# Undulator Based Source Overview

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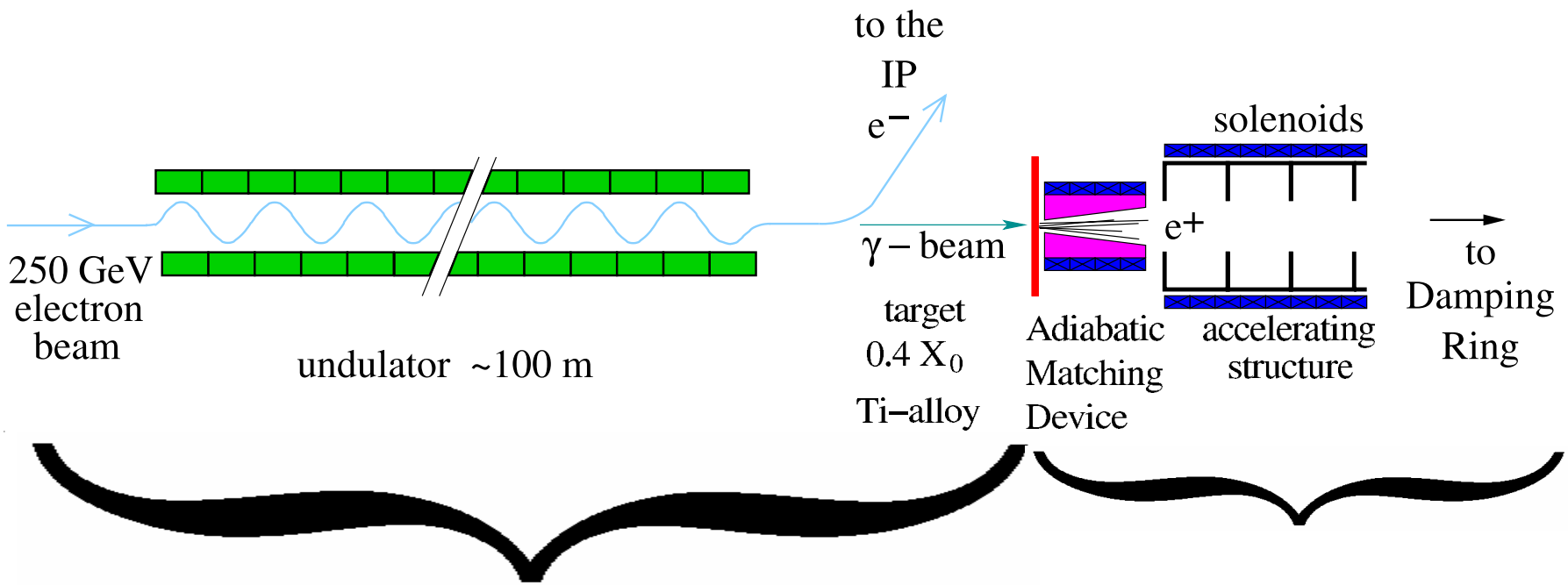
# Introduction

- Going to talk about the main parts of the design
  - Undulator
  - Collimators
  - Target
- Outstanding issues
- Who, How, When work is going to be done (?)
- Personal View

# Basic Schematic – Floettmann 1st ILC Workshop KEK




- Covered In this talk
- Not covered In this talk
- (yesterday)

# Parameters

- Electron Beam Parameters through the undulator (TESLA TDR)

| Parameter | Unit | Value |
|---|---|---|
| $\beta_x$ | m | 225 |
| $\beta_y$ | m | 100 |
| $\alpha_x$ | | 0 |
| $\alpha_y$ | | -100 |
| $\sigma_x$ | μm | 67 |
| $\sigma_y$ | μm | 2.8 |
| $\sigma_{x'}$ | μrad | 0.30 |
| $\sigma_{y'}$ | μrad | 2.8 |

| Parameter | Unit | Value |
|---|---|---|
| (Min) Energy | GeV | 150 |
| Natural Emittance | m rad | $2\ 10^{-11}$ |
| Average Current | μA | 45 |
| Rep-Rate | | 5 |
| Bunches per pulse | | 2820 |
| # $e^-$ per bunch | | $2\ 10^{10}$ |
| Coupling | | 0.004 |
| Energy Spread | | 0.001 |

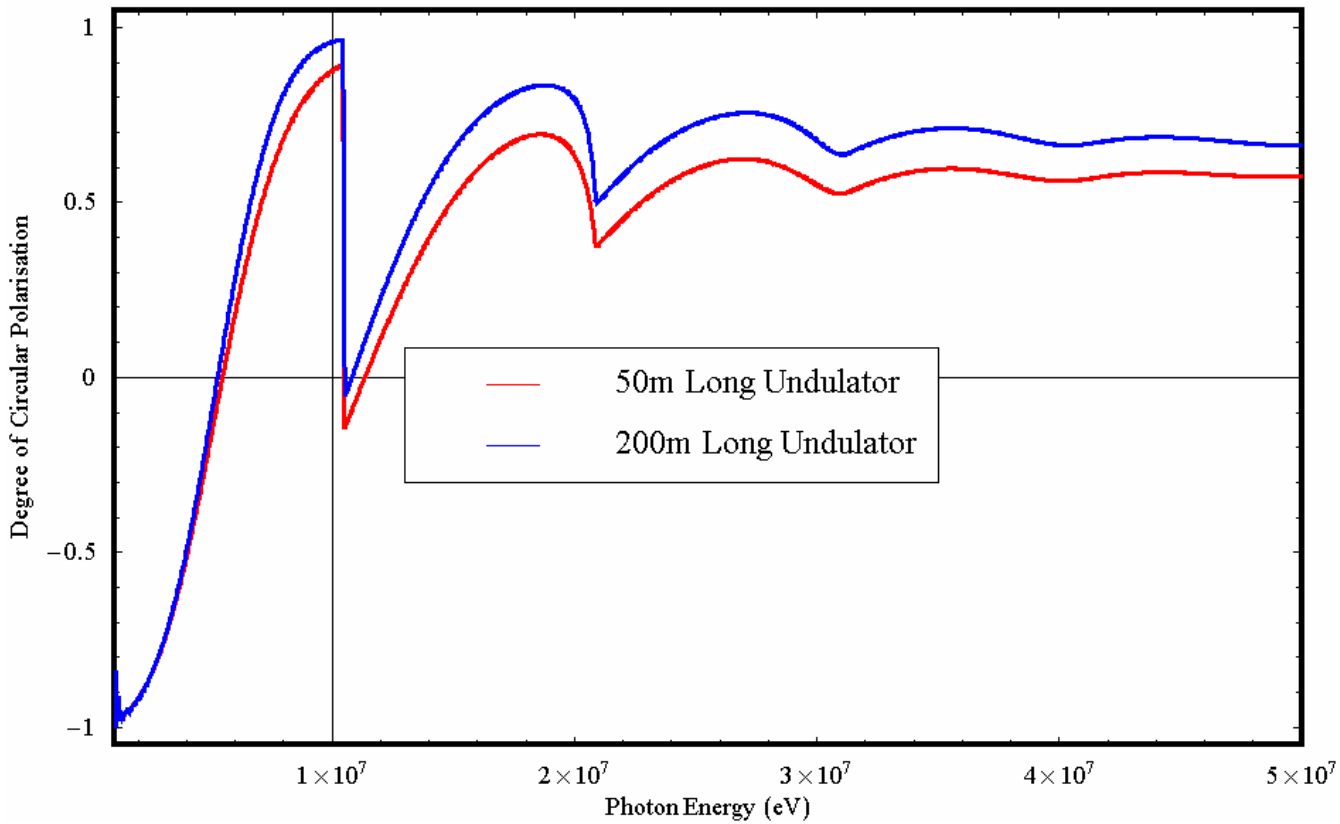
# Parameters

- Agreed Undulator Parameters – from Daresbury Workshop based on current models
- Parameters used are achievable (unless otherwise stated)

| Parameter | Achievable based on current models | Possible for ILC? |
|---|---|---|
| $\lambda u$ | 12 | 10 |
| Min Beam Energy | 150 | 150 |
| Nominal Kx, Ky | 0.84, 0.84 | 1, 1 |
| 1st Harmonic (MeV) | 10.4 | 10.6 |
| On Axis B (T) | 0.75 | 1.07 |
| e+ Polarisation | 0.6 | 0.6 |
| Yield (e+ / e-) | 1.5 | 1.5 |

# Undulator Length and Polarisation

- Polarisation depends upon length of undulator and degree of collimation
- Off axis photons are not circularly polarised
- 60% is required by physics – could be higher if required?



