Characterization of Scintillator Plastics for the Upgrade of ATLAS detector using EPR

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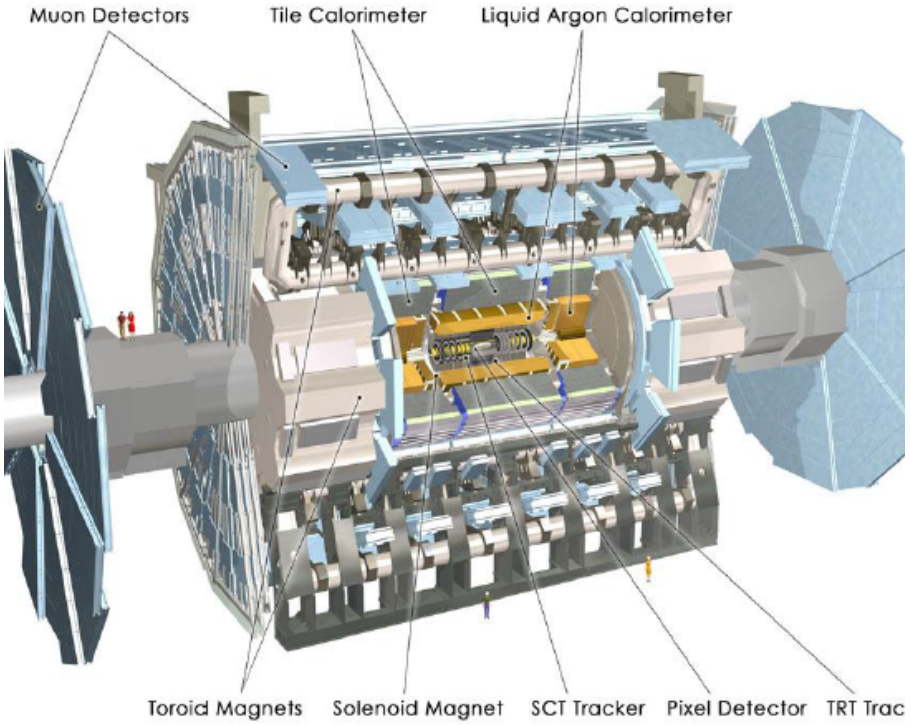
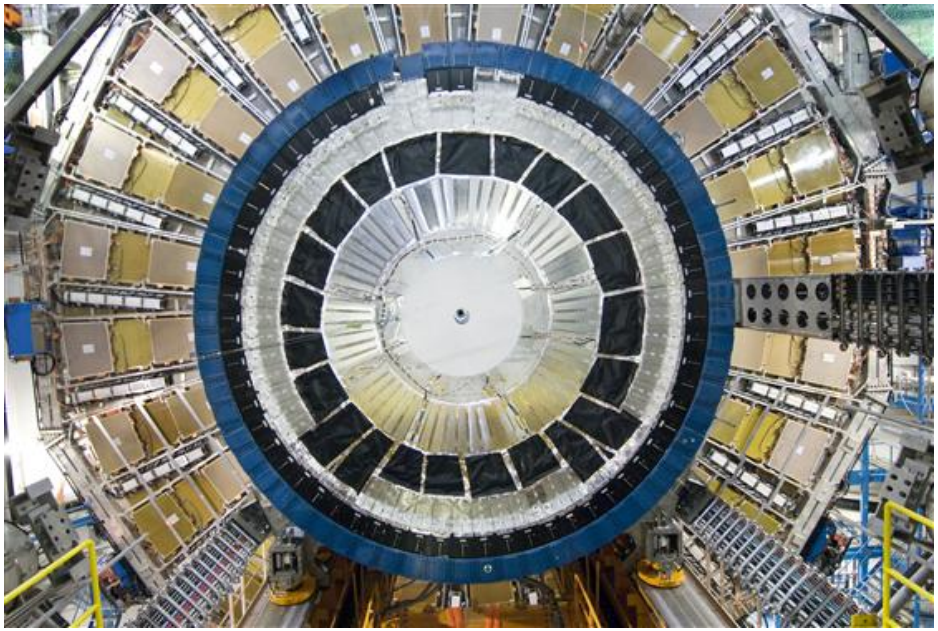
ATLAS Detector

- General purpose detector investigating inelastic p-p collisions
- One of four collision points able to measure 14 TeV collisions
- Minimum Bias Trigger Scintillator (MBTS) plastics situated on inner face of Endcap of TileCal
- Used for effective mean for p-p collision and veto beam background



