Fusion Gamma-ray Measurements using Gas Cherenkov Detector

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GRH Team

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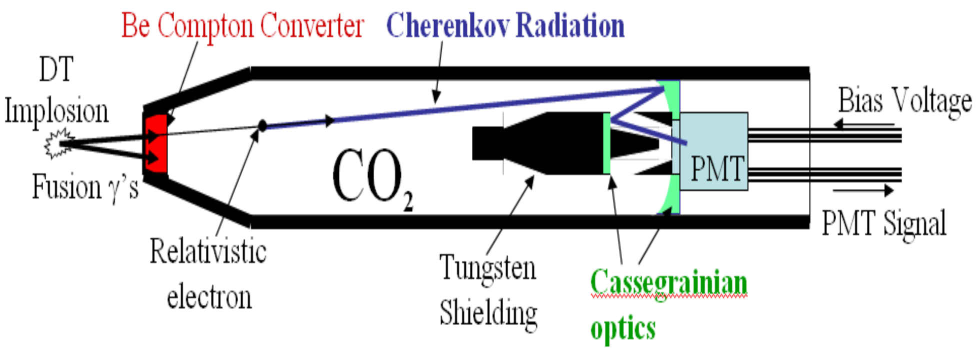
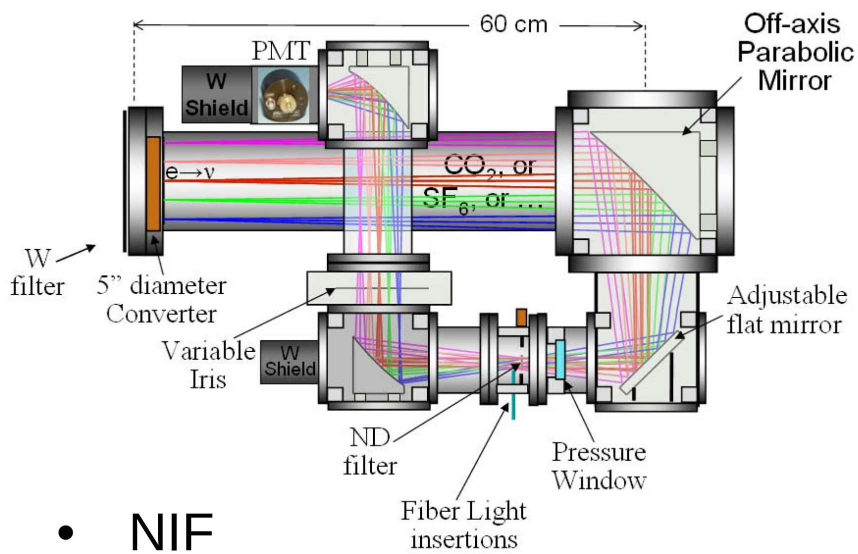
GCD/GRH has been developed by LANL in collaboration with AWE and LLNL

- Gas Cherenkov Detector (GCD)



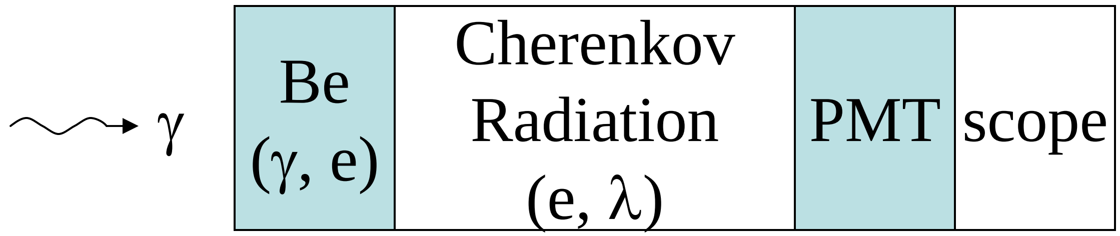
- Omega (TIM-based)
- Threshold Energy = down to 6.3 MeV (CO2 @ 100 psi)
- PMT & Streak Camera-based (tested)
- ~10^{11} min. n-yield @ 20 cm

- Gamma-ray Reaction History (GRH)

