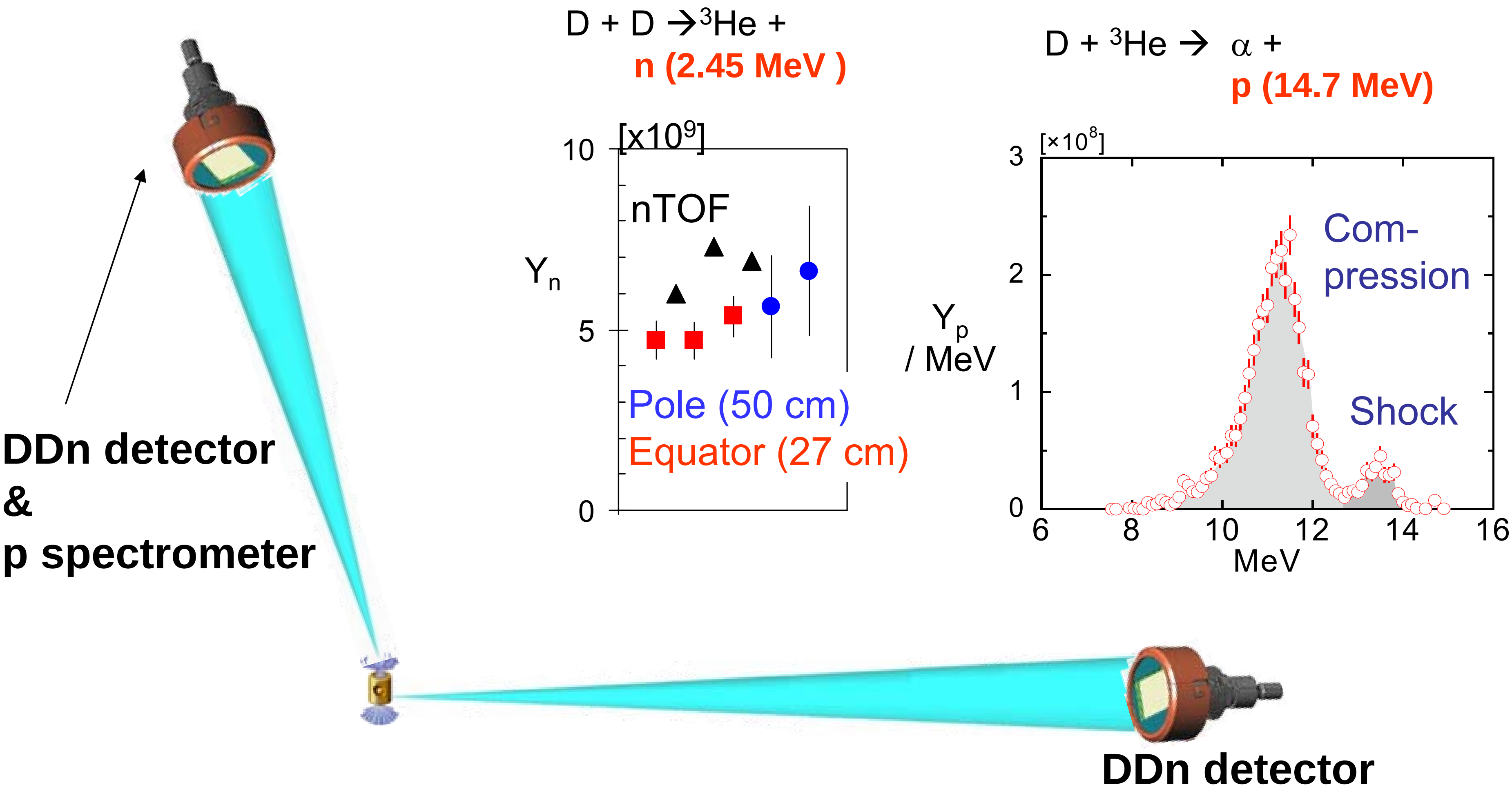
Compact DD-neutron detector for OMEGA and the NIF