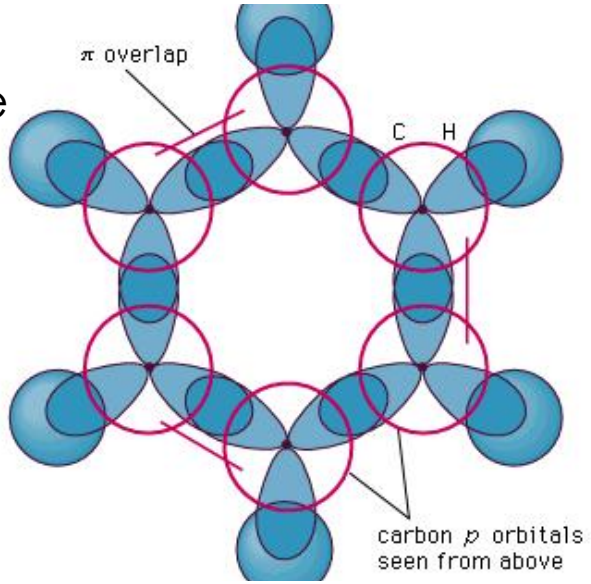
MBTS Plastics

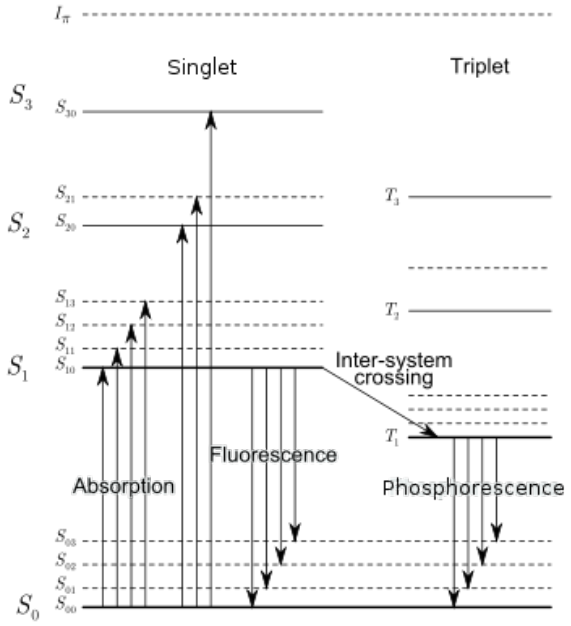
- 16 triggers on both Endcaps
- Polystyrene 2cm thick
- Susceptible to radiation damage
- Scintillation mechanism damaged



Scintillation in Organic Materials

- Excited material gives off light: luminescence
- Scintillation (Photoluminescence) is luminescence
- Undergone by delocalized π-electrons



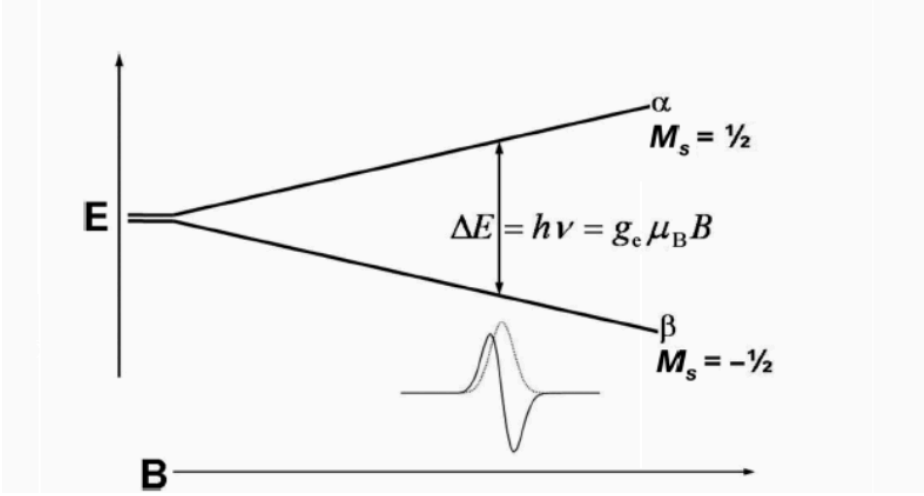


Goals

- Investigate radiation damage in two types of plastic scintillators: Polyvinyl toluene (PVT) and polystyrene (PS)
  - PVT: ELJEN Technologies: EJ200, EJ208, and EJ260
  - PS: Dubna
- Analysis using electron paramagnetic resonance (EPR) and nuclear magnetic resonance (NMR)
- Computational approach using Vienna Ab-initio Simulation Package (VASP)

