Measurement of Li thickness on Mo tiles by Rutherford Back Scattering of alpha particles

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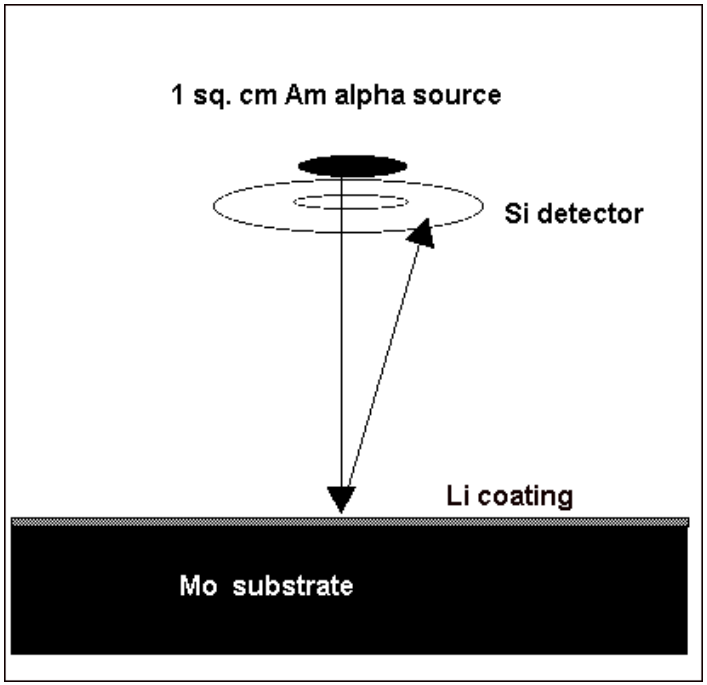
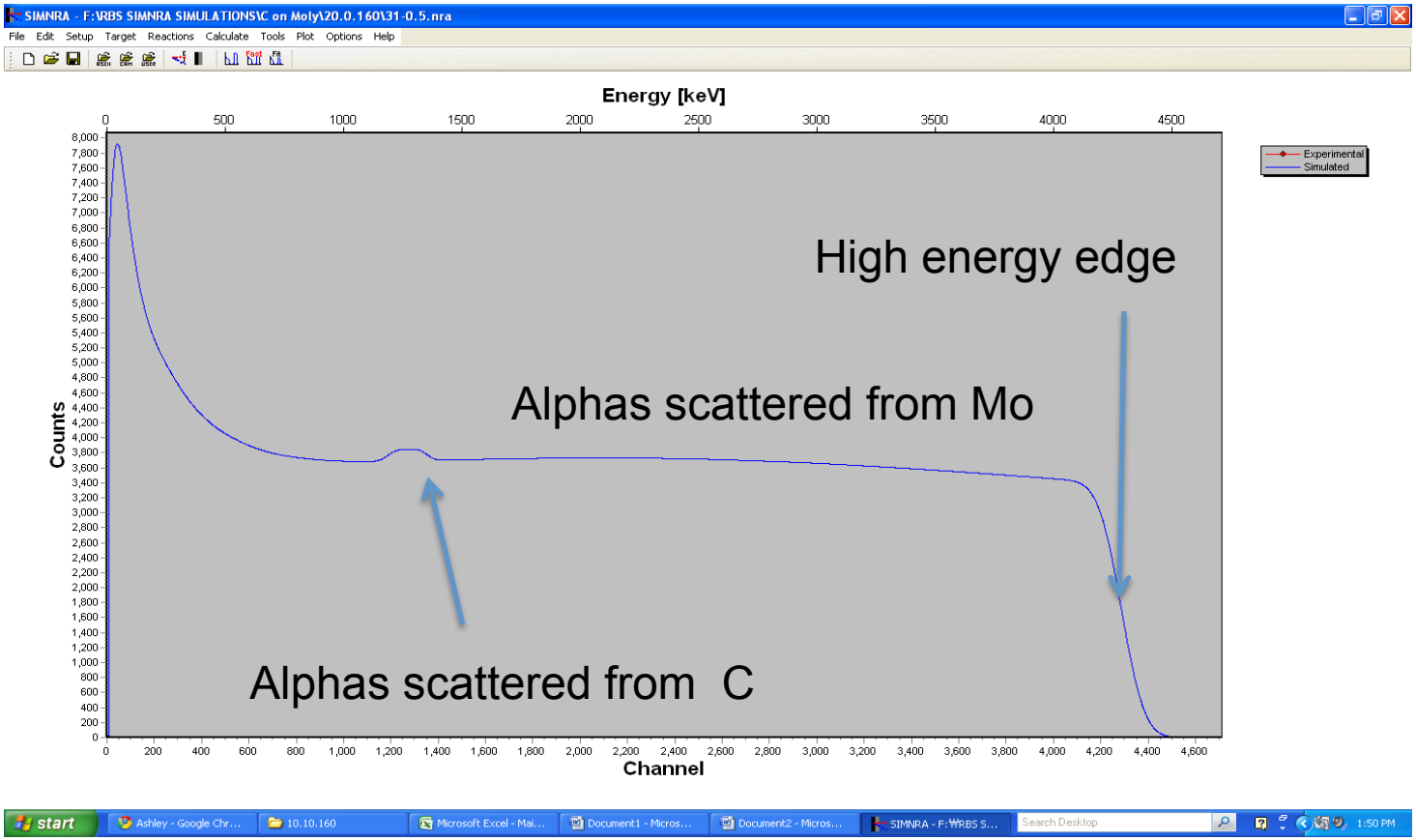
Routine in situ measurement of the thickness of coatings Mo tiles