NIF shot N091123 (D^{3}He fuel)



Fredrick Séguin, MIT, for the NIC team

NIC
The National Ignition Campaign

OVERVIEW

- A compact, CR39-based detector for DD-neutrons has been designed for use in ICF experiments

- It is integrated into the assembly used for compact proton spectrometers so they can be used simultaneously at multiple positions in the target chamber

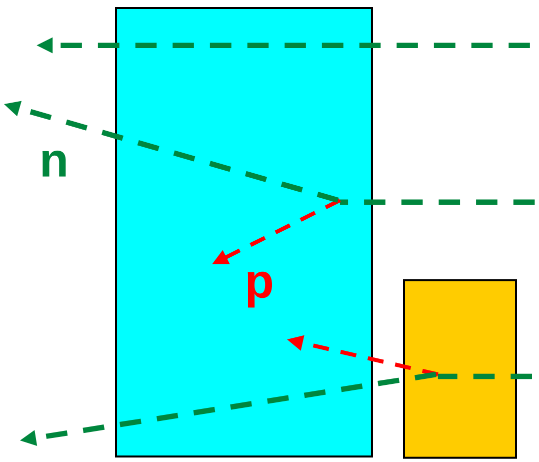
- The detector has been calibrated and characterized on the MIT Cockroft-Walton accelerator

- Neutron yield measurements were made during the 1st NIF campaign (in 2009).

- Future developments will include neutron spectrometry and DT-neutron detection

The detector is based on the response of CR-39 to protons elastically scattered by neutrons

CR39 ($C_{12}H_{18}O_7$)

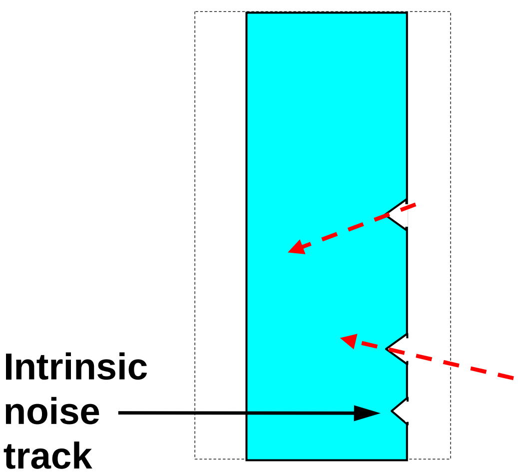


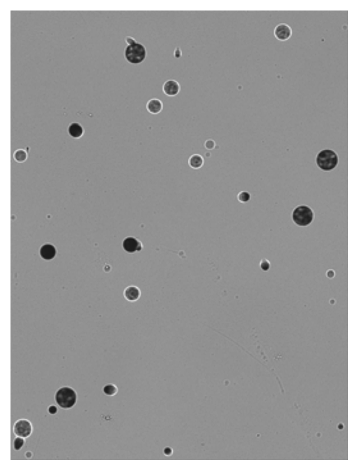
Most neutrons go through CR-39 without interacting

Some neutrons scatter a proton in the CR-39

A neutron can also scatter a proton into the CR-39 from an external “neutron-to-proton converter containing H