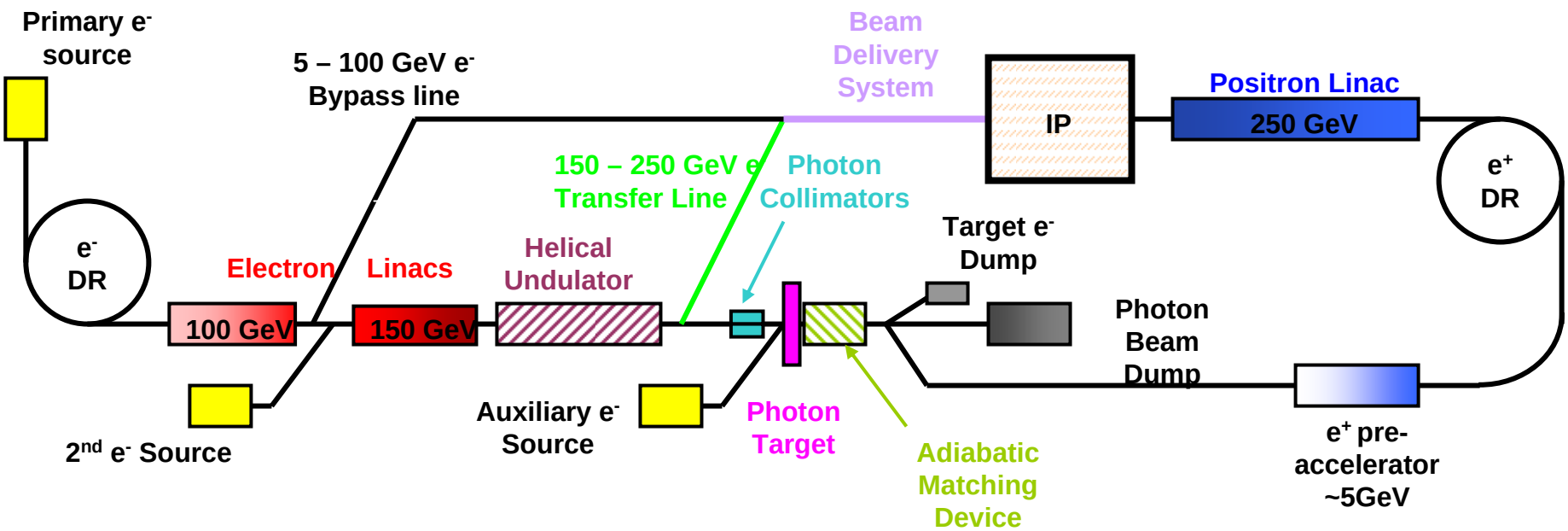

Circular polarisation of photons forming a 1mm spot on a target

# Layout Issues

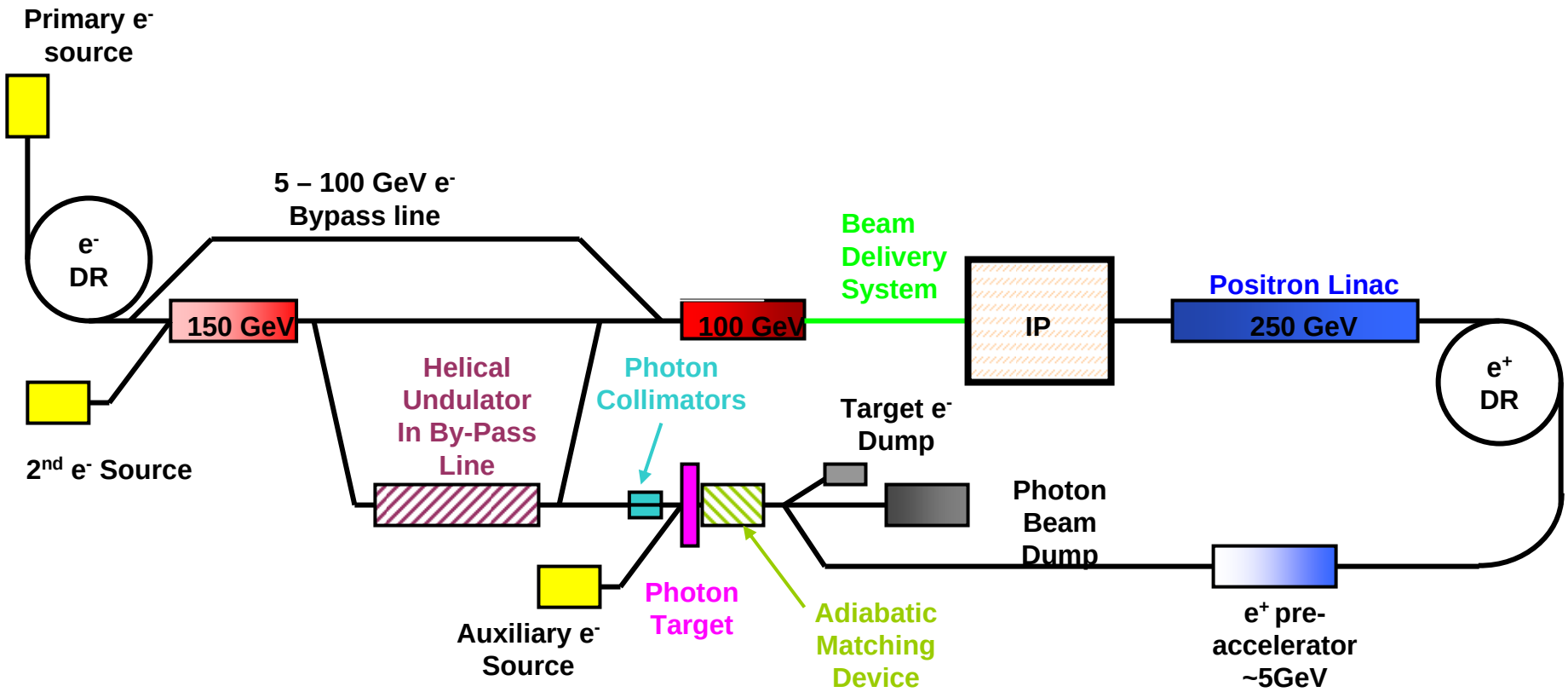
- Energy of Beam through Undulator?
- Agreed 150 GeV Minimum but…
  - Fixed energy range?
  - Variable energy range (150GeV to 250GeV)
- GigaZ operation – (optional)
- Low energy beam for IP and high energy beam for Undulator
  - Extra Transfer Paths?
  - Deceleration of Electron Beam? (only if undulator is at 150GeV)
- All schemes will work, but which is best?
- Decision before we leave

# Schematic Layout – Undulator @ 250GeV & Transfer Paths

NB bypass line can go anywhere between 50GeV and 100GeV

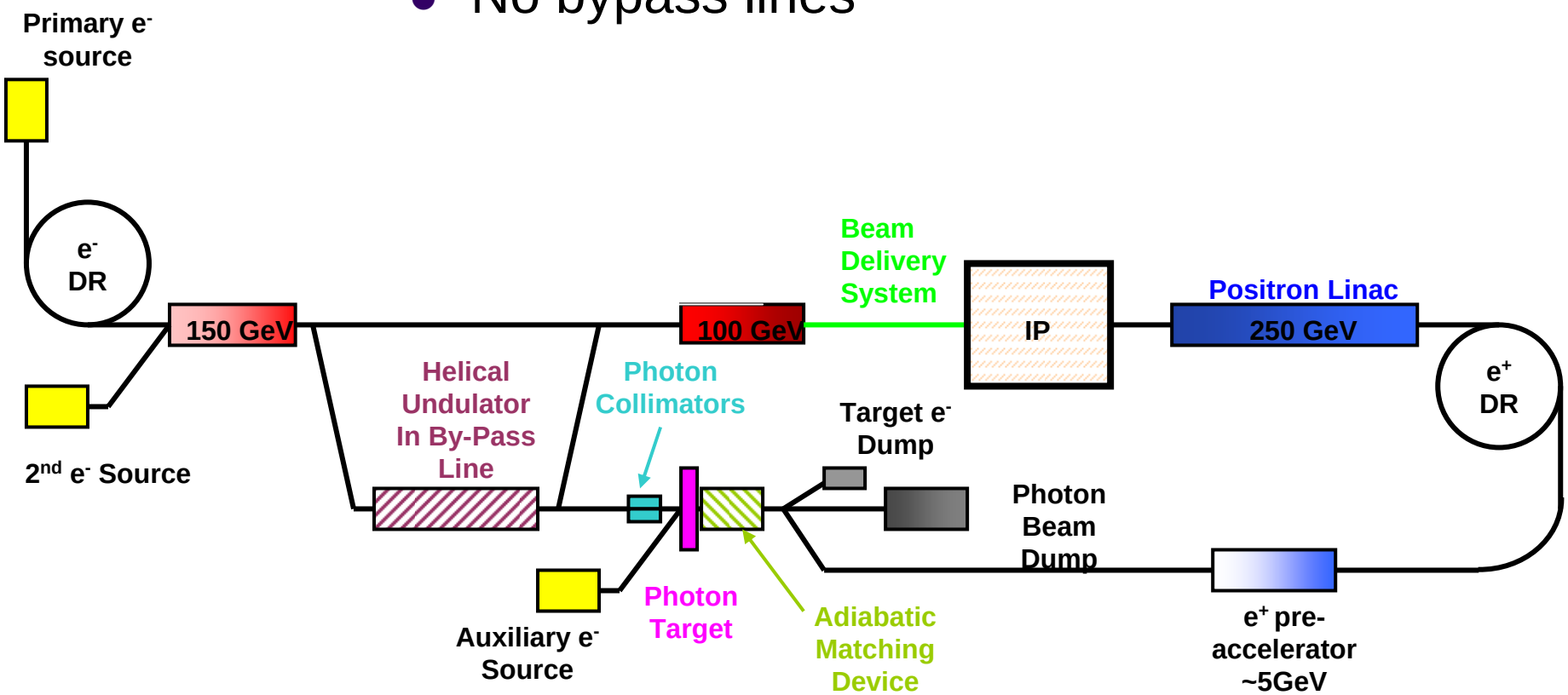


# Schematic Layout – Undulator @ 150GeV & Transfer Paths



# Schematic Layout – Undulator @ 150GeV & Deceleration

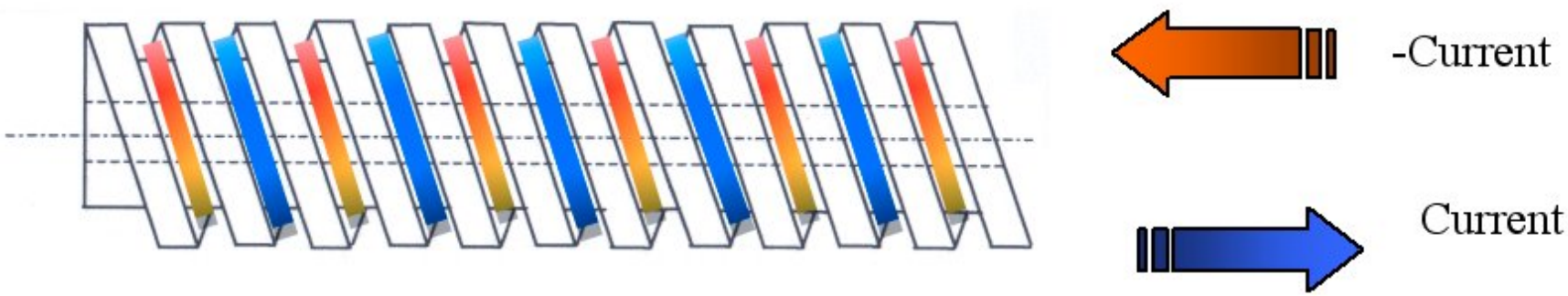
- No bypass lines



# Layout Issues

- 150 GeV
  - How do the changes in the beam due to the undulator effect the operation of the linac after the undulator?
  - Getting the beam to the beam dump in GigaZ operation
- 250 GeV
  - Getting the beam to the beam dump in GigaZ operation
- Particle losses < $10^{-5}$ per meter in beam dump lines
- Deceleration
  - Energy jitter, emittance increase, energy spread
  - Getting the beam to the beam dump
- Decision at this meeting?