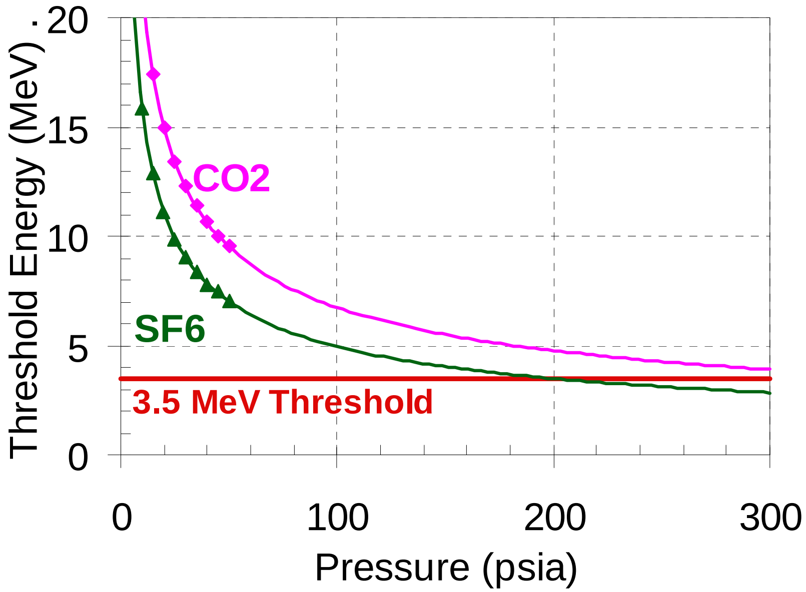


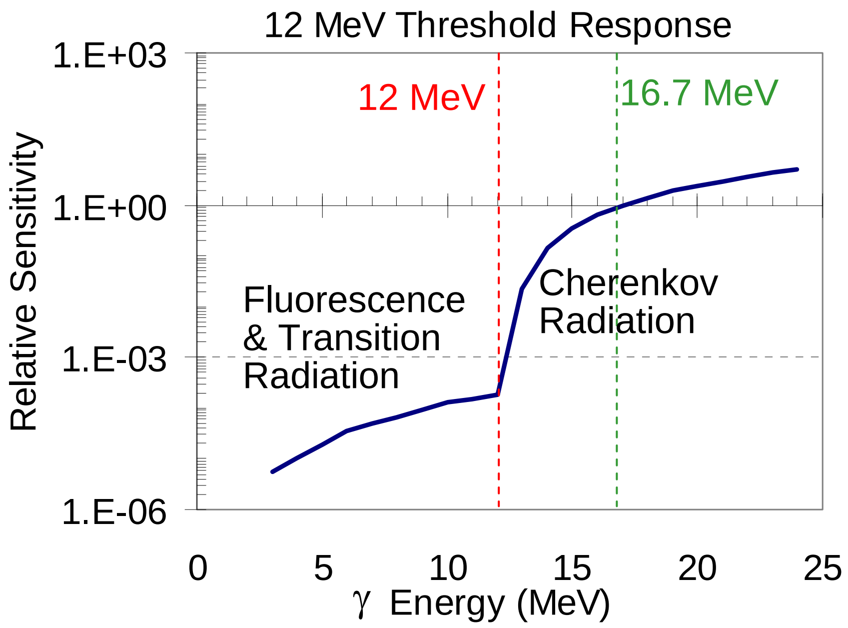
- NIF
- Threshold Energy = down to 3.5 MeV (SF6 @ 200 psi)
- PMT & Streak Camera-based
- 3×10^{13} min. n-yield @ 6m

Threshold GCD captures 16.75 MeV DT Fusion Gamma-rays



Two stage converter





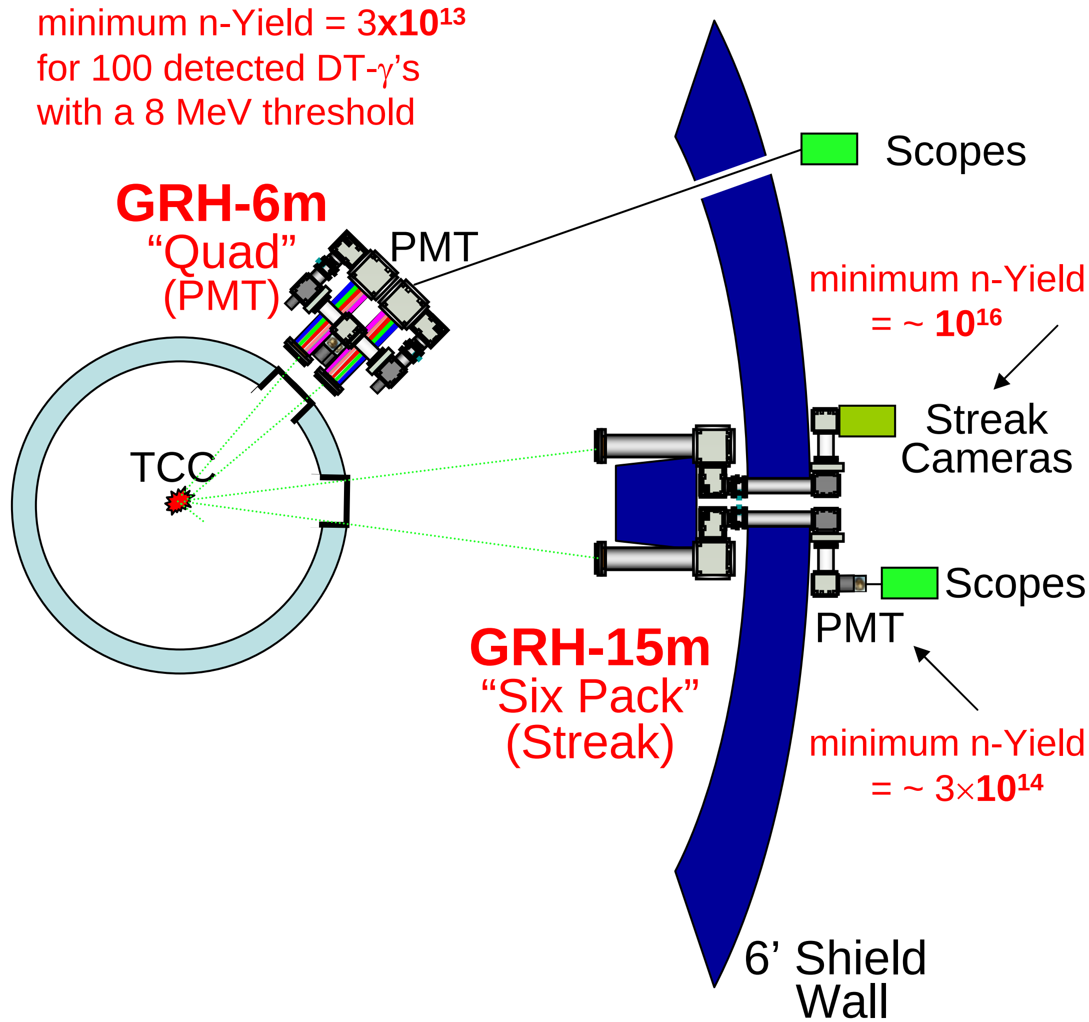
GRH is an essential instrument for NIF fusion reaction studies