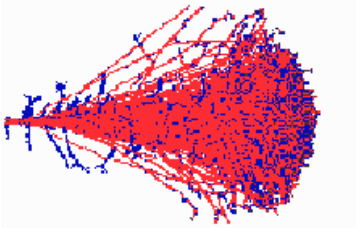
Paramagnetism and The Zeeman Effect

- Damage to plastics not exactly know
  - Damage to benzene ring
  - Unpaired electrons and Ions formed
- Paramagnetism
  - Induced by external magnetic field to material in direction of magnetic field
  - Separation of energy levels

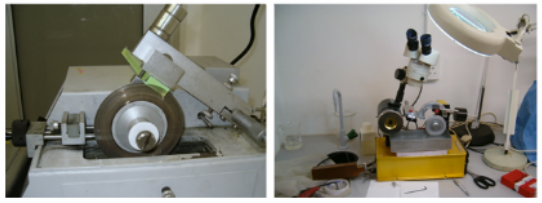


Sample Preparation

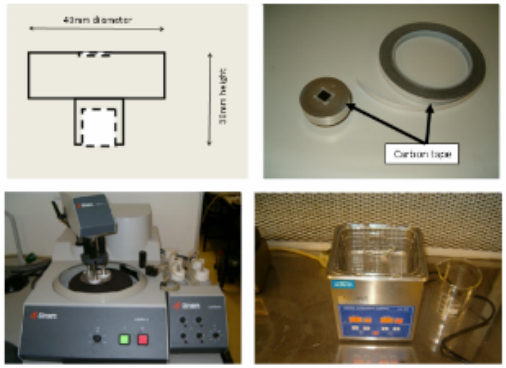
SRIM/ TRIM for 6 MeV protons

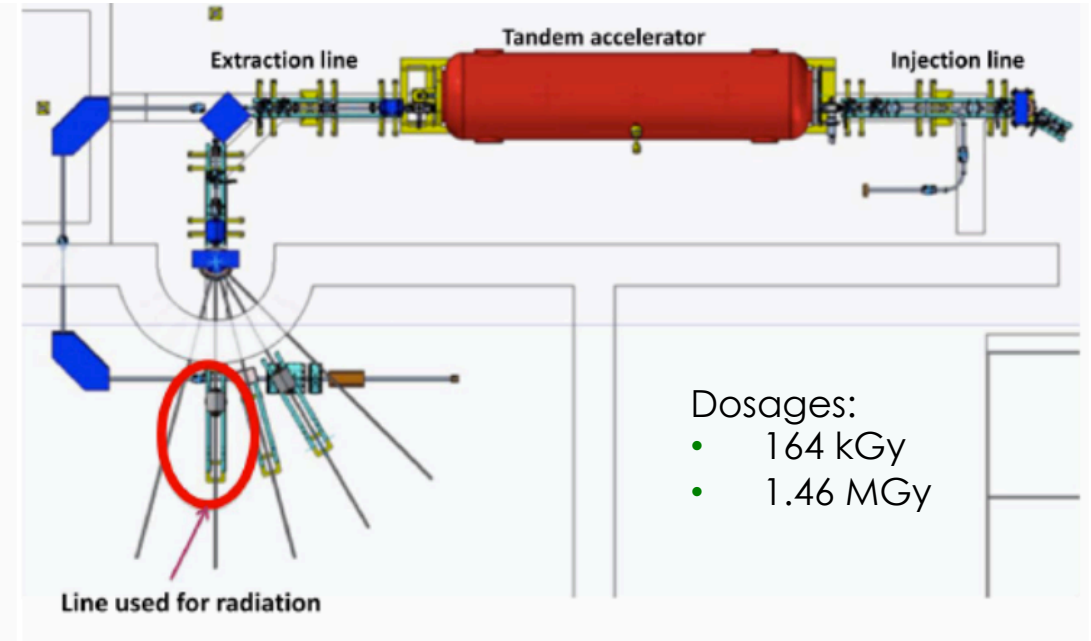


250 μ m in width
2.07 MeV ave. energy per proton



Cutting and polishing