- Use Rutherford Back Scattering of alpha particles
- Am^{241} source
- Solid state detector
- Probe inserted to 10 cm above Mo divertor tiles



Desire measurement to be possible at least on a daily basis (few hour counting duration)

Simulated alpha particle spectrum



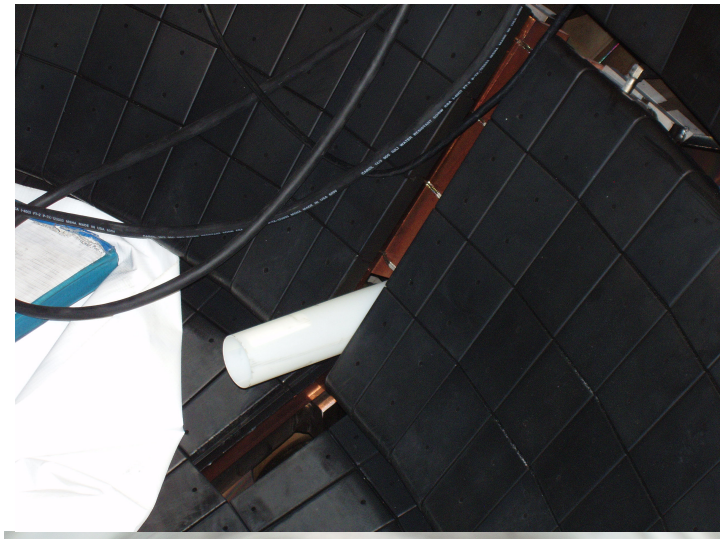
- Energy spectrum of alpha particles from Am^{241} source scattered from 0.5 μ thick C over Mo tile
- SIMNRA simulation Matej Mayer, Max-Planck-Institut fu¨r Plasmaphysik, Garching, Germany

Estimate of count rates

- Commercially Am^{241} sources are available in the mCi range.
  - For $\Delta E \sim .3$ MeV.
  - stopping power for 5 MeV alphas in Am is about 300 keV/mg/cm^2
  - 1 cm^2 source with thickness of 1 mg /cm^2 is about 3 mCi
  - 10^8 α/s ~ 10^6 α/s onto 1 cm^2 at distance of 10 cm
- $d\sigma/d\Omega = 1.296\ (mb/sr)(Z_1Z_2/E_\alpha)^2\ [\sin^{-4}(\theta/2)-2(M/A)^2]$ for
  - E_α = 5 MeV, M = 4, A = 96, Z_1 = 2, Z_2 = 42, θ = 160°
  - $d\sigma/d\Omega$ = 387 mb/sr
- Stopping power for 5 MeV α in Mo is 368 keV/mg/cm^2
  - 100 keV in 0.27 mg/cm^2 6.022e23 atoms/96g => 100 keV in 1.69e20atoms/cm^2
  - 387 (mb/sr)10^{-27}(cm^2/mb) 0.1sr 1.69e20 (/cm^2)
  - 6.54e-5 fraction scattered into 0.1sr/100 keV
- Scattered α from Mo would be ~5/s in a 100 keV wide bin for a 1 cm^2 detector at 10 cm in flattop.
  - Modest optimization of geometry could increase rate 2-5 times without significantly affecting energy resolution (for example an annular detector)
  - Counting for a hour would be enough to measure Li coating thickness of 1 to 15 μ on Mo