Bang Time Accuracy

	GRH6m	GRH15m
THD(1e14)	< 25 ps	
THD(1e16)	< 25 ps	< 20 ps
DT(1e19)		< 20 ps

Burn Width Accuracy

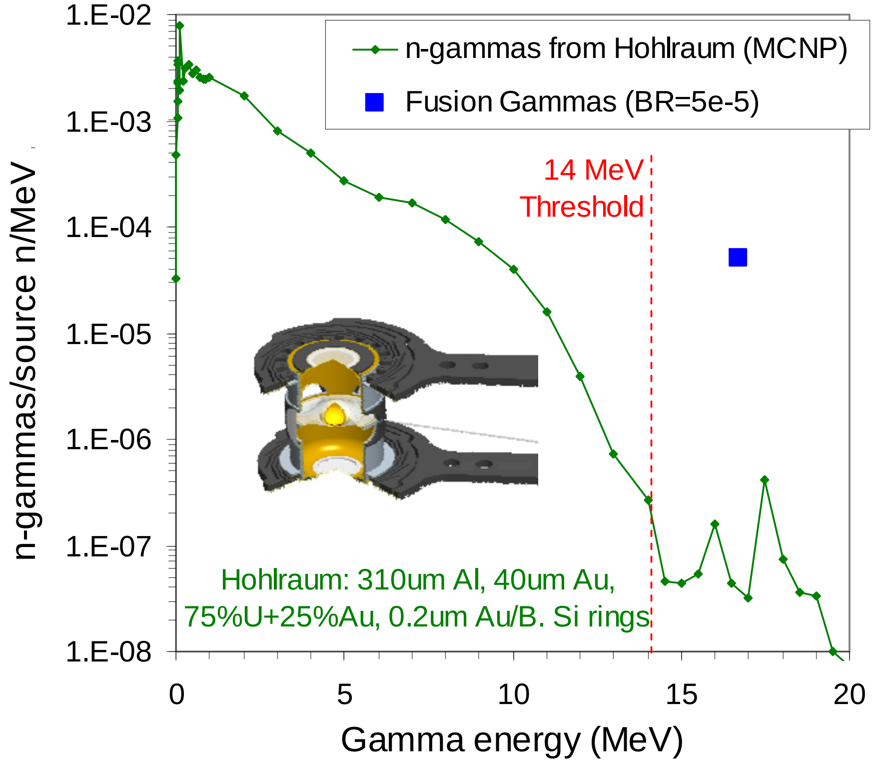
	GRH6m	GRH15m
THD(1e14)	< 10 ps	
THD(1e16)	< 10 ps	< 3 ps
DT(1e19)		< 3 ps

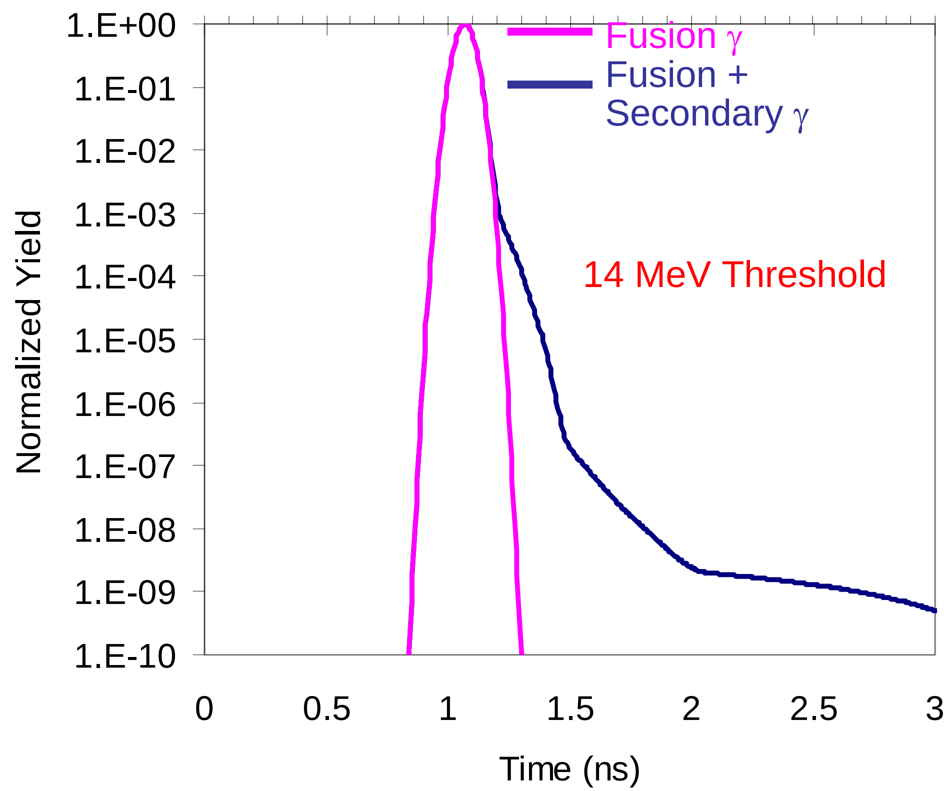


A challenge faced by the GRH is potential interference of γ_p with various γ_s

- NIF indirect implosions generate various gamma-rays
- Fusion gammas (γ_p)
  - DT (16.75 MeV)
  - HT (19.8 MeV)
- n-induced secondary gammas (γ_s): (n,γ), (n,n')γ, (n,p)γ …
  - Capsule materials (12C @ 4.44 MeV, 16O @ 6.1 MeV)
    - May be used to bolster GRH signal (~synchronous)
    - Possible time-dependent ρR diagnostic
  - Hohlraum materials (Au, U, Al, Si)
    - May also be used to bolster signal, but must be aware of BT shift (< 60 ps)

N-induced Secondary Gamms from Hohlraum & TMP can be thresholded out (calculation by Lucille Dauffy)