# Super-Conducting Design



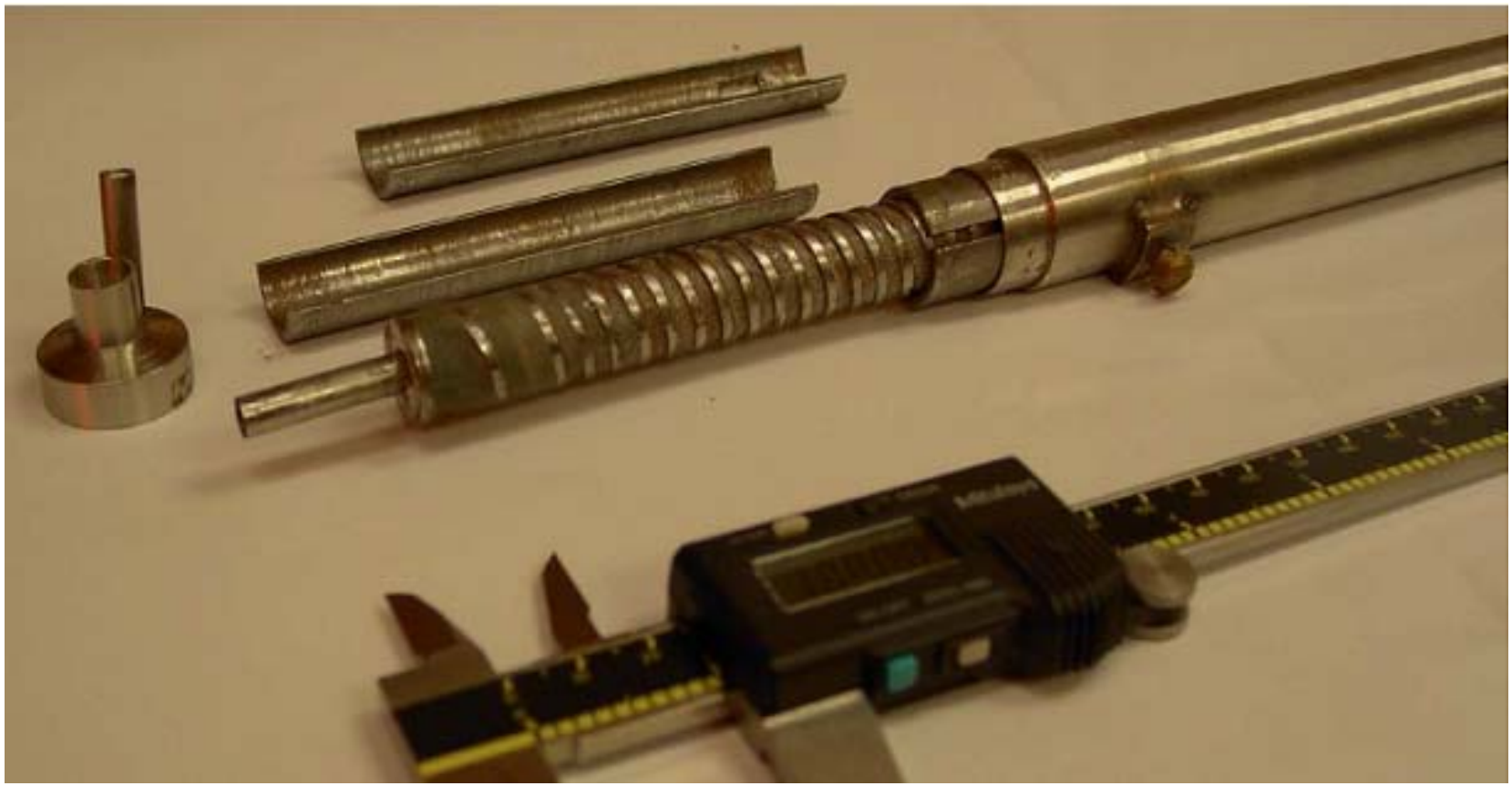

- Wires wrapped in a double helix around a former
- Current is passed in opposite directions through each helix
- Longitudinal fields cancel leaving a rotating dipole field on axis

# Current Super-Conducting Models

| Parameter | Units | Current Models | |
|---|---|---|---|
| $\lambda u$ | mm | 10 | 14 |
| Min Beam Energy | GeV | 150 | 250 |
| Nominal Kx, Ky | Max | 0.5, 0.5 | 1.05, 1.05 |
| 1st Harmonic | MeV | 17.1 | 20.2 |
| On Axis B | T | ~0.5 | 0.8 |
| Length | m | ~0.3 | 0.3 |
| Beam Stay Clear | mm | 6 | 4 |

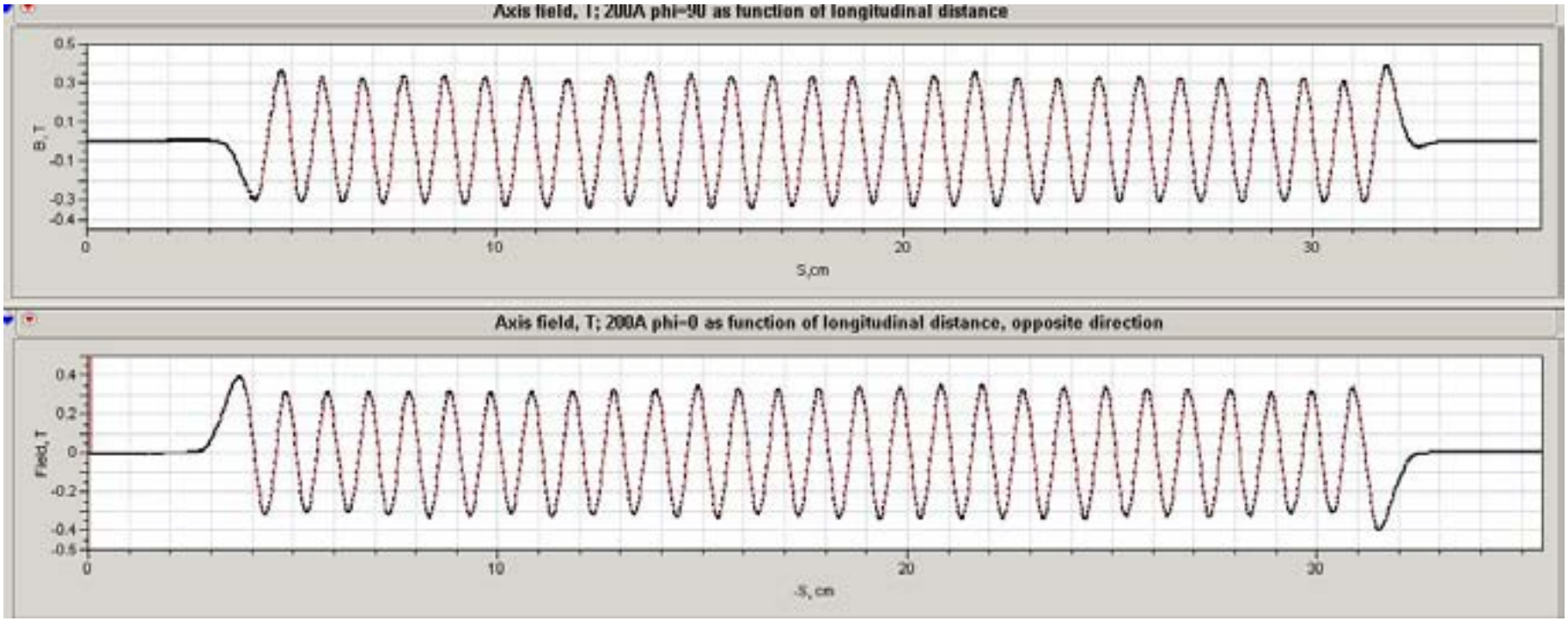
# Super-Conducting Model

- 10mm period model



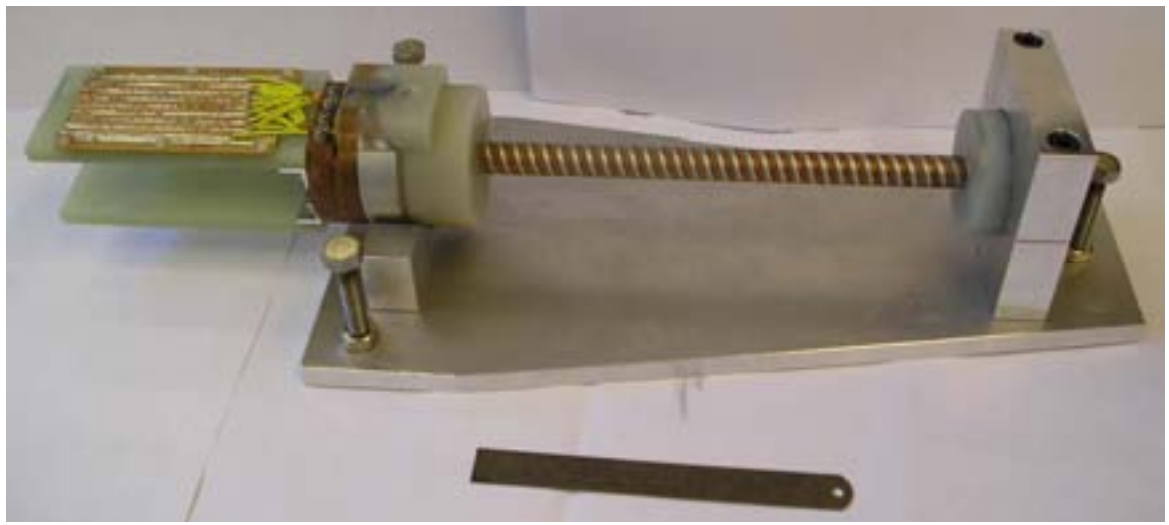
# Field Measurements

- Field measured at 200A (tested to 400A)