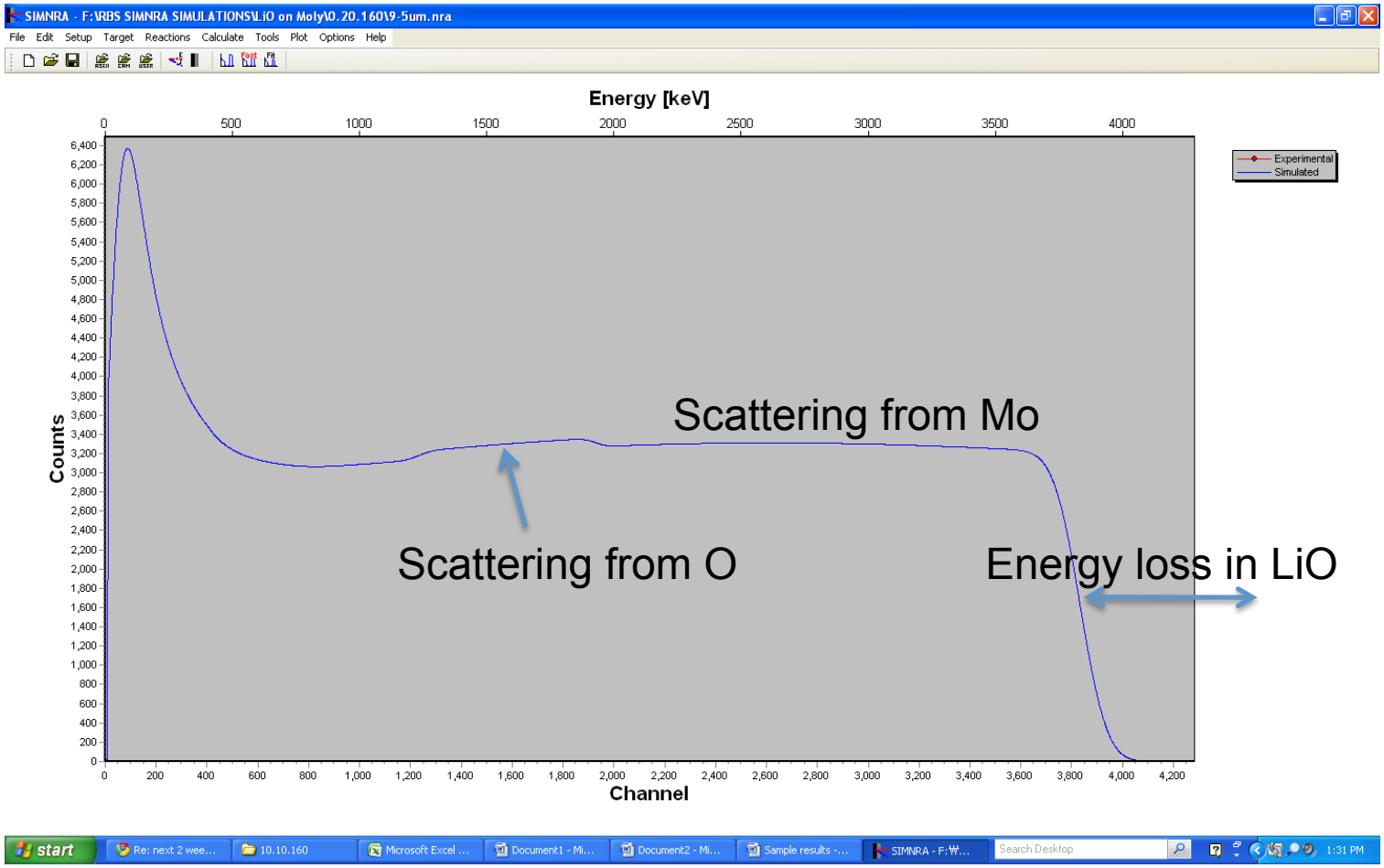
Requirements

- Short term: test viability
  - Suitable Am source
  - Solid state detector and multichannel analyzer (or other data acq. System)
  - Vacuum chamber
  - Mounting hardware
  - Mo sample and Mo sample with thin coatings (C for simplicity)
- Implementation
  - Valve on NSTX with manual probe assembly (port with access to lower divertor at proper height exists)
  - Mounting hardware for source, detector and electronics
- Source is nothing special, radiation safety requirements are nothing unusual