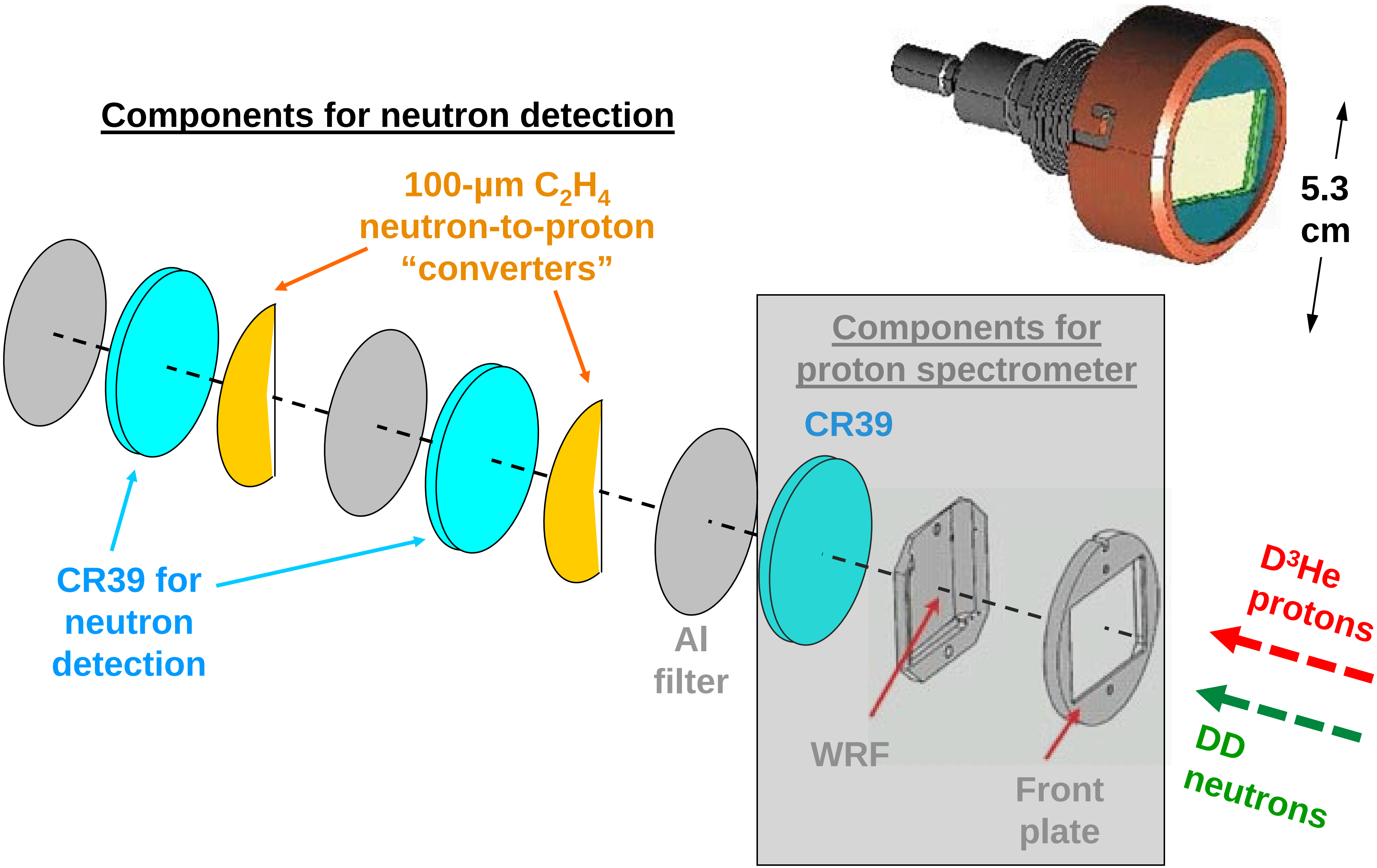
Etching removes CR39, reveals proton tracks (and some spurious noise tracks)