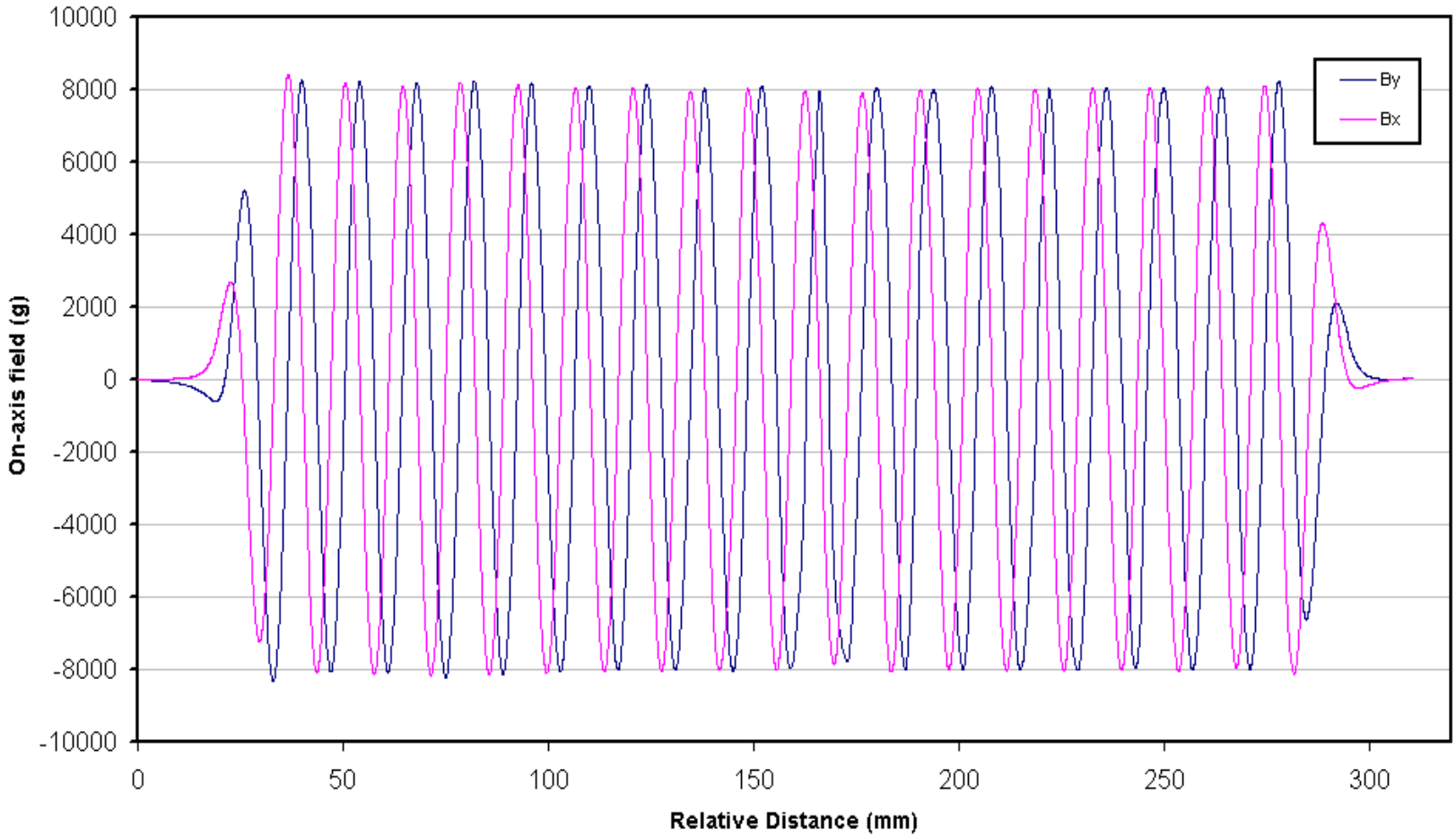
# Super-Conducting Model

14mm period Model



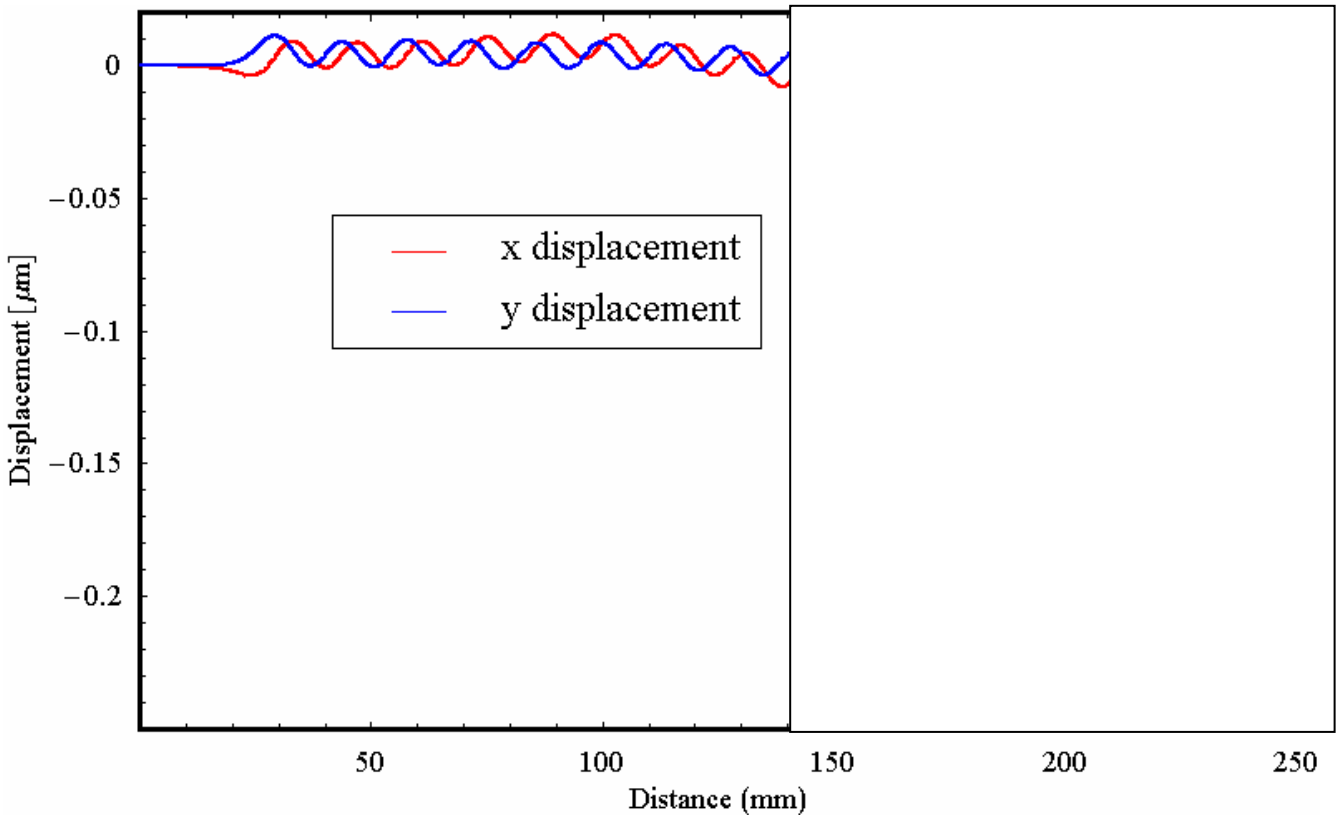
# Super-Conducting Models

- 14mm Period Field Measurements

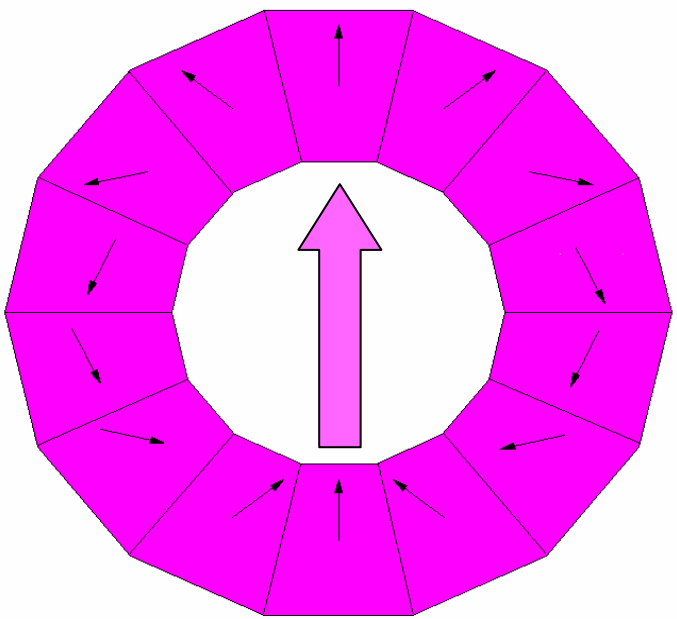


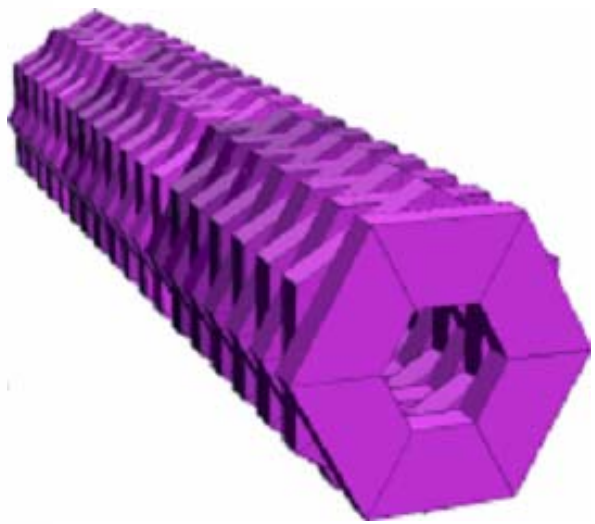
# Trajectory Calculations (250GeV electrons)