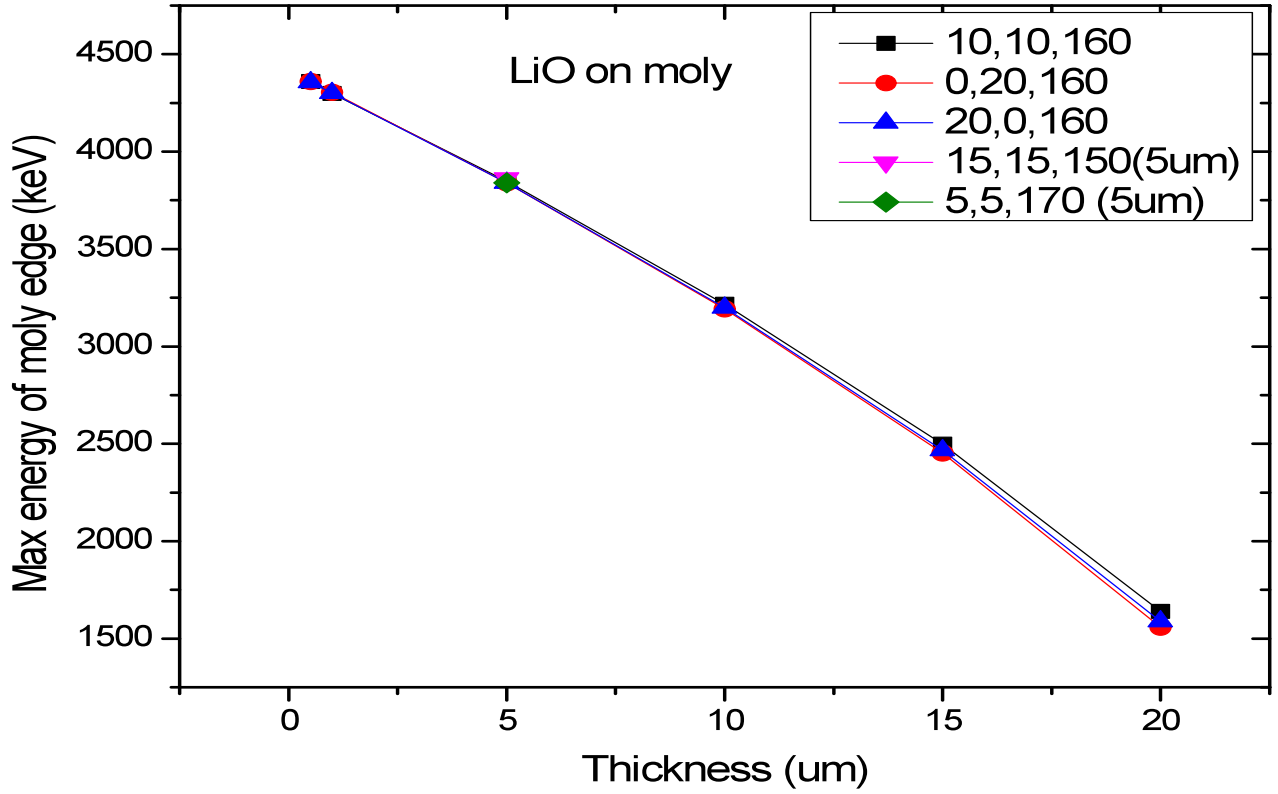
9. Thickness of LiO=5um

Note: peak due to scattering from O is broadened by energy loss in layer



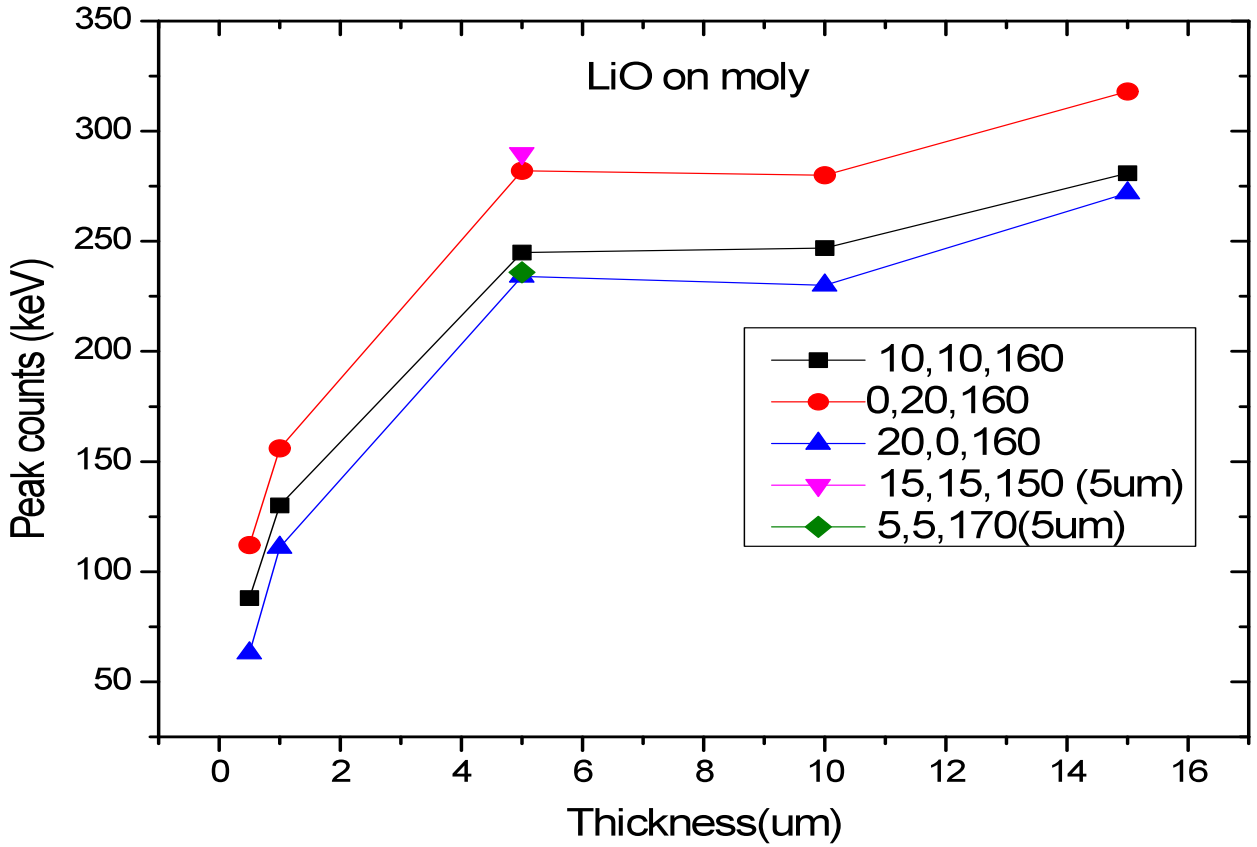
LiO on moly
Max energy vs thickness plot for different angles