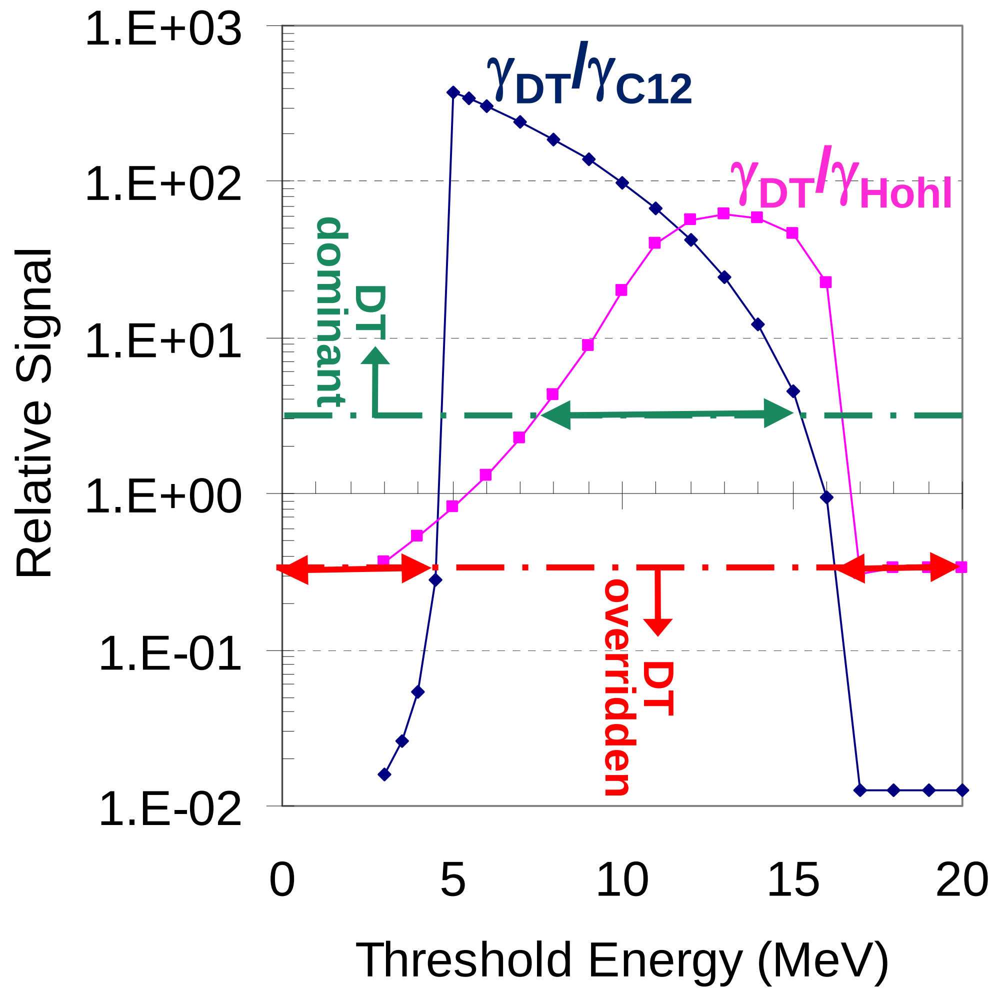


- ~100x more Secondary γ's than Fusion γ's
  - Cross sections uncertain, needs experimental validation

- ~60 ps delay between Fusion & Secondaries γ's
- Insignificant Bang Time shift (<10 ps) down to ~6 MeV threshold

Hohlraum γ's never dominate the signal (by Hans)

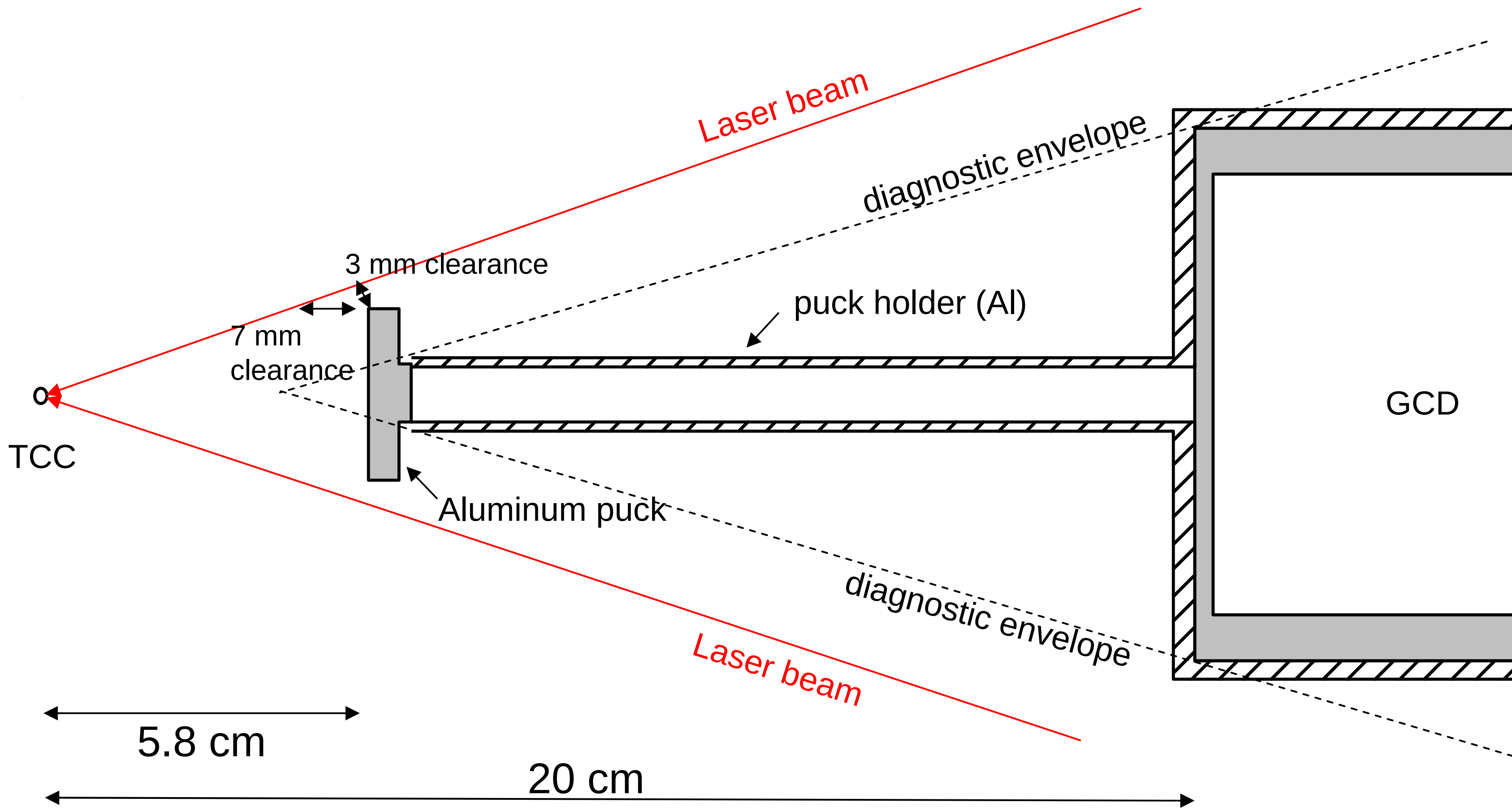
- DT γ's dominate signal (i.e., >3x) for Thresholds 7.5 to 15 MeV
- C12 γ's dominate at <4.5 MeV
- Hohlraum γ's never dominate, but can be comparable to DT γ's at 4.5 to 7.5 MeV thresholds