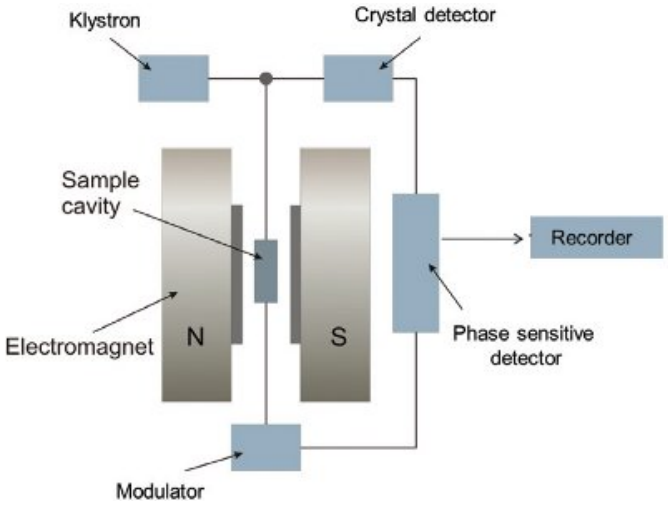


Dosages:
- 164 kGy
- 1.46 MGy

iThemba LABS Gauteng Tandem Accelerator

Electron Paramagnetic Resonance

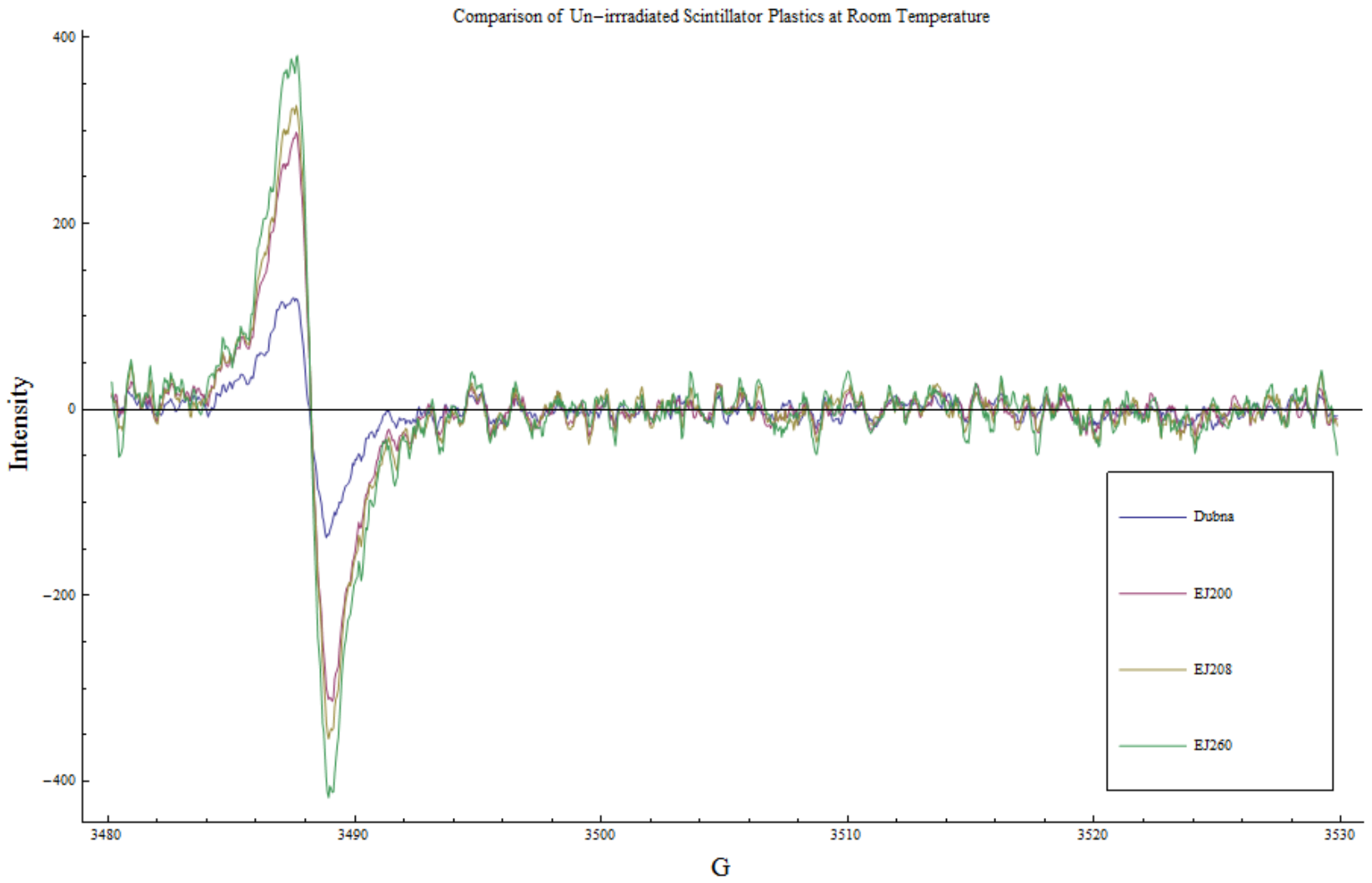
General EPR X-Band Spectrometer



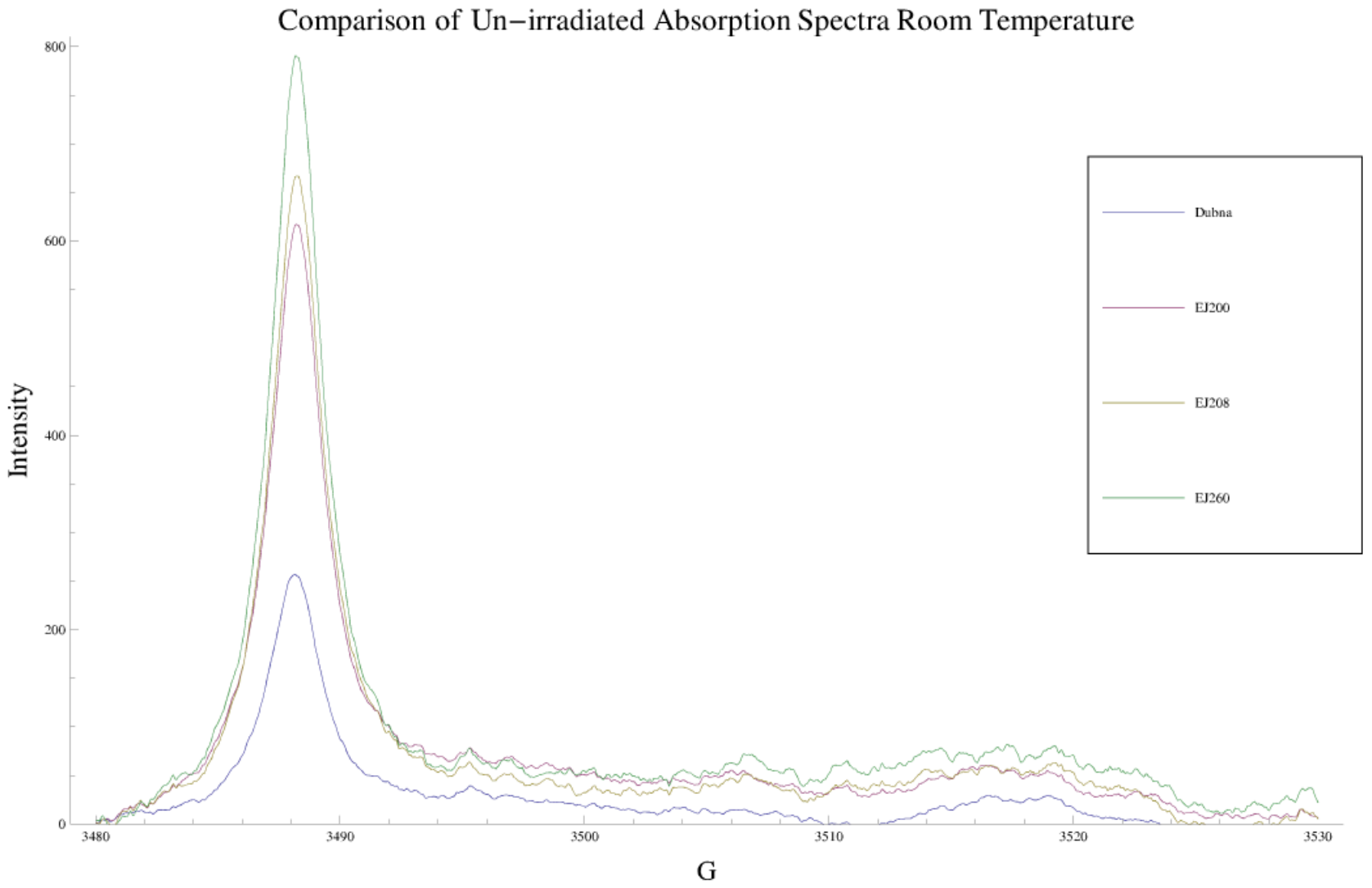