- Atomic ratio LI:O = 80:20

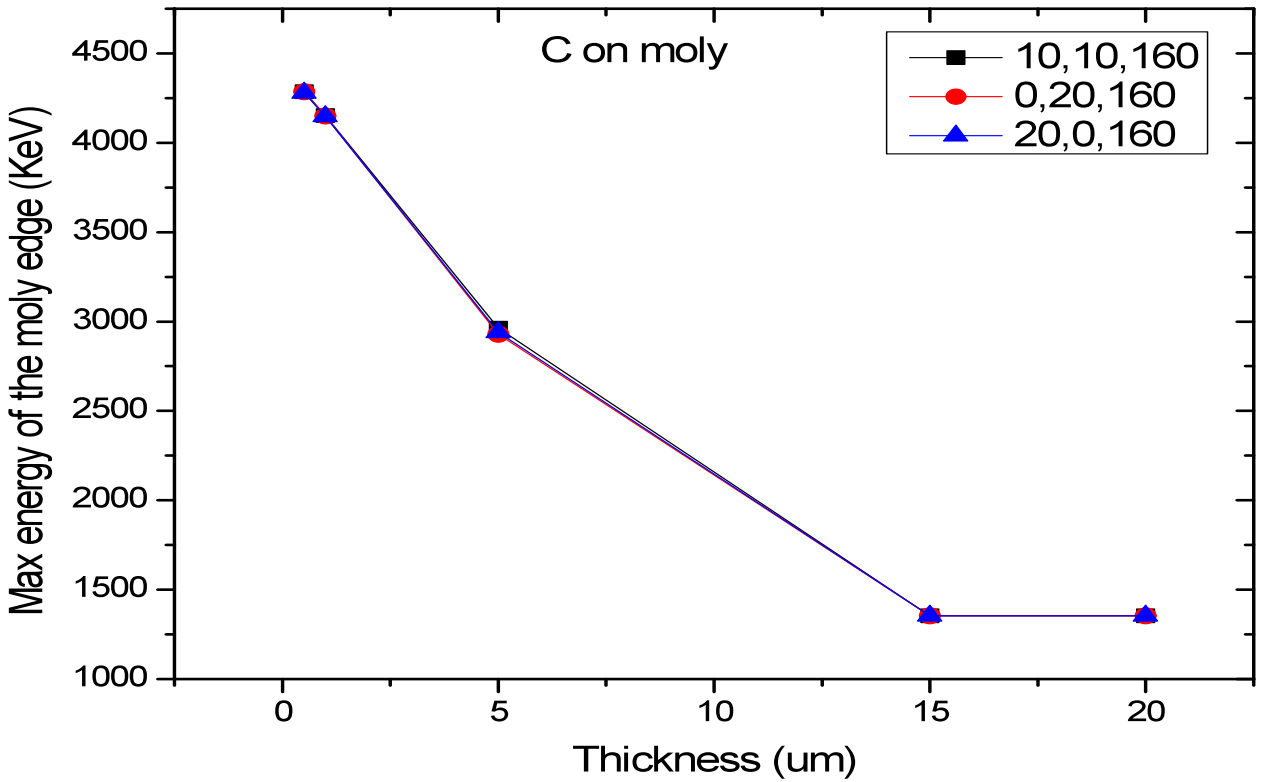


LiO on Mo
Peak count vs thickness plot for different angles

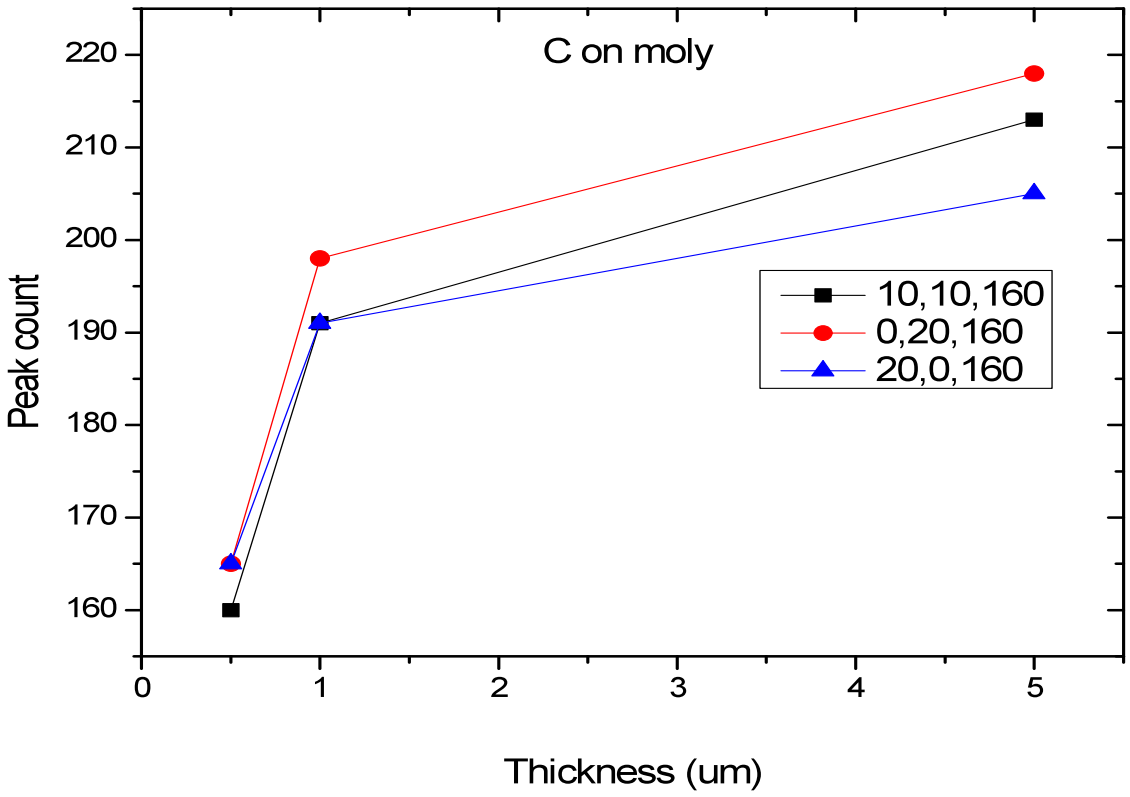
- Atomic ratio LI:O = 80:20



C on Mo
Max moly energy vs thickness plot for different angles