Experimental goal is to simulate γ_s from a NIF hohlraum & Proximity Sources

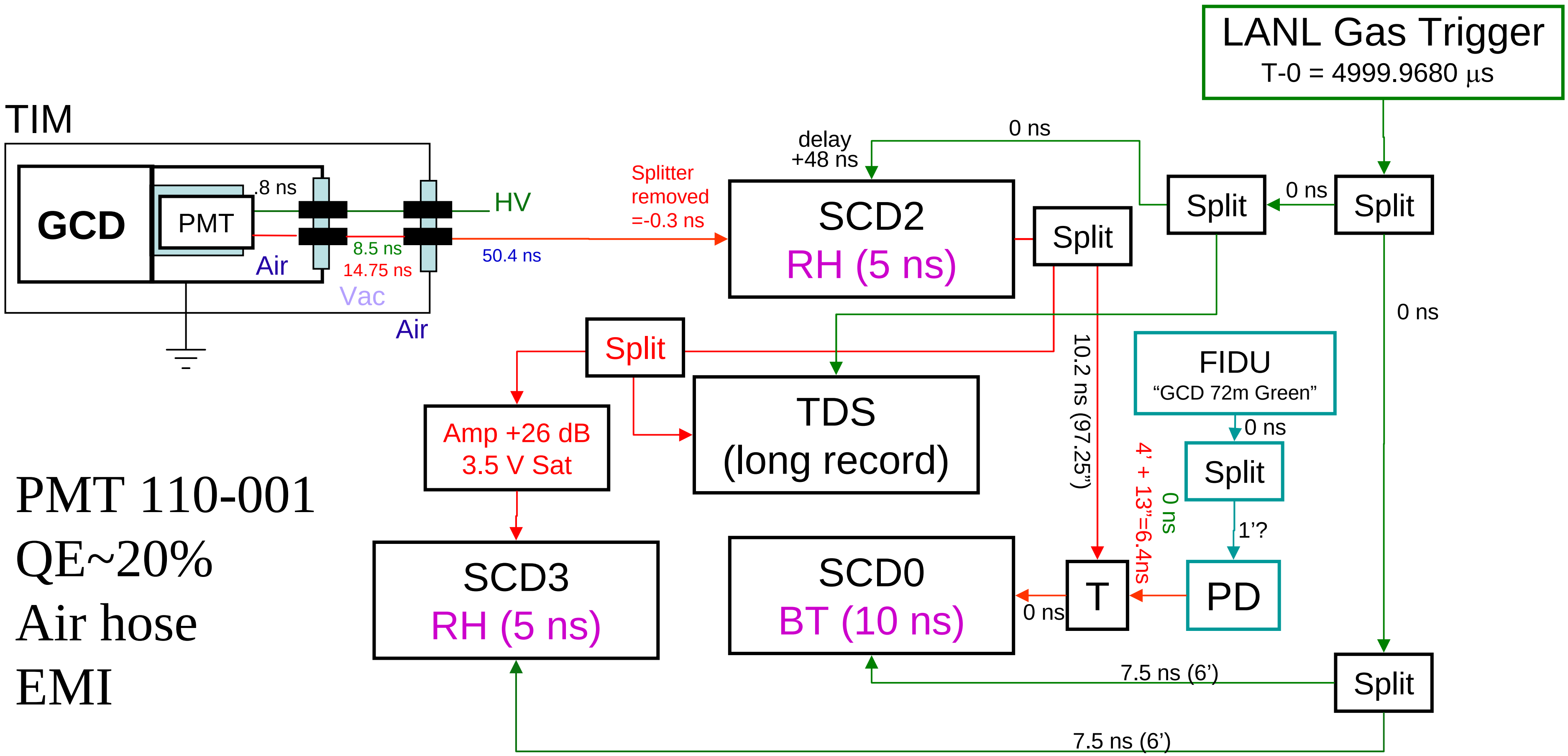
- NIF hohraum simulation experiment at OMEGA
  - GRH performance study (threshold response)
  - Gamma interference study (bang time, burn width)
  - Code (MCNP/ACCEPT) validation
    - If neutron rate and (n,γ) cross-sections are known, γ_s can be a GRH code validation source
    - cf) Calibrated 'electron' (LINAC) and 'gamma' (HIGS) source are also used for validation
    - Uncertainty in fusion gamma branching ratio
- γ_s as a GRH calibration source
  - γ_s serves as in-situ GRH calibration source
  - γ_s serves as a broad energy source
  - various puck materials are available (Al, Al2O3, Cu,…)
  - Provide one method for Branching Ratio (=T(d,γ)/T(d,n)) determination
    - Multiple methods needed to reduce uncertainty