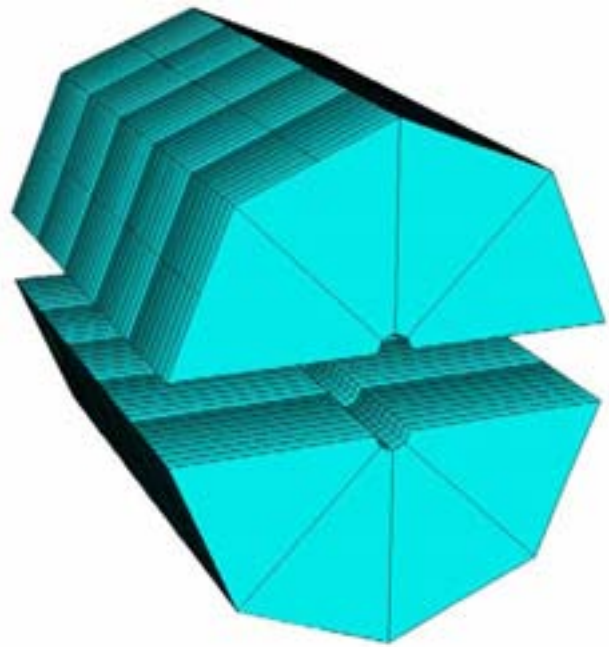
- goes bad at ~140mm - Measured data is bad at that point
- Up to 140mm helix looks good - ~10nm diameter
- 1 bad point can send the trajectory off axis



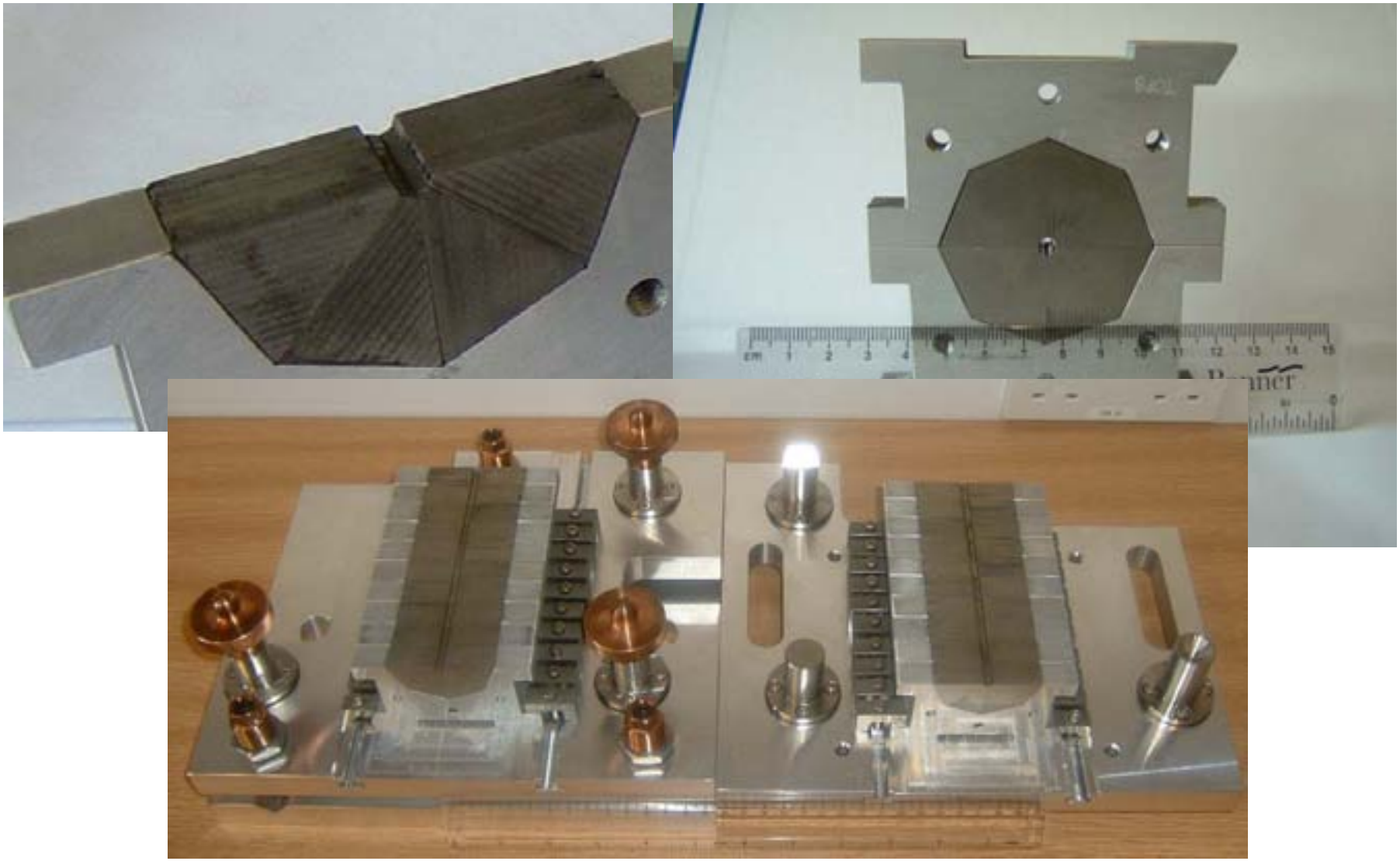
# PPM Design





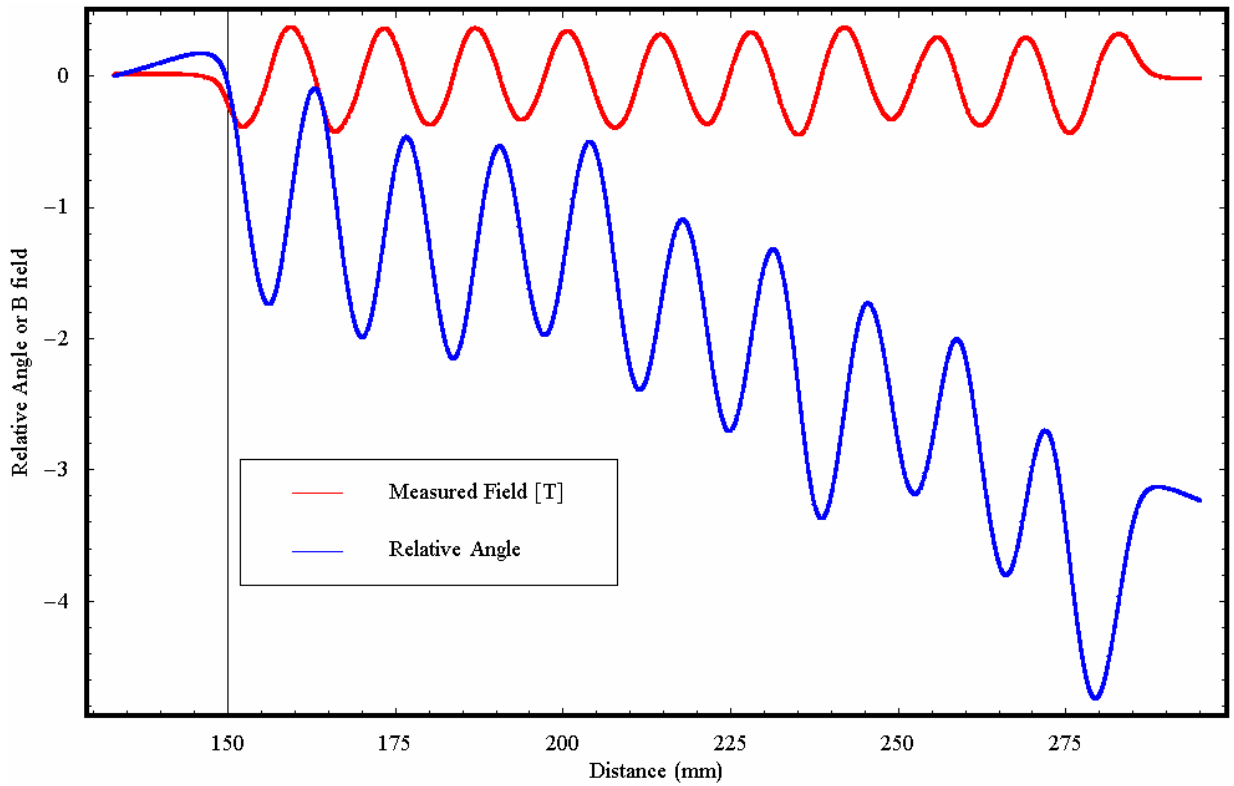


# Pure Permanent Magnet Model



# PPM Measurements

- Field Measurements Still Ongoing
- Initial Measurements show lower field than expected
- Open circuit remenance of magnet blocks lower than expected



# Issues for the Undulator

- How can we Increase the field strength?
  - Iron poles (iron sleeve is simple)
  - PPM @150k
- How can we measure the field more accurately?
  - Pulsed Wire measurements? (@ 4K?)
  - **Beam Tests**
- How long a module can we make?
- 'Helical Collaboration' & Cornell are collaborating to build a fully working prototype