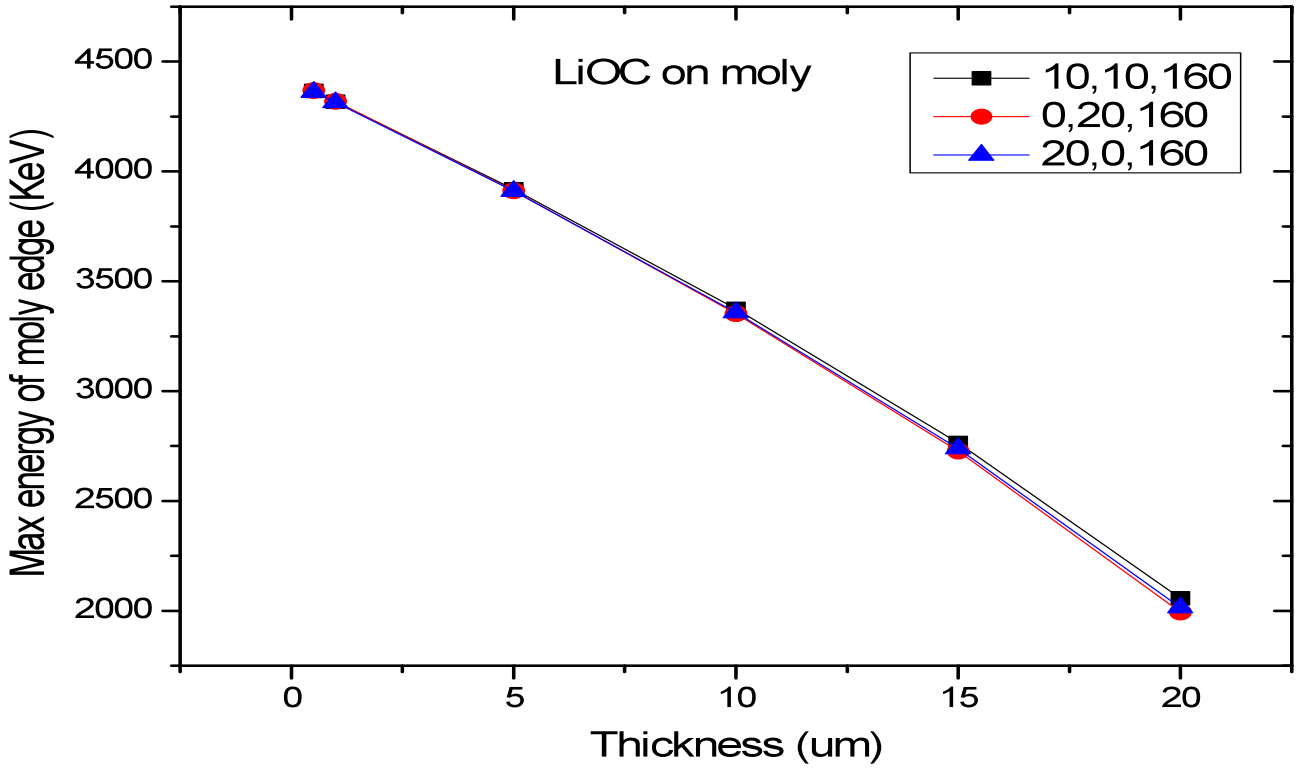


C on Mo
Peak count vs thickness plot for different angles

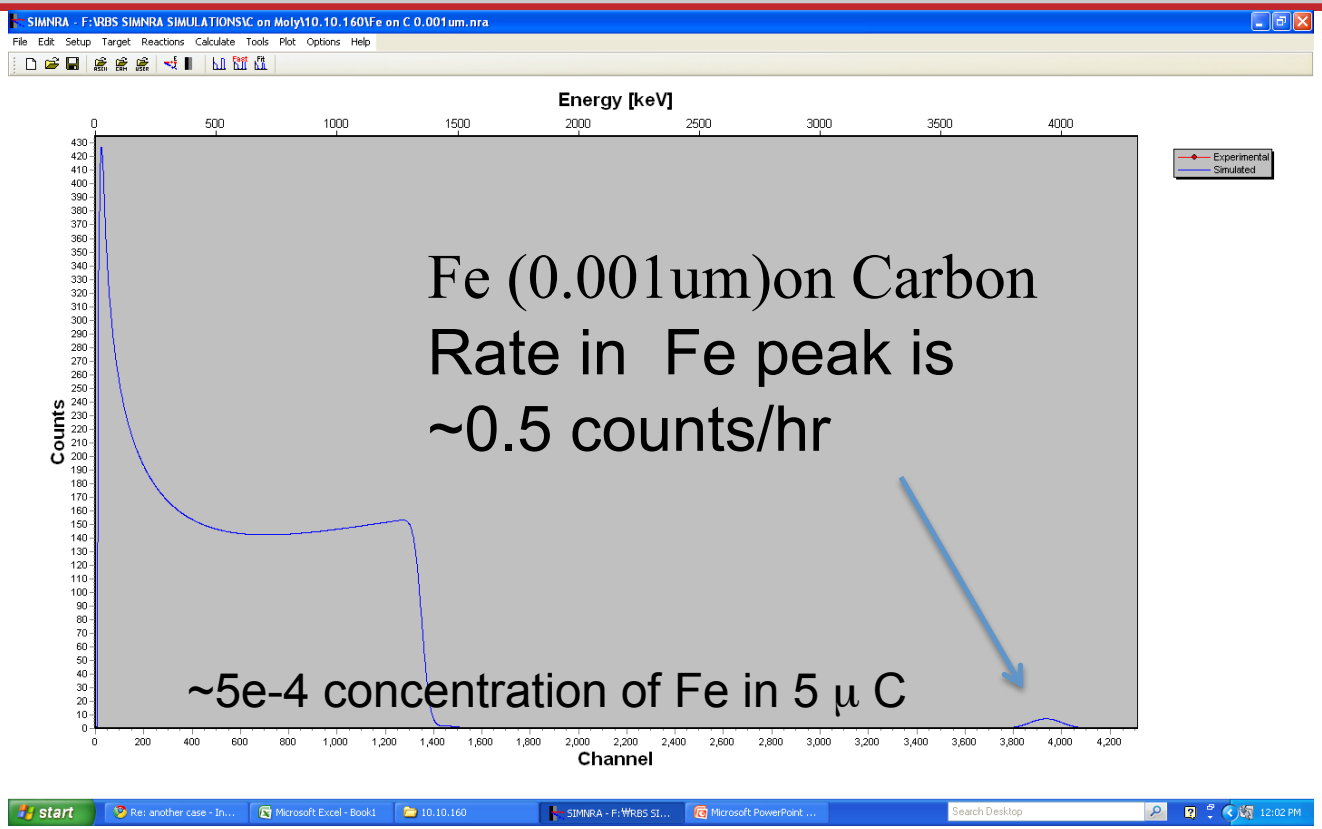


LiOC on Mo
Max moly energy vs thickness plot for different angles

- Atomic ratio LI:O:C = 90:5:5