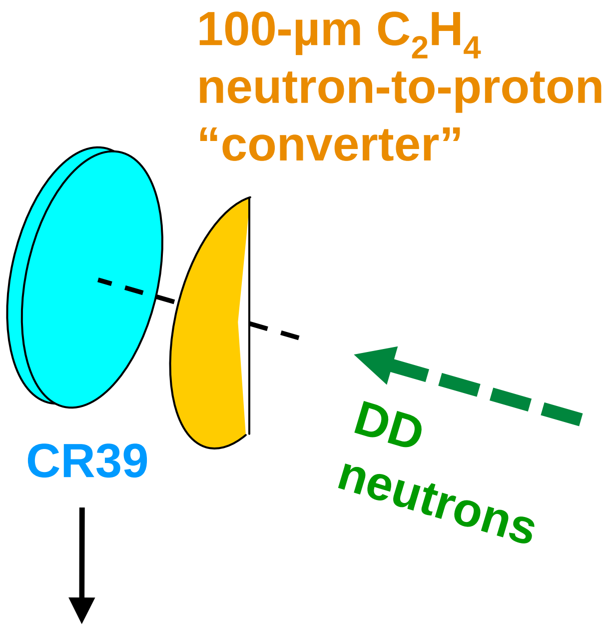


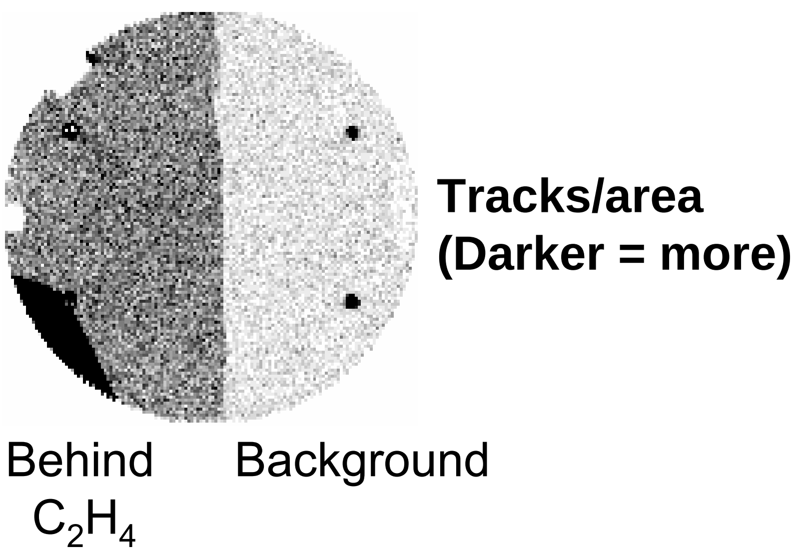
Microscope images shows proton tracks on front of CR39

The detector is assembled in a modular package along with a WRF proton spectrometer

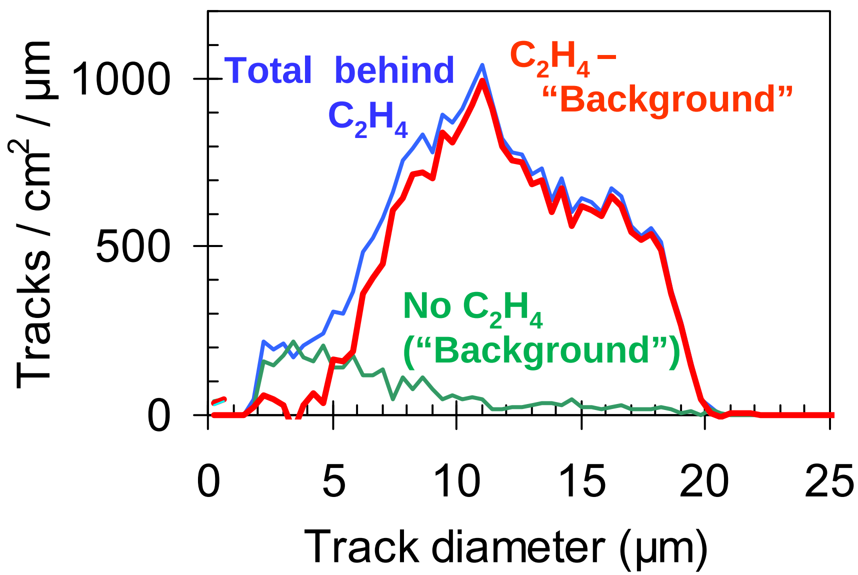


Use of C_2H_4 converter with background subtraction results in increased yield accuracy, especially at low yields