# Undulator Prototype Milestones

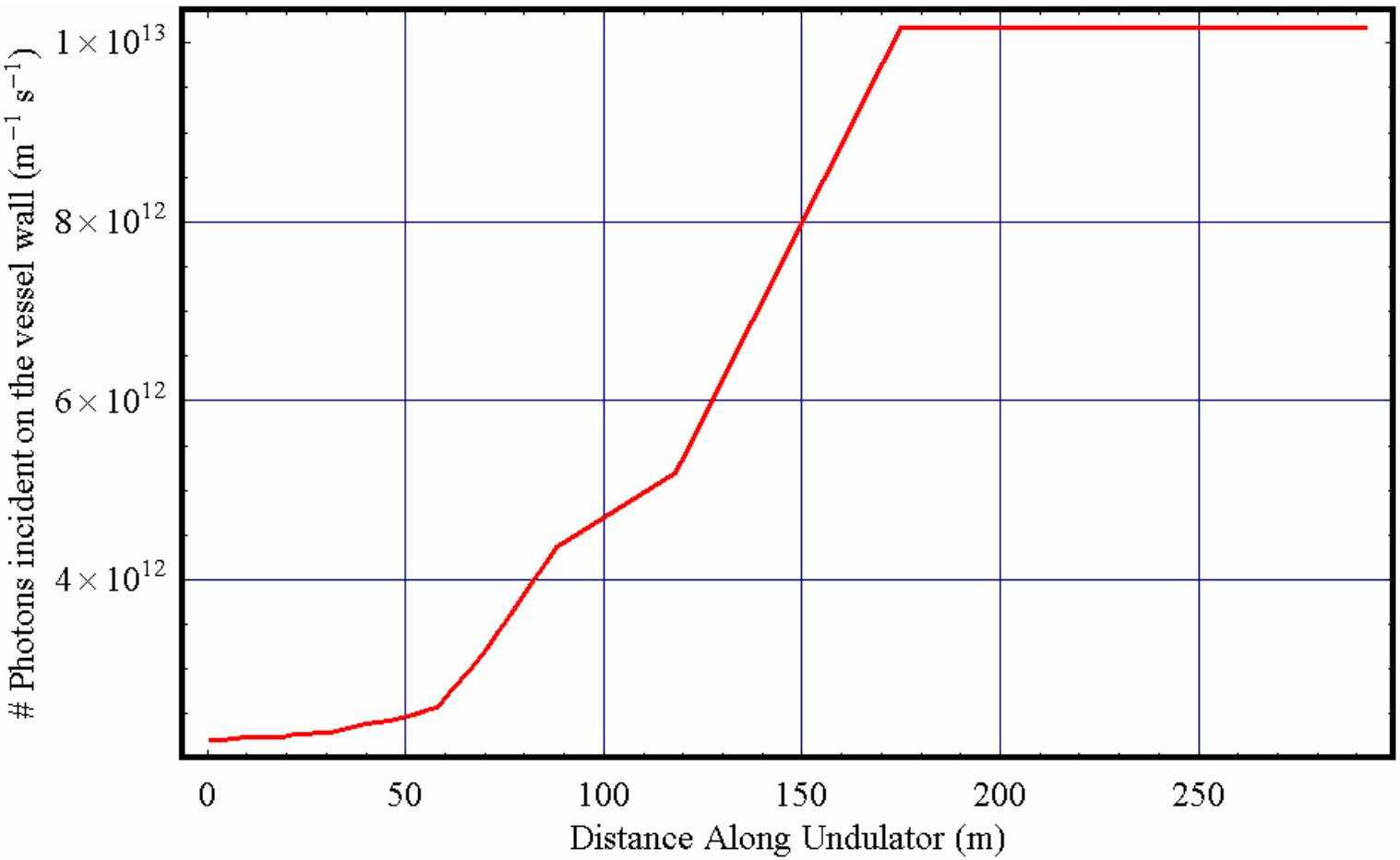
- Decision on physical parameters
  - August 2005 (at Snowmass)
- Decision on undulator technology (PPM vs. SC)
  - October 2005
- Conceptual design of undulator module
  - January 2006
- Undulator prototype design
  - July 2006
- Undulator prototype manufacture and tests in the lab
  - July 2007
- ILC undulator technical design
  - December 2007

# Vacuum Issues

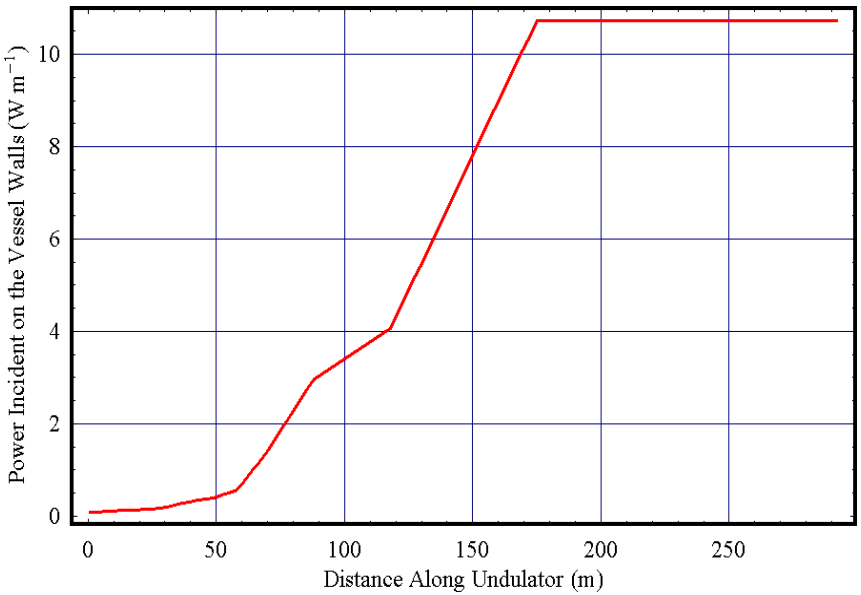
- Can we achieve the vacuum along 2-5m long ~4mm aperture vessels? (4mm is the minimum it could be)
  - Required vacuum ~$10^{-8}$
- For the PPM option a NEG coated vessel is required
  - Collaboration between Daresbury and CERN to build a 1m long NEG coated Vessel
- For the SC option we rely on Cryo-Pumping
- Both these options would be fine if there were **NO** photons incident on the vessel walls – Clearly this is not the case