‘Hockey Puck’ experiments are conducted at the OMEGA laser facility (Nov. 2008 and April 2009)



Diameter of Al puck = 3 cm
Thickness of Al puck = 0.5 cm (+ 0.2 cm holder side)

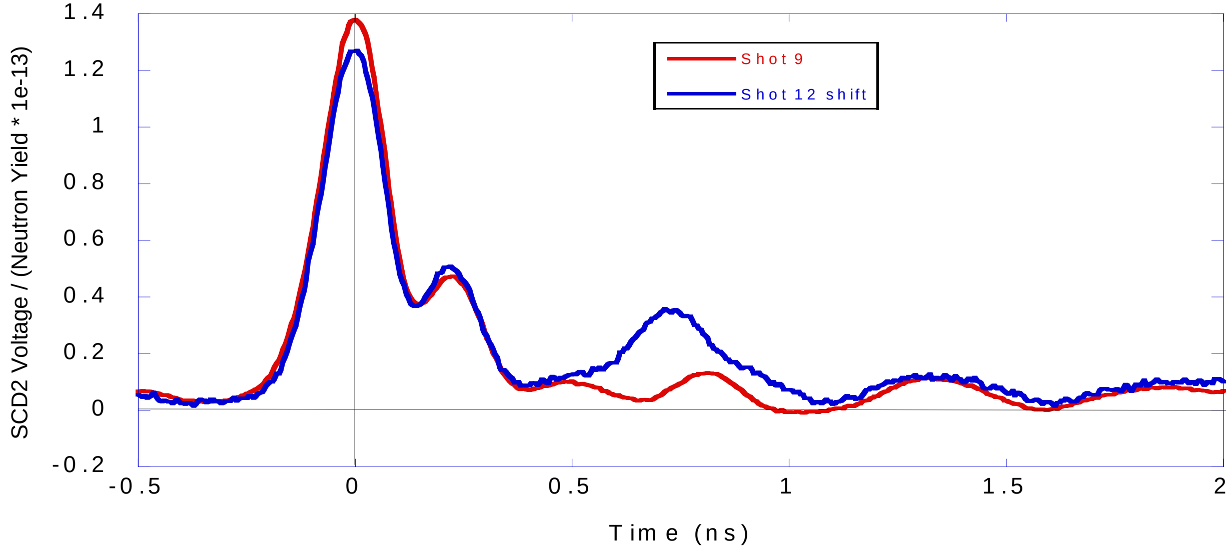
GCD Signal Configuration

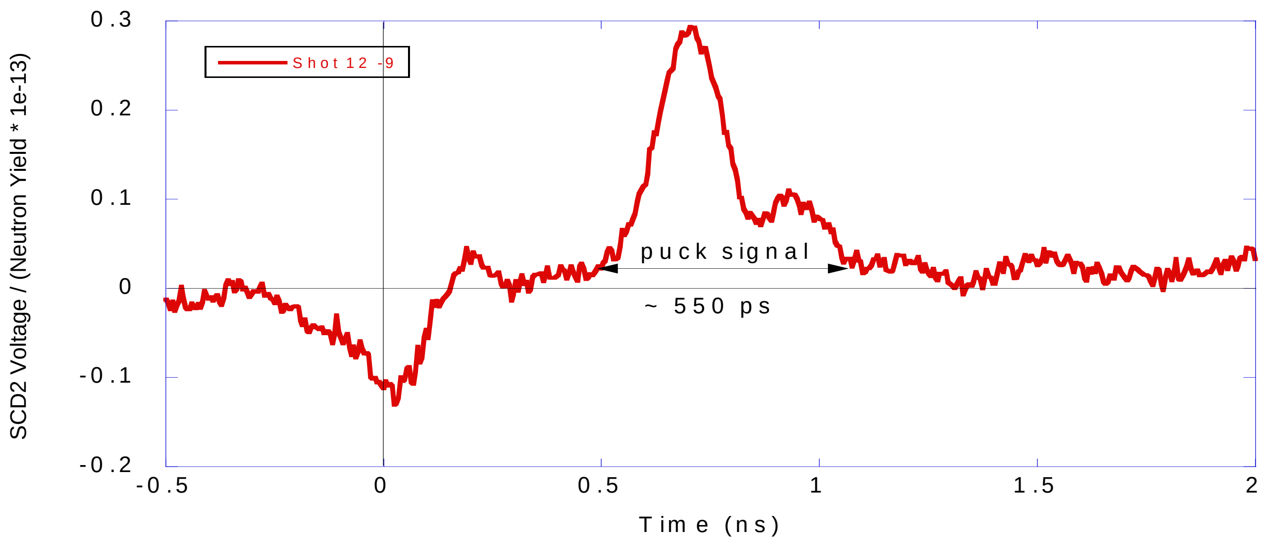


PMT 110-001
QE~20%
Air hose
EMI

*assuming 1.2 ns/ft for signal cable