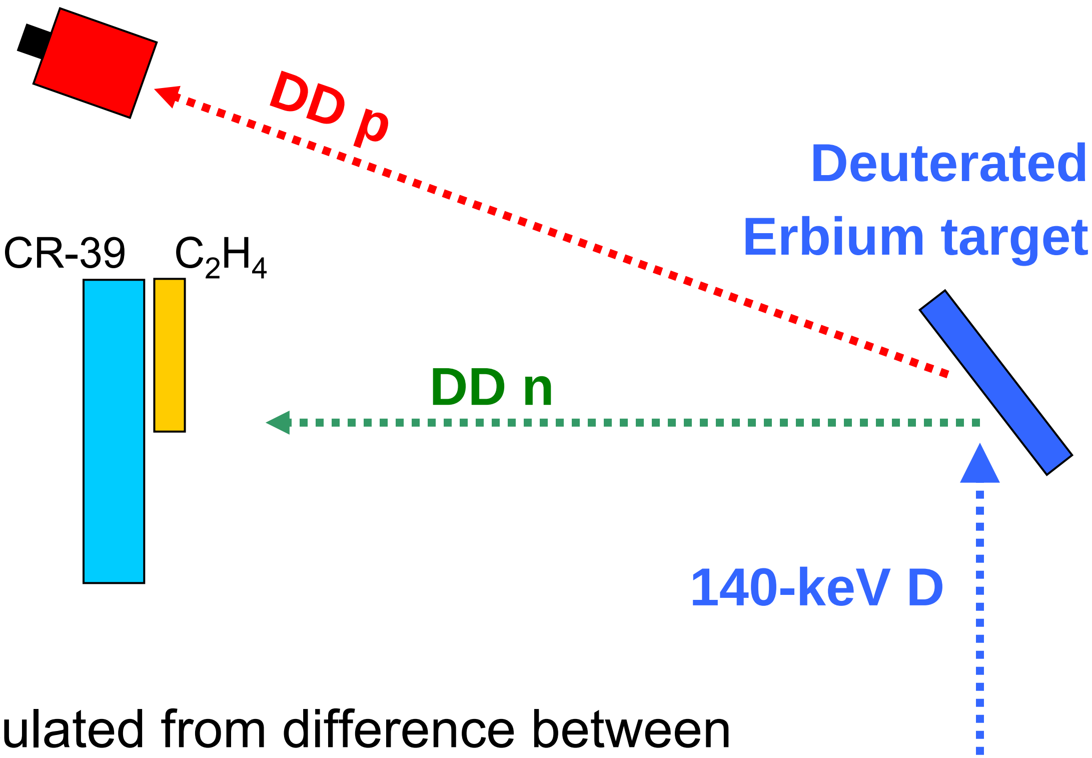


- More tracks from converter improves statistics
- Background subtraction "cancels" intrinsic noise

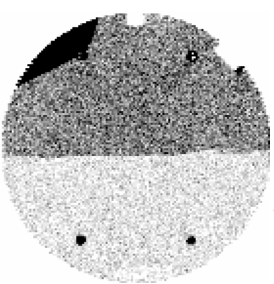


The relationship between incident neutron fluence and CR39 track density was calibrated with the MIT CW accelerator