EPR Spectrometer at Wits, NMR LAB

Bruker ESP380e

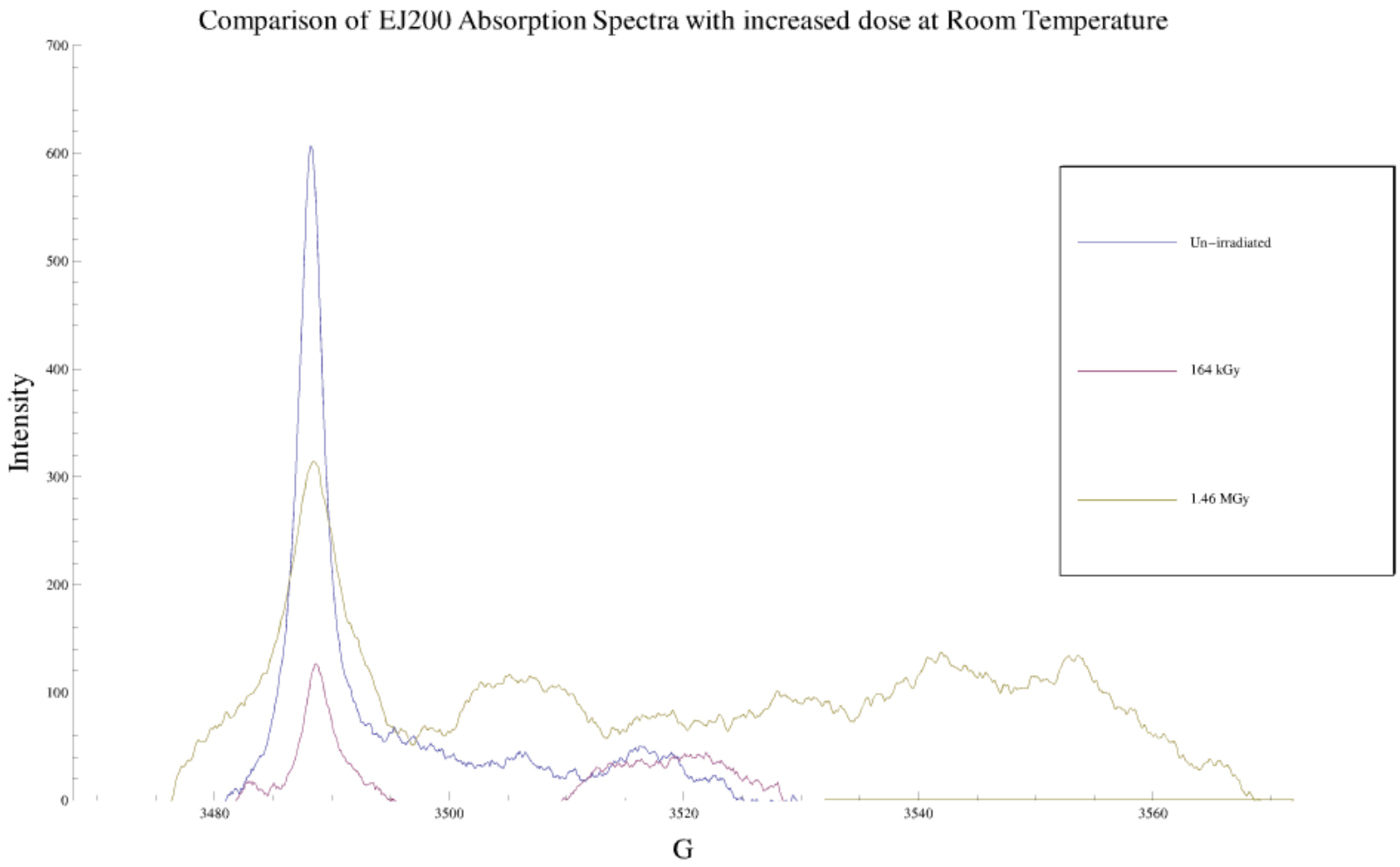
Results: Un-irradiated Derivative Form



Results: Un-irradiated Integral Form



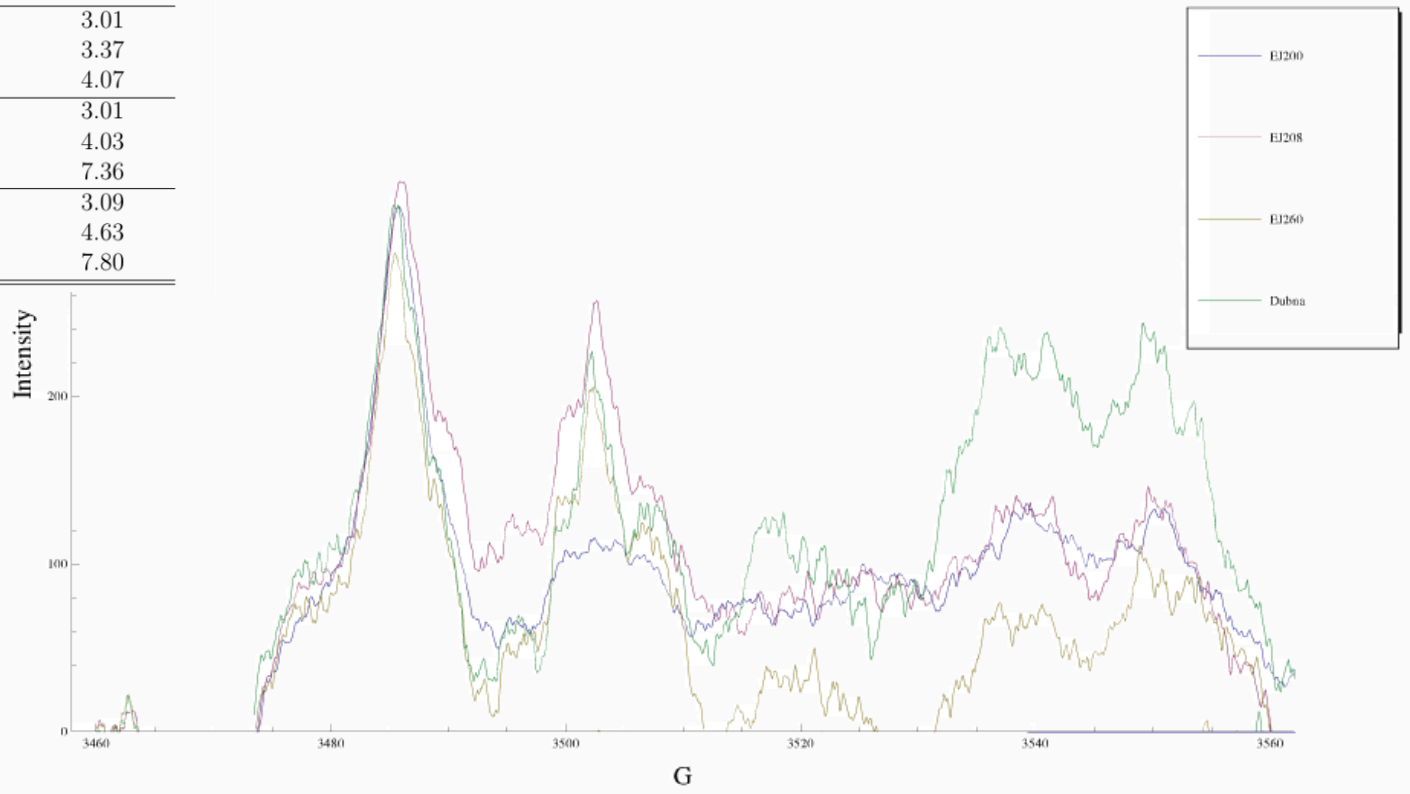
Results: EJ200 Increased Dose



Results: All samples at 1.46 MGy

Sample Grade	Dose	Peak Intensity	FWHM
EJ200	0	612	3.11
EJ200	164 kGy	128	3.22
EJ200	1.46 MGy	342	6.12
EJ208	0	667	3.01
EJ208	164 kGy	212	3.37
EJ208	1.46 MGy	340	4.07
EJ260	0	790	3.01
EJ260	164 kGy	283	4.03
EJ260	1.46 MGy	301	7.36
Dubna	0	257	3.09
Dubna	164 kGy	435	4.63
Dubna	1.46 MGy	303	7.80