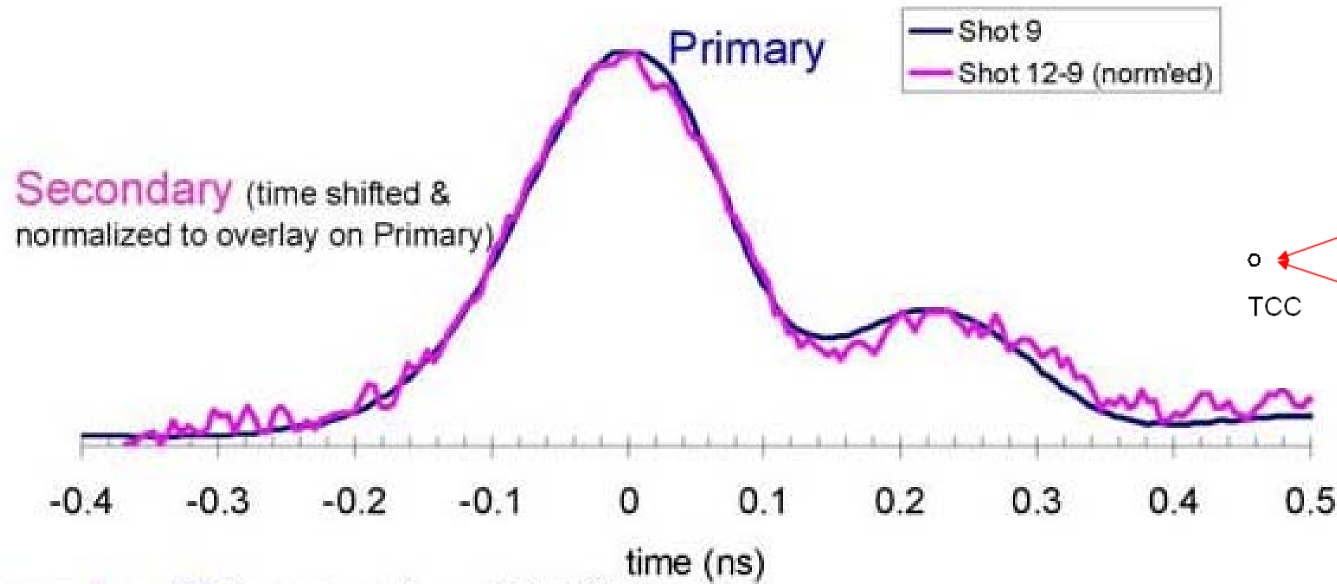
Clean Signals but improperly located puck

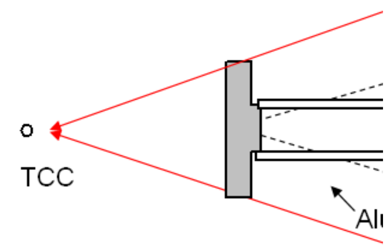




- gamma attenuation = 1 - γ_p/γ_{po} = ~ 0.081 ~ 8.1 % measured (more scattering)
- ~ 550 ps γ_s pulse

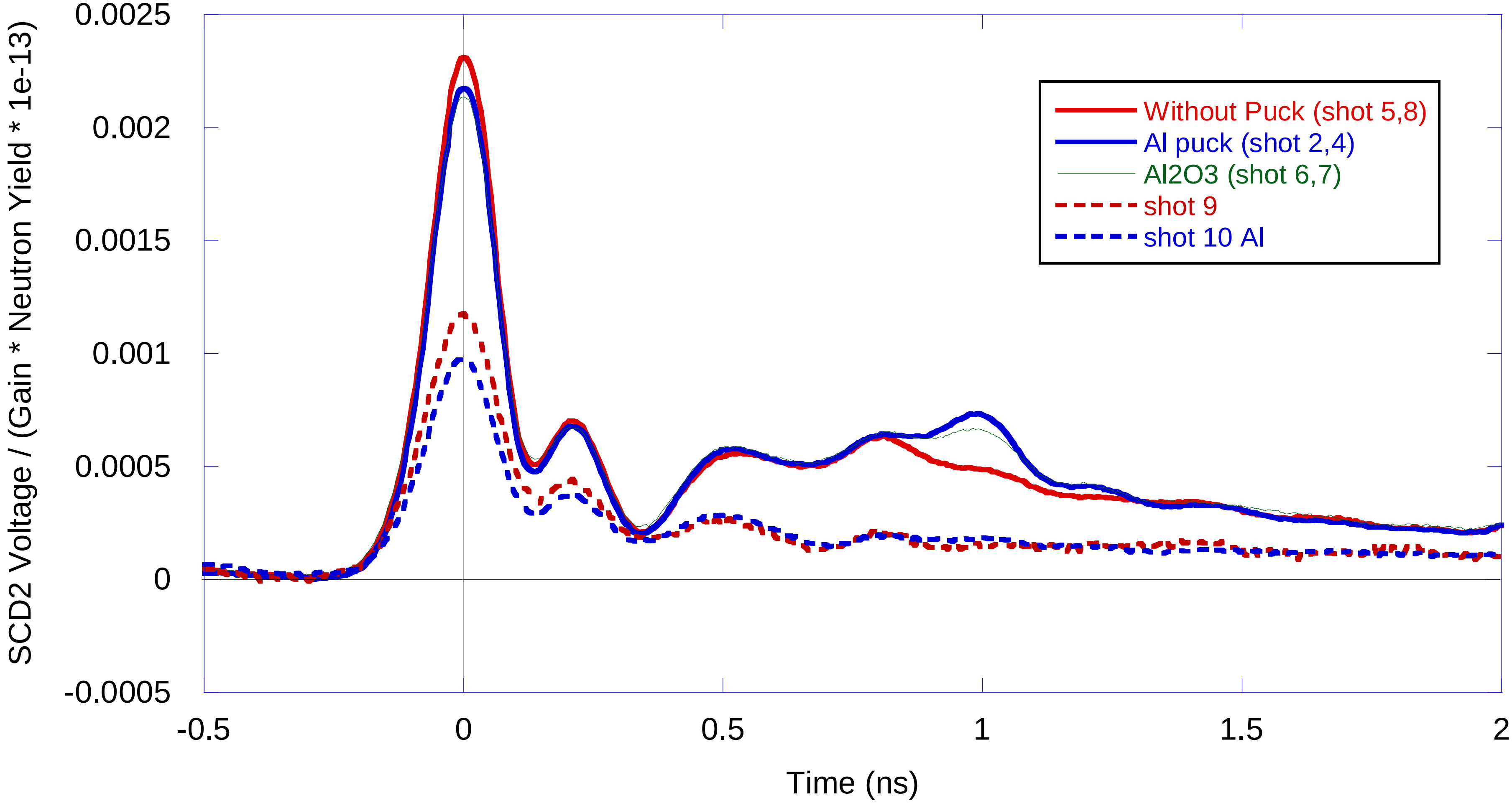
Data Analysis: Primary/Secondary ratio & timing (by Hans)