SBD for absolute measurement of DD-p fluence F_p



DD-n fluence F_n calculated from F_p, then corrected by +8%*



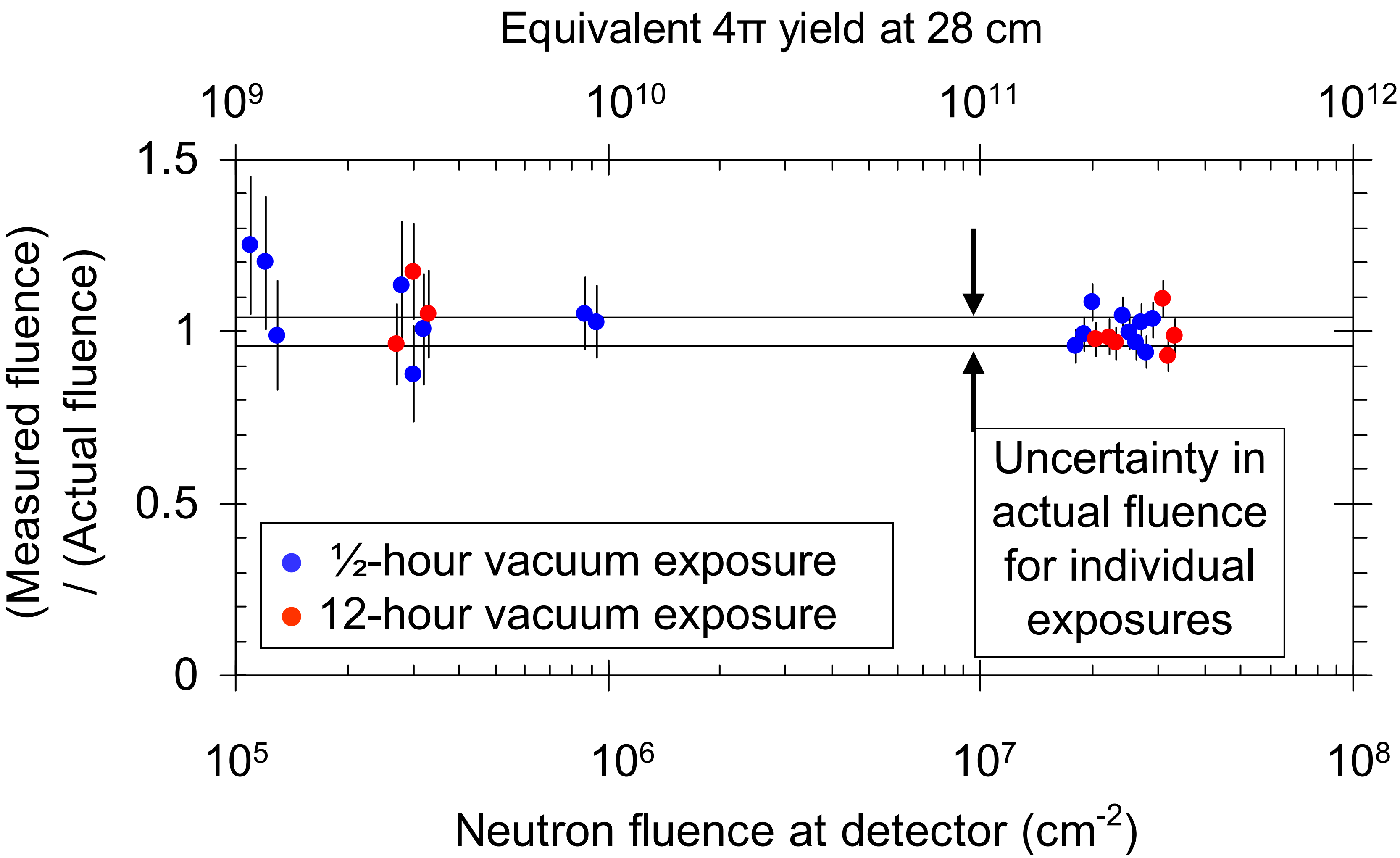
N_t (tracks / cm^2) calculated from difference between value under C_2H_4 filter and value in "background" region