Comparisons of all samples at 1.46 MGy



Moving Forward: EPR

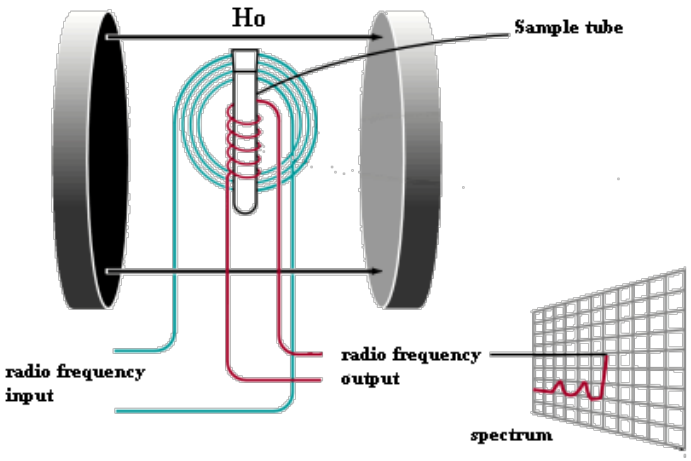
- EPR results were conducted at room temperature
  - Increase in temp. ➔broadening line width ➔ incorrect interpretation
  - Low temperatures are needed
  - Quantitative analysis needed

Moving Forward: NMR (Nuclear Magnetic Resonance)

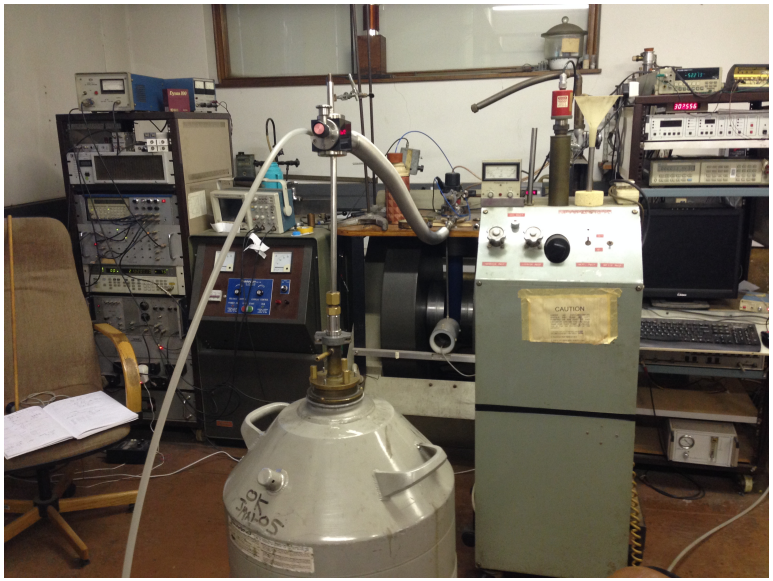
- Analogous to EPR but makes use of intrinsic spin of atomic nucleus
- Similar approach to testing samples
- NMR identifies molecular structure
  - Larmor frequency from chemical shift
  - Spin relaxation times
- Hope to find correlation between these results and EPR

Nuclear Magnetic Resonance

General NMR spectrometer

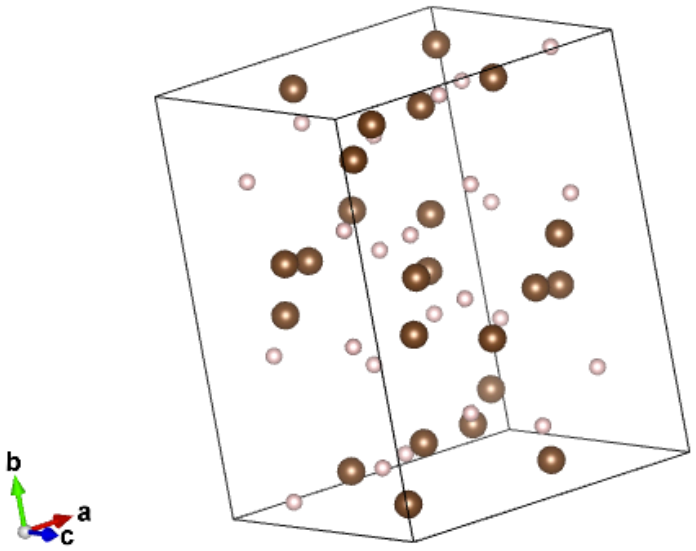


NMR spectrometer at Wits, NMR LAB



Moving forward: VASP (Vienna Ab-initio Simulation Package)

- Ab-Initio quantum mechanical molecular dynamics
- Uses density functional theory
- Computationally replicate EPR and NMR results
- Deeper understanding of the damage done to the plastics



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