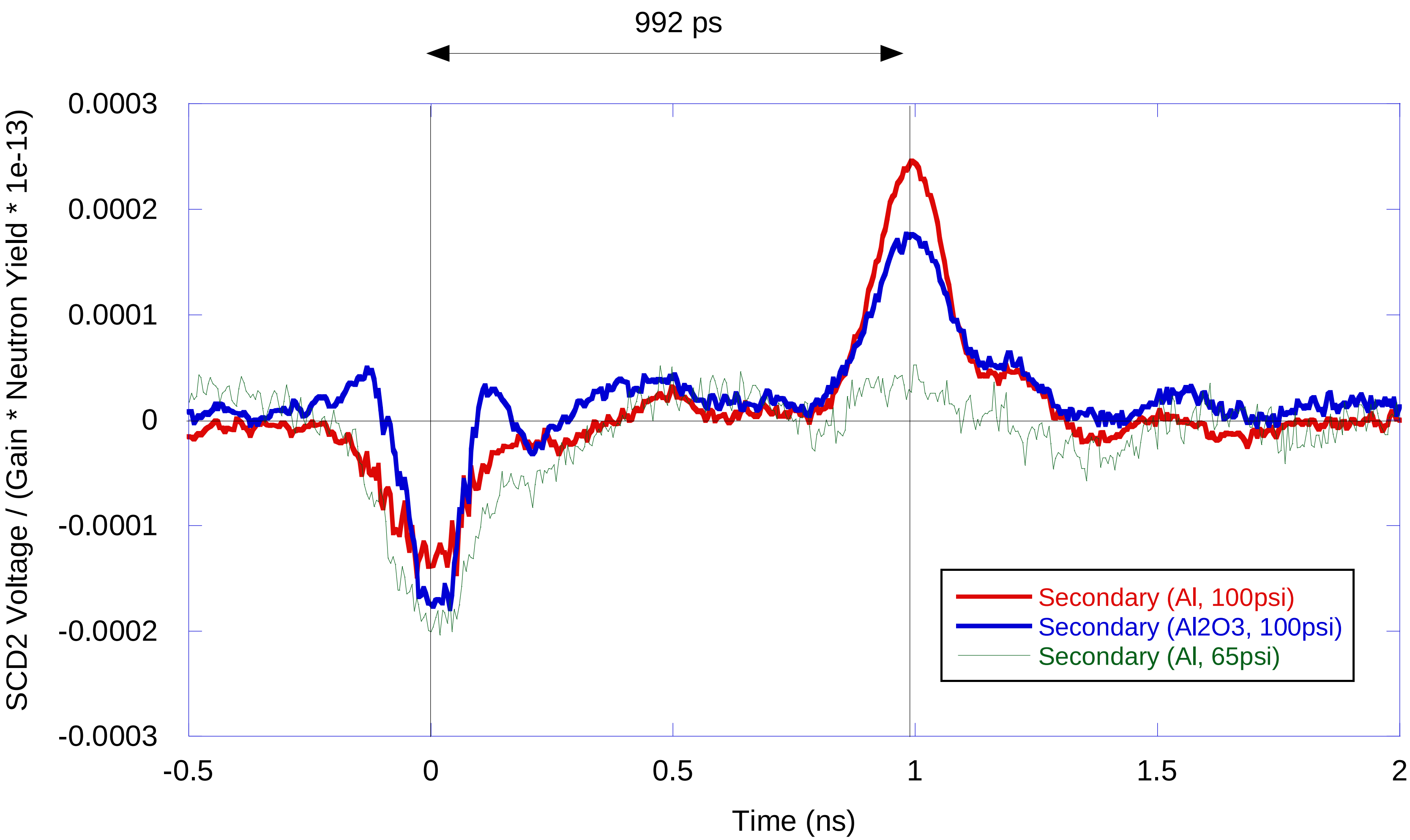


- Secondary/Primary ratio = 21.6%
- Secondary signal shifted by 704 ps
  - γ's: c= 29.98 cm/ns (33 ps/cm); 14.1 MeV n's: v_n= 5.19 cm/ns (193 ps/cm)
    - ➢ Neutrons are delayed 160 ps/cm relative to γ's
  - Face of Puck is at 704/160 = 4.40 cm
  - Back end of secondary signal should be smeared out by ~90 ps relative to the primary signal (80 ps for 0.5 cm thick puck + 10 ps for Doppler spreading), but appears to only be smeared by ~20 ps

Secondary gamma production and Primary gamma attenuation are observed



Secondary/Primary Ration and Time Delay



γs/γp (Al, 100psi) = 0.107,   γs/γp (Al2O3, 100psi) = 0.076

γs/γp (Al, 65 psi) ~ 0.017,   992ps/160ps = 6.2 cm

Summary

- Successful day at OMEGA on Nov. 2008
  - Aluminum puck (D = 3 cm, t = 0.5 cm) at two locations
  - γ_s/γ_p ~ 0.216 and γ_s/γ_{po} ~ 0.198 @ 4.4 cm or less location
- Successful day at OMEGA on April 8, 2009
  - γ_s/γ_p ~ 0.107 at Al, 6 MeV
  - γ_s/γ_p ~ 0.076 at Al2O3, 6 MeV
  - γ_s/γ_p ~ 0.017 at Al, 8 MeV
- Next OMEGA shot day on May 13-14 or later
  - Additional puck materials (Cu, Si, SiO2)
- A coupled MCNP/ACCEPT calculation (by Jamie, Carl, Joe)
  - Provide one method for Branching Ratio (=T(d,γ)/T(d,n)) determination