Could be used to measure Fe on graphite lower limit of thickness is about 1 nm



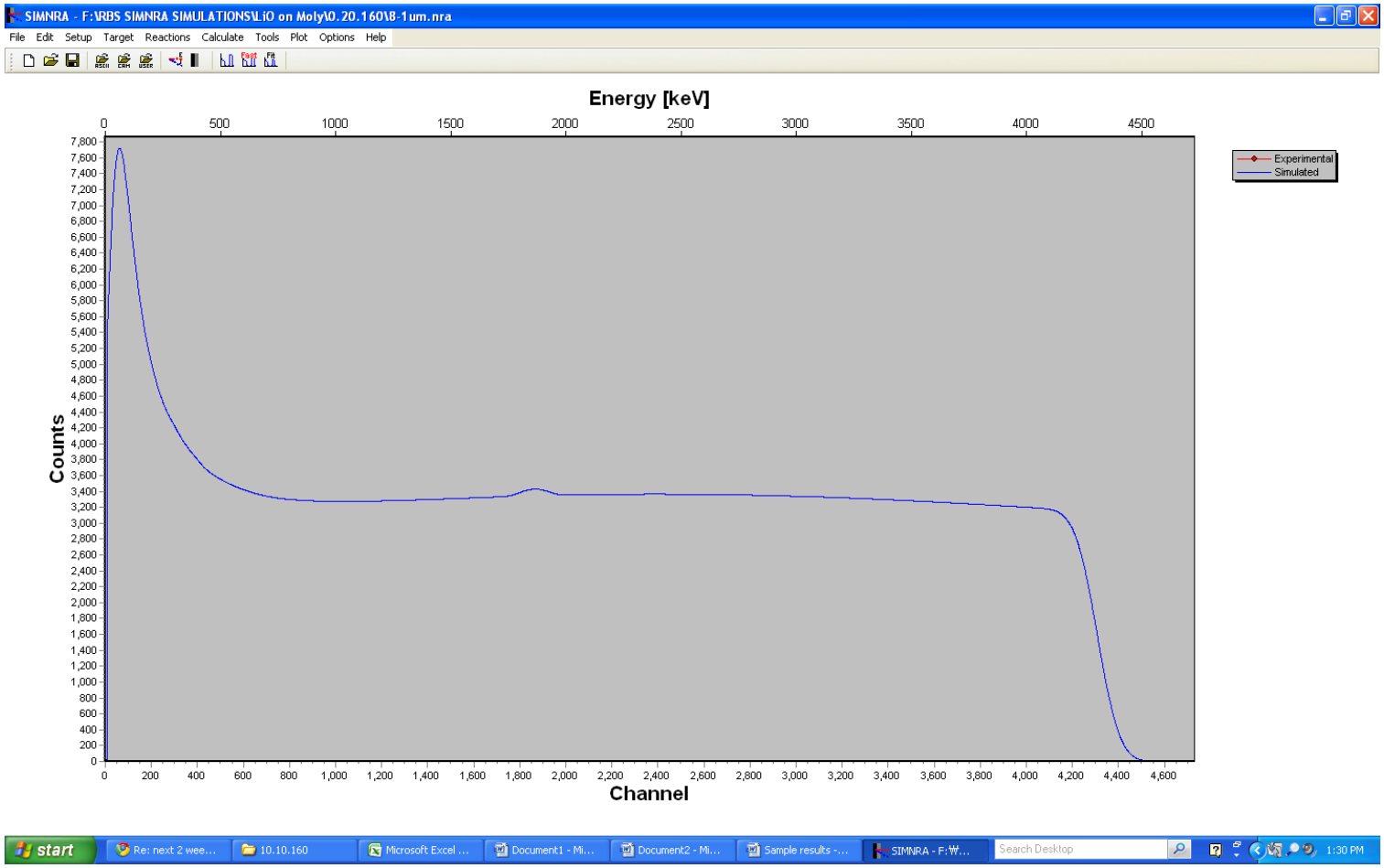
- Orient source and detector to point towards graphite
- Midplane probe would need long stroke
- A few times during the run
- Manual probe to minimize cost and risk