# Photon Flux Along the Vessel Walls

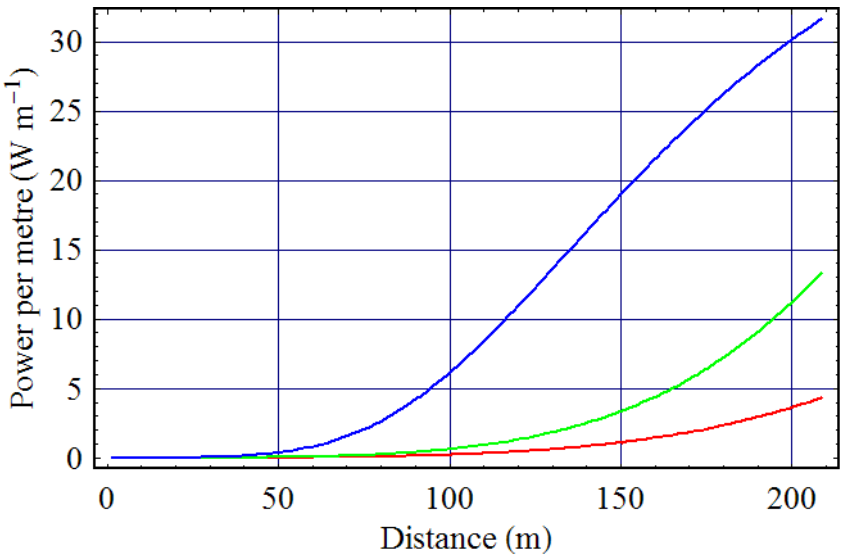
- Based On Numerical Simulation



# Power Deposited Due to Synchrotron Radiation



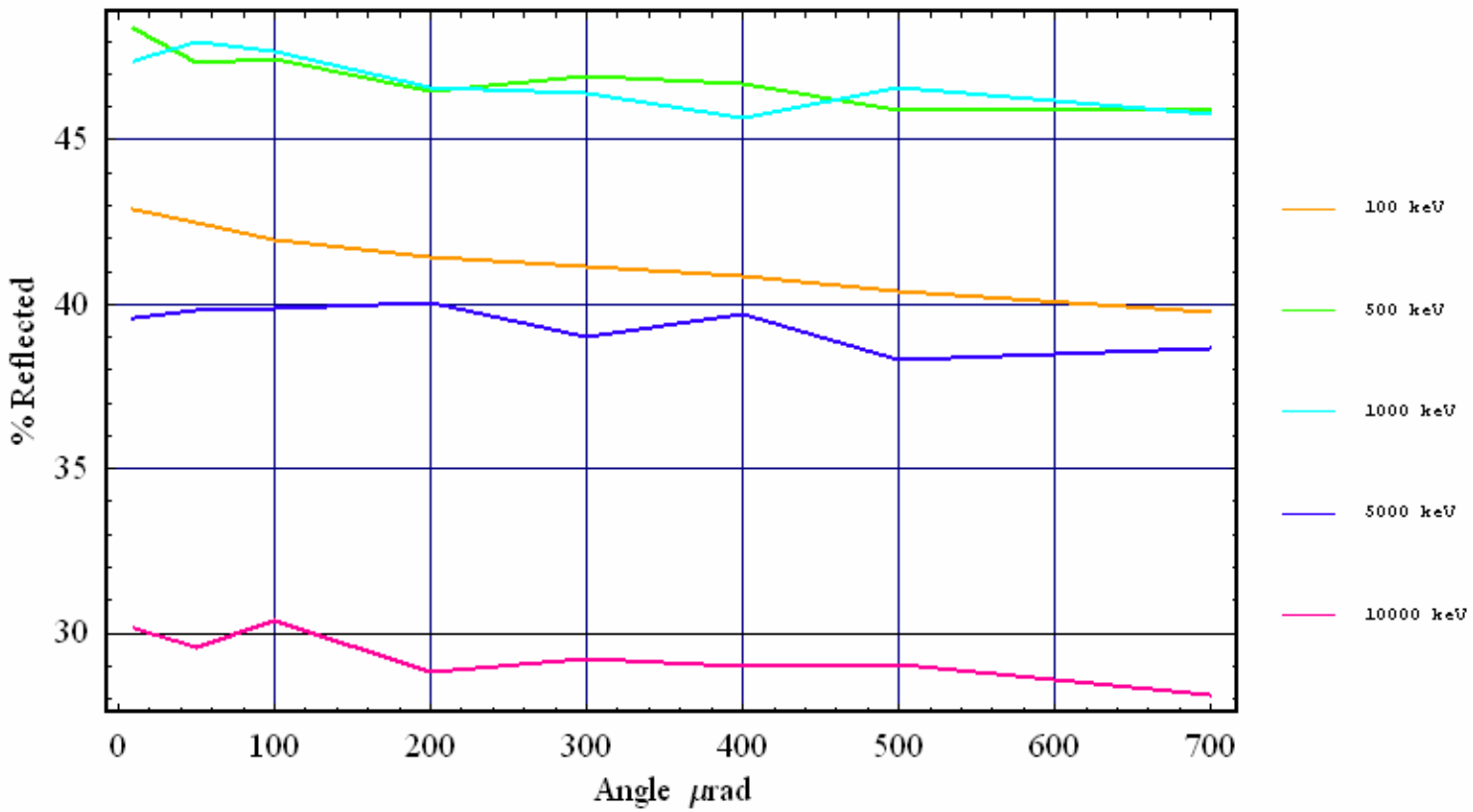

- Numerical Calculation
- 150 GeV
- 12mm Period




- Analytic Calculation
- 50 GeV, 150 GeV, 250 GeV
- 14mm Period

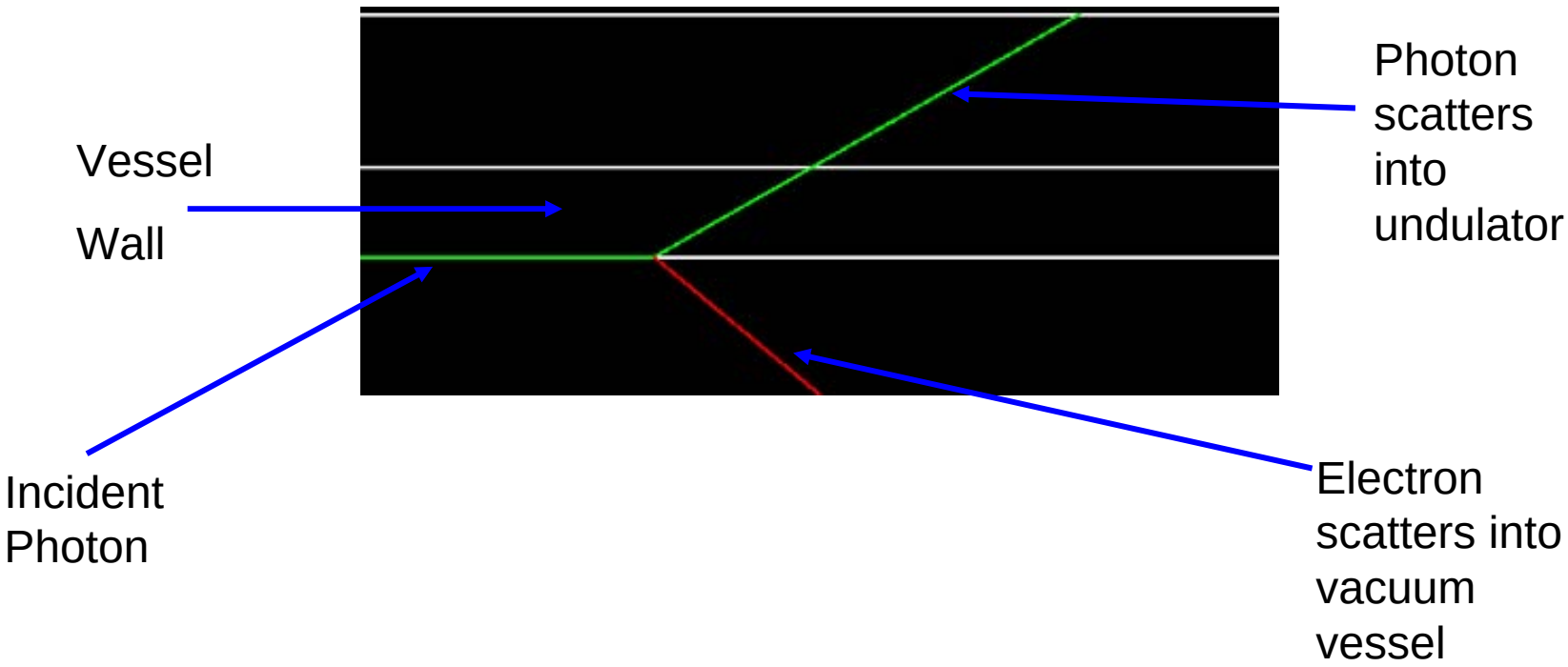
# What Happens to the Photons?

- Geant 4 has been used to analyse what happens to the incident photons
- E.g. some get reflected



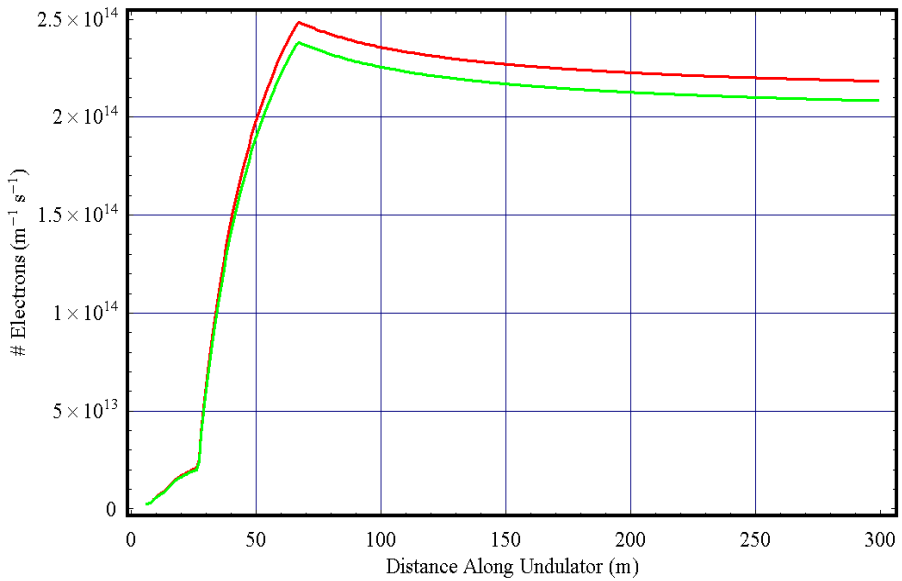
# What Happens to the Photons? Secondary Particles

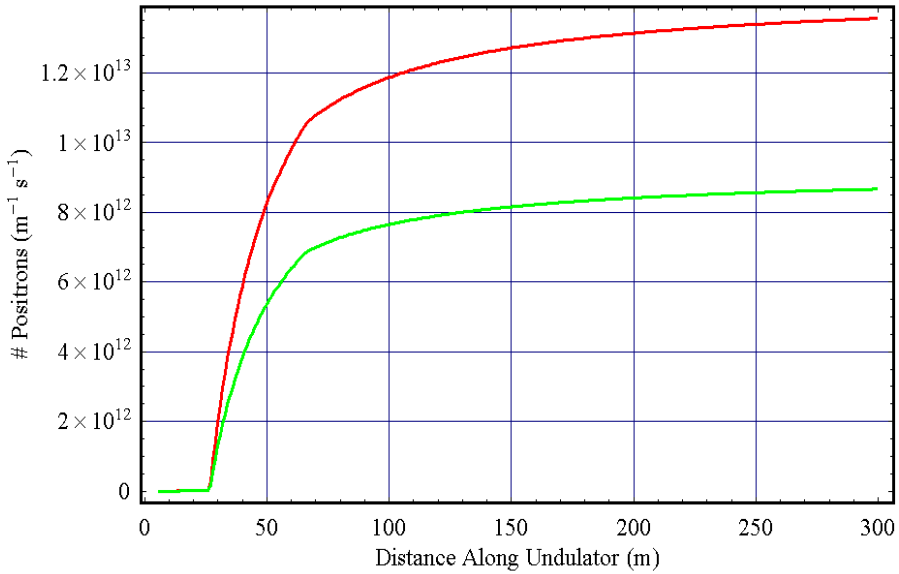
- G4 analysis shows sometimes electrons/positrons are produced and scatter into vessel



# What Happens to the Photons? Secondary Particles

- Red Steel Vessel, green Aluminium vessel




- Secondary Electrons
- Secondary Positrons

# Vacuum Issues

- Vacuum seems achievable
- Secondary particles
  - ~1 $e^-$ and ~0.05 $e^+$ per metre per incident electron are created
  - Electron cloud effect on beam needs to be calculated
- Calculations are the worst case (smallest aperture no collimation)
- SR collimation along length of undulator can dramatically reduce **all** effects
- Collimation will probably be required for SC device due to power deposited

# Wakefield Affects of a Narrow Vacuum Vessel

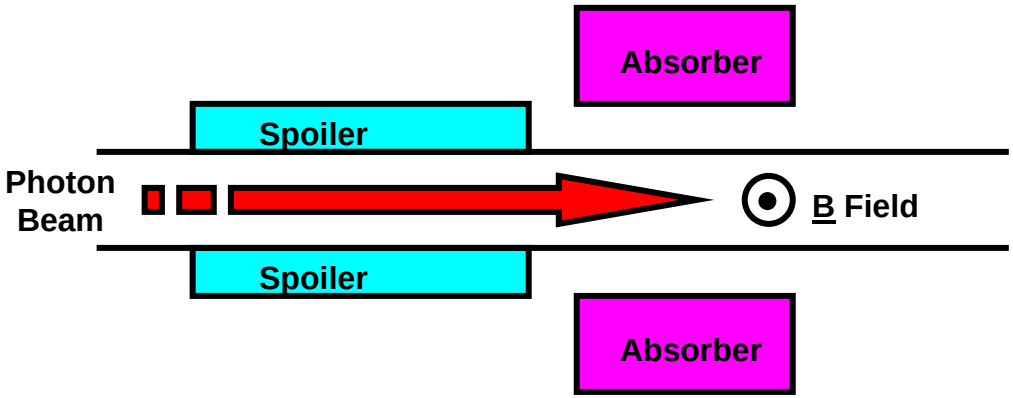
- 4mm diameter 'Cylindrical Round Pipe' studies done

