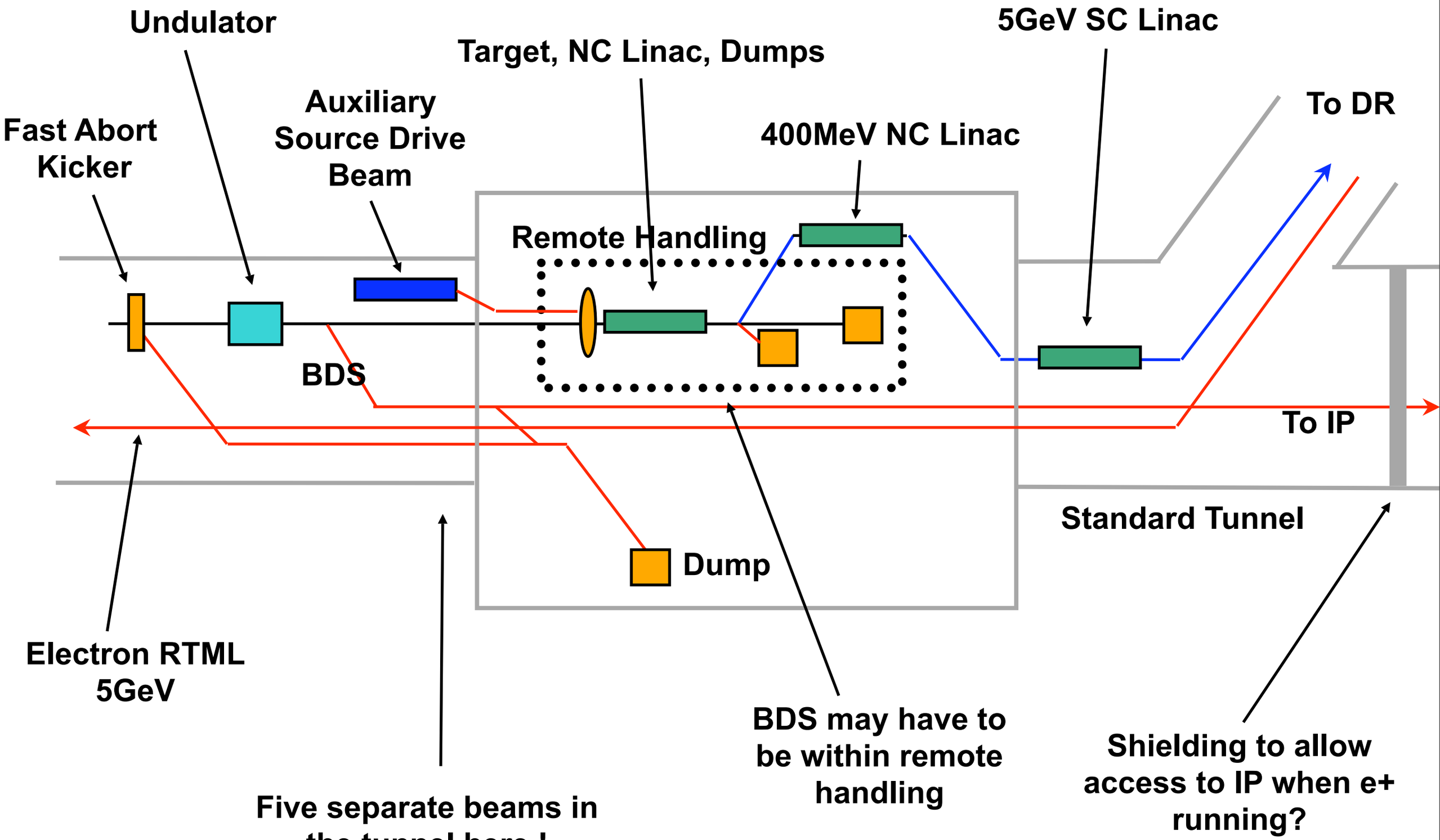
ILC Undulator Section



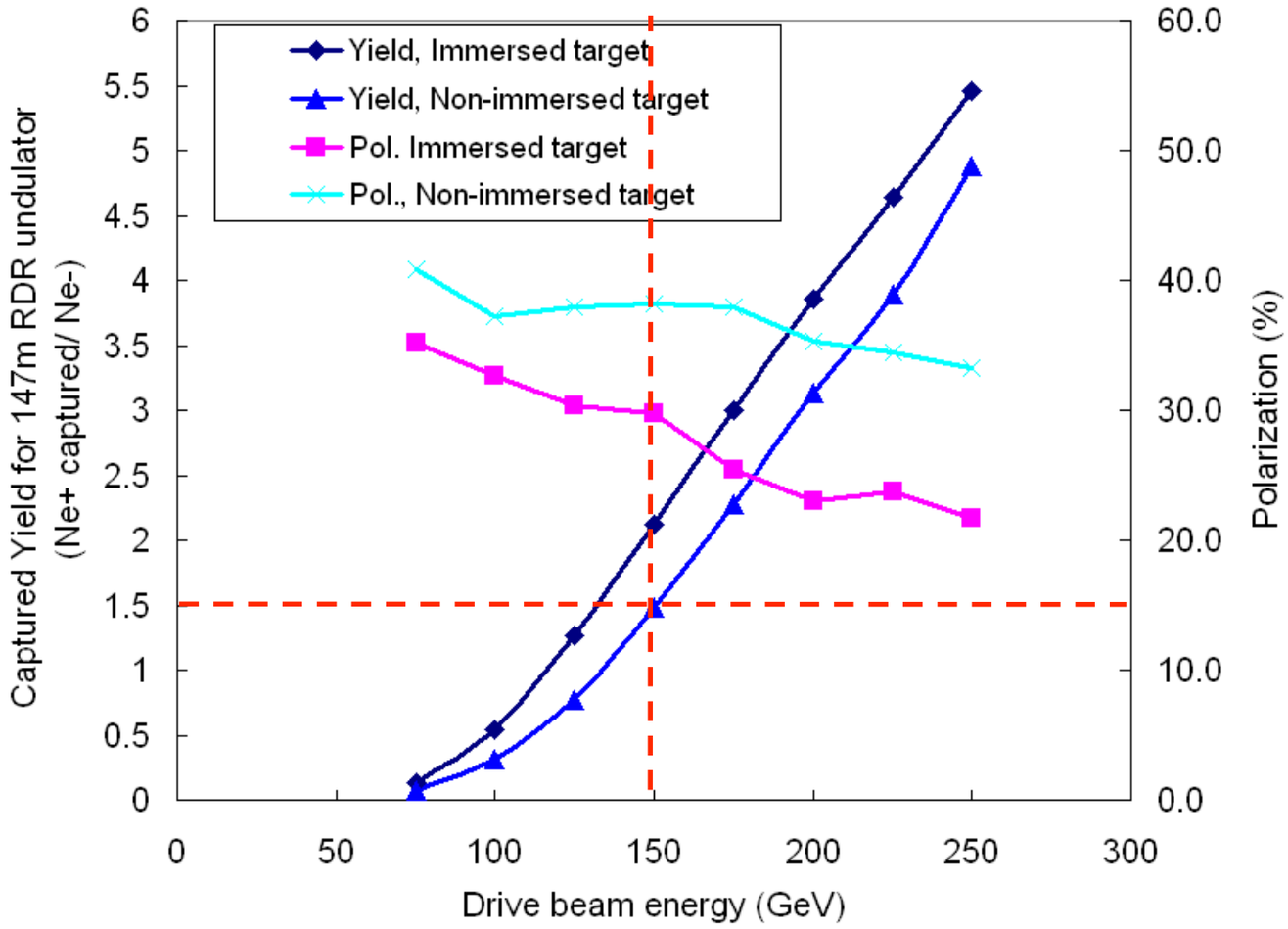
Minimum Machine

- Undulator moved to the end of the linac
  - This allows for sharing of infrastructure with the auxiliary source
  - Removal of the 1.2km insert at 150 GeV
  - Sharing of the tunnel (and shaft) with the BDS
  - Use quarter wave transformer as capture magnet as lower risk
- The undulator was originally placed at 150 GeV (BCD White Paper) primarily for physics reasons to maintain design luminosity over the full electron energy range

Minimum Machine Layout



Minimum Machine



The key issue for the positron source is how to maintain the luminosity with low energy (<150GeV) operation

At some energy below 150 GeV the yield will fall by a factor of two and ILC could then operate in a pulse sharing mode

The source needs to be re-optimised for the undulator at the end of the linac

Next Steps

- Complete commissioning of the undulator
- Analyse the target experiment data
- Generate a feasible flux concentrator design
- Detailed studies of the lithium lens

- Design integration of the new layout with CF&S
- Assess schemes for low energy running

Thanks to all who contributed to this presentation