Summary

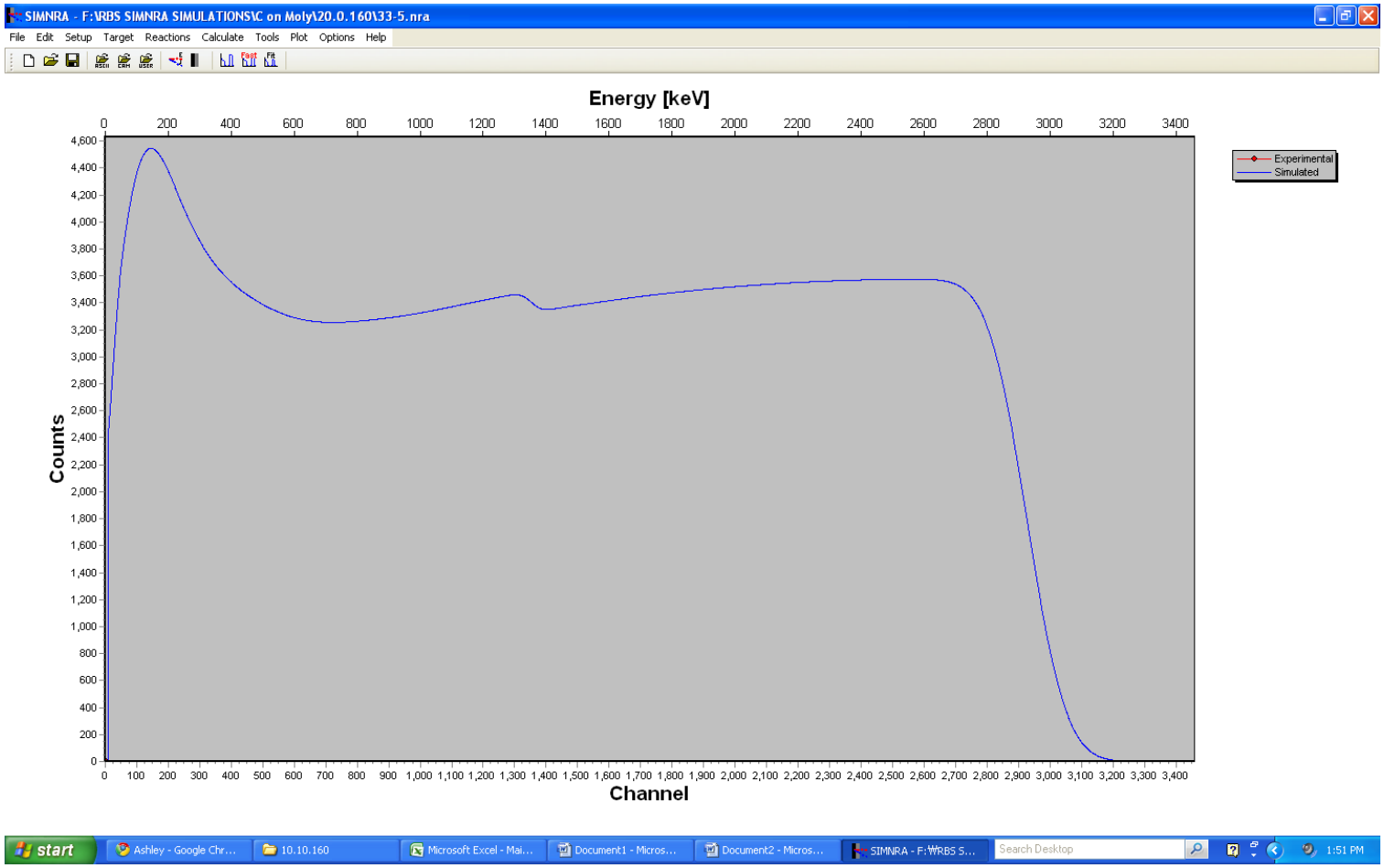
- It appears feasible to measure the thickness of Li on a Mo substrate from 1 to 20 μ thick (C coating up to about 10 μ)
  - Technically since alpha particles slow down primarily on electrons, it is the areal density of electrons that is measured
- If the fraction of C or O exceeds about 10% of Li, the relative amount of can be inferred, subject to uncertainties due do resonant nuclear reactions.
- Remains to be done:
  - Investigate effects of geometry
  - Finalize source strength and detector size/shape
  - Design collimator
- Port for inserting a probe holding the scattering assembly about 10 cm above the Mo tiles exists and will have a valve.

8. Thickness of LiO = 1um

Note: peak at about 1800 keV is due to scattering from O



33. Thickness of C=5um



41.Thickness of LiOC = 15um

Note: Low concentration of O (5%) is barely visible at 1900 keV