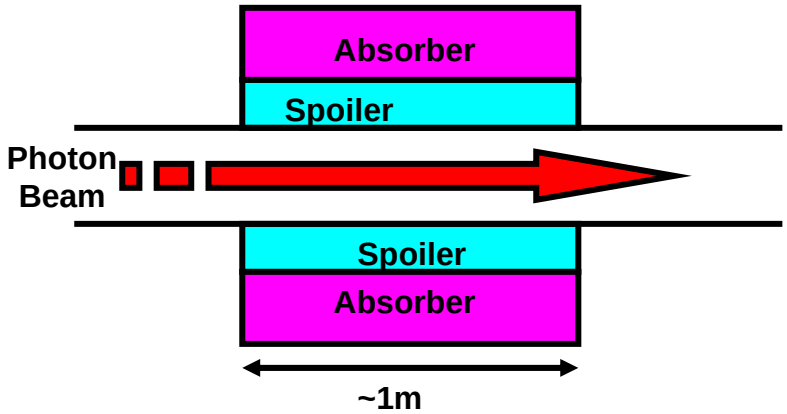
| Vessel Material | $\Delta E$ (MeV) | $\sigma_e/E_0$ | $NLK_{trans}$ (MeV mm$^{-1}$) |
|---|---|---|---|
| Copper | 49 | $2\ 10^{-4}$ | 2.4 |
| Aluminium | 63 | $2.6\ 10^{-4}$ | 2.7 |
| Stainless Steel | 361 | $12.6\ 10^{-4}$ | 11.1 |

- What are the effects of the surface roughness of real pipes?
- What is the emittance degradation?
- Calculations based on anomalous skin effect for SC magnet?
- Check with measured conductivities for real pipes

# Collimators – compact DESY design

- Due to high energy photons a compact design can be used
- High energy photons scatter at greater angles



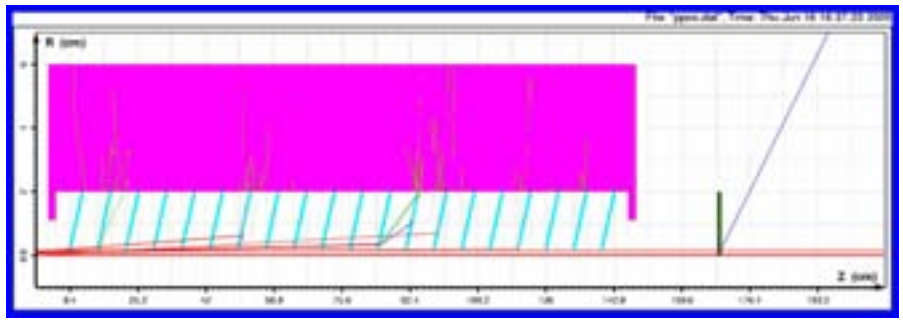

- Traditional design

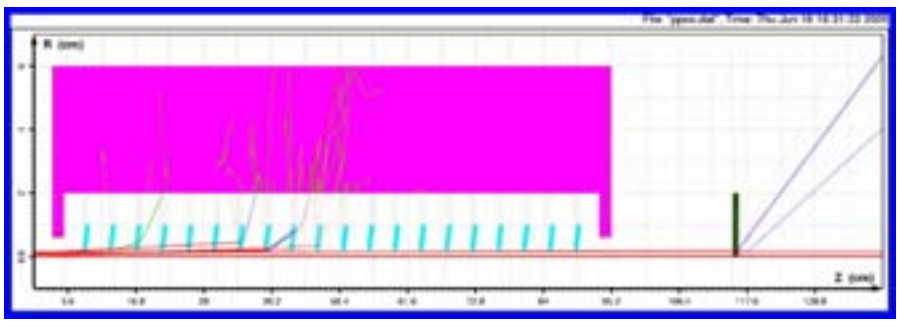
- Compact design
- No B field

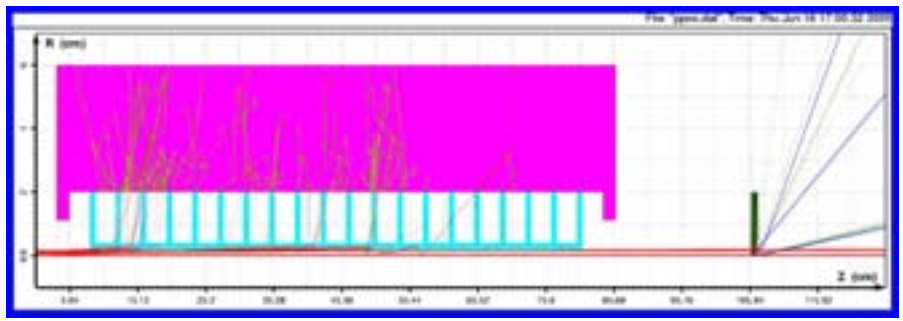
- Niobium spoiler, copper absorber (for example)

# Different geometry of spoilers studied

- Simulations based on EGS4 for 250GeV Beam
- Need to be re-done for 150GeV beam ?
- Larger angular divergence of photons so maybe not
- Optimise parameters

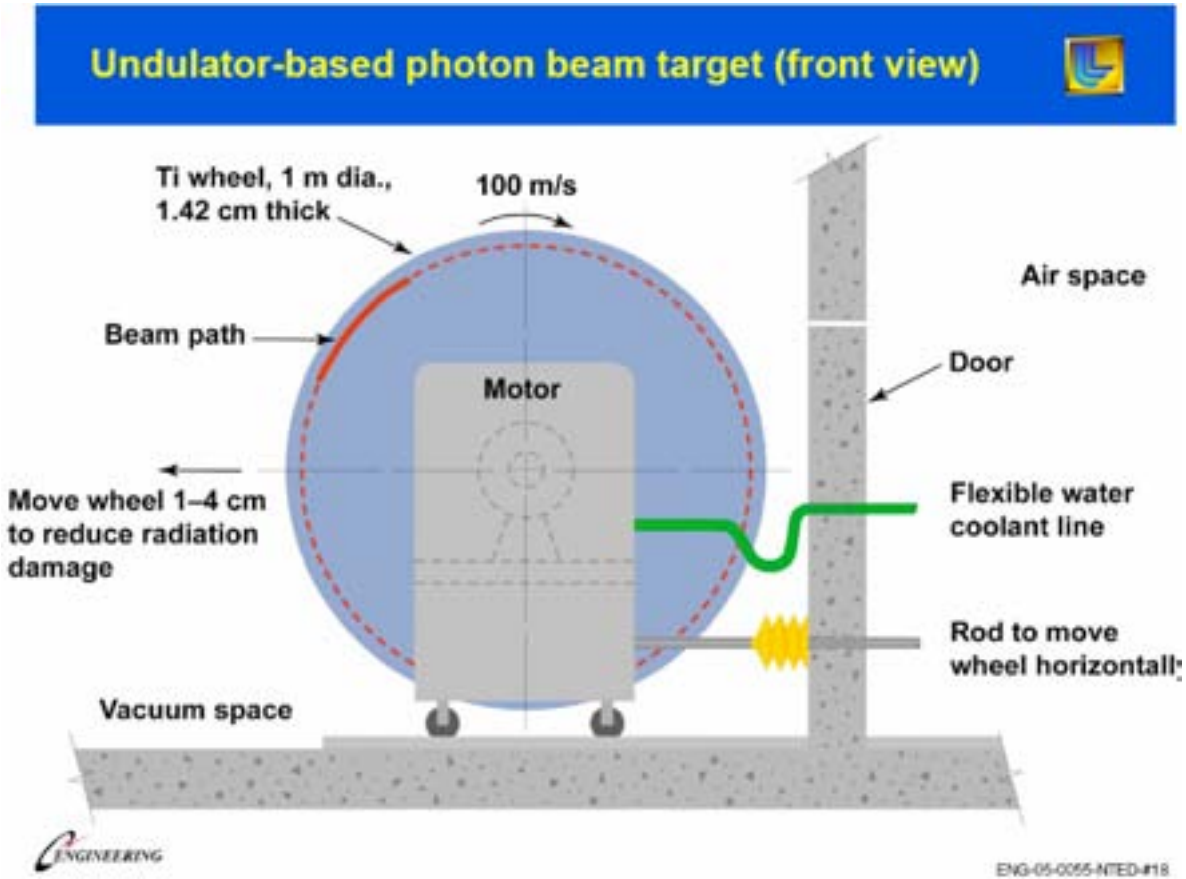






# Target

- 0.4 radiation length Ti target
- Engineering design of target and vault is being carried out, USA, Europe




Werner Stein – Daresbury Workshop

# Target Issues

- Mechanical Reliability
- Radiation hardness and effects of radiation damage
- Remote handling
  - Must be considered from the start
- Plans for a fully working prototype to be built for mechanical reliability test
  - It is more important to test the radiation hardness too
- Some radiation hard Ti Alloys need to be looked at

# Simulations

- Current Simulations based on:
- EGS
  - Polarisation added in an ‘ad-hoc’ manner
- Geant 4
  - No polarisation (but being added as we speak DESY)
- Activation simulations?
- Full cradle to grave simulations have started

# Effects on the beam

- Work done on theoretical errors (R Glanz PhD)
  - Energy Lost (extra linac required)
  - Focussing effects,
  - Emittance degradation, increase in energy spread, Etc.
  - Compare with measured field errors
  - Beam Tests would help a lot here too

# Summary

- Every major component has been studied and we are now on second/third iteration for many of them
- A number of decisions still need to be made (and agreed by everyone), e.g.
  - Position of undulator
- However these decisions only effect the optimisation of the source **not the feasibility**

# The End