$$F_n = 2620\,(1 - 0.116\,\delta - 0.008\,\delta^2)\,N_t$$

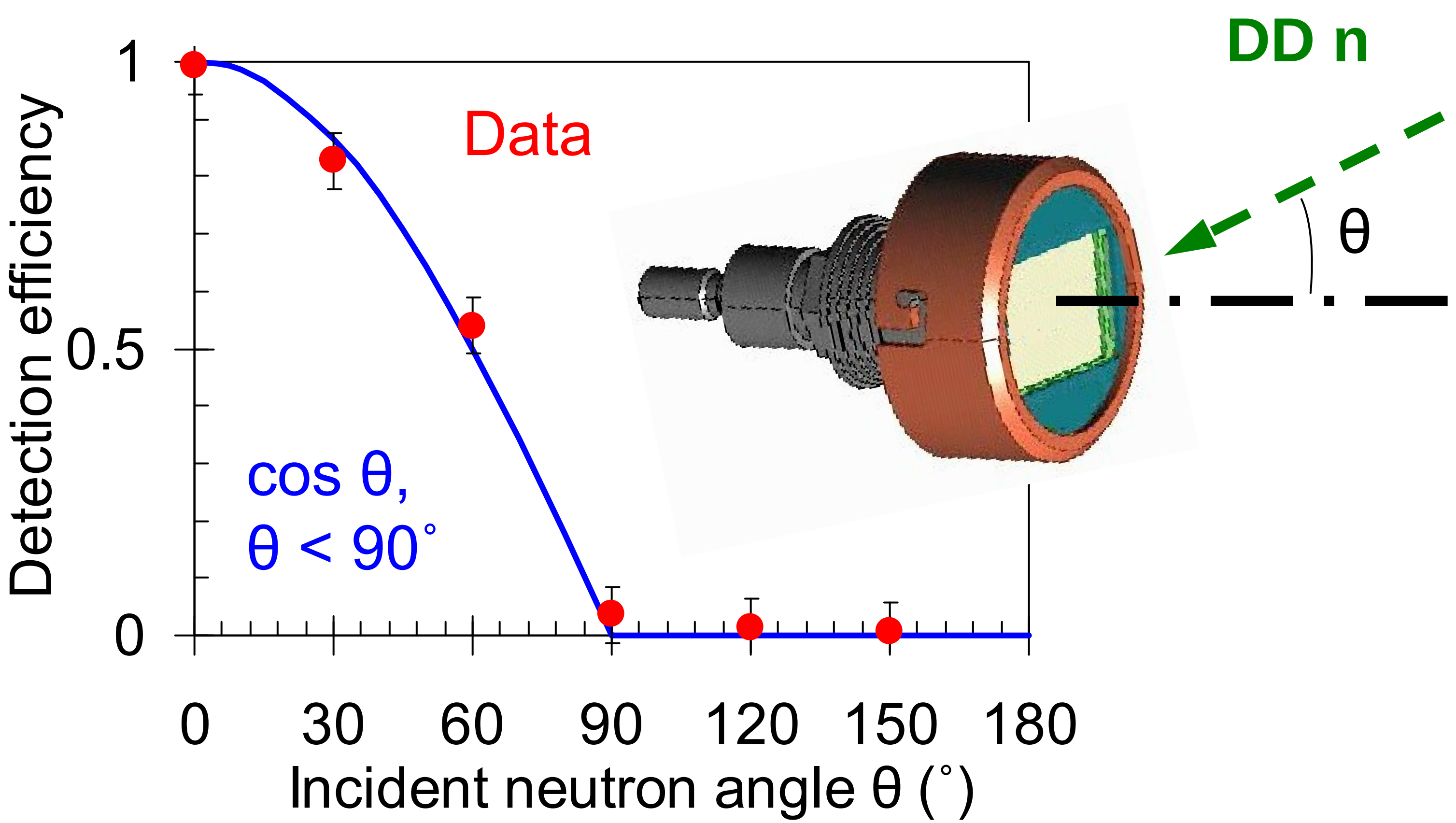
where $\delta = D_m$ in μm – 20 (see p. 4)

* For scattered neutrons, predicted by MCNP & weighted by direction (p.8) and energy (p. 12).

Accelerator data and the calibration are self consistent over a wide range of fluences, vacuum conditions



The detector is directional



Key detector performance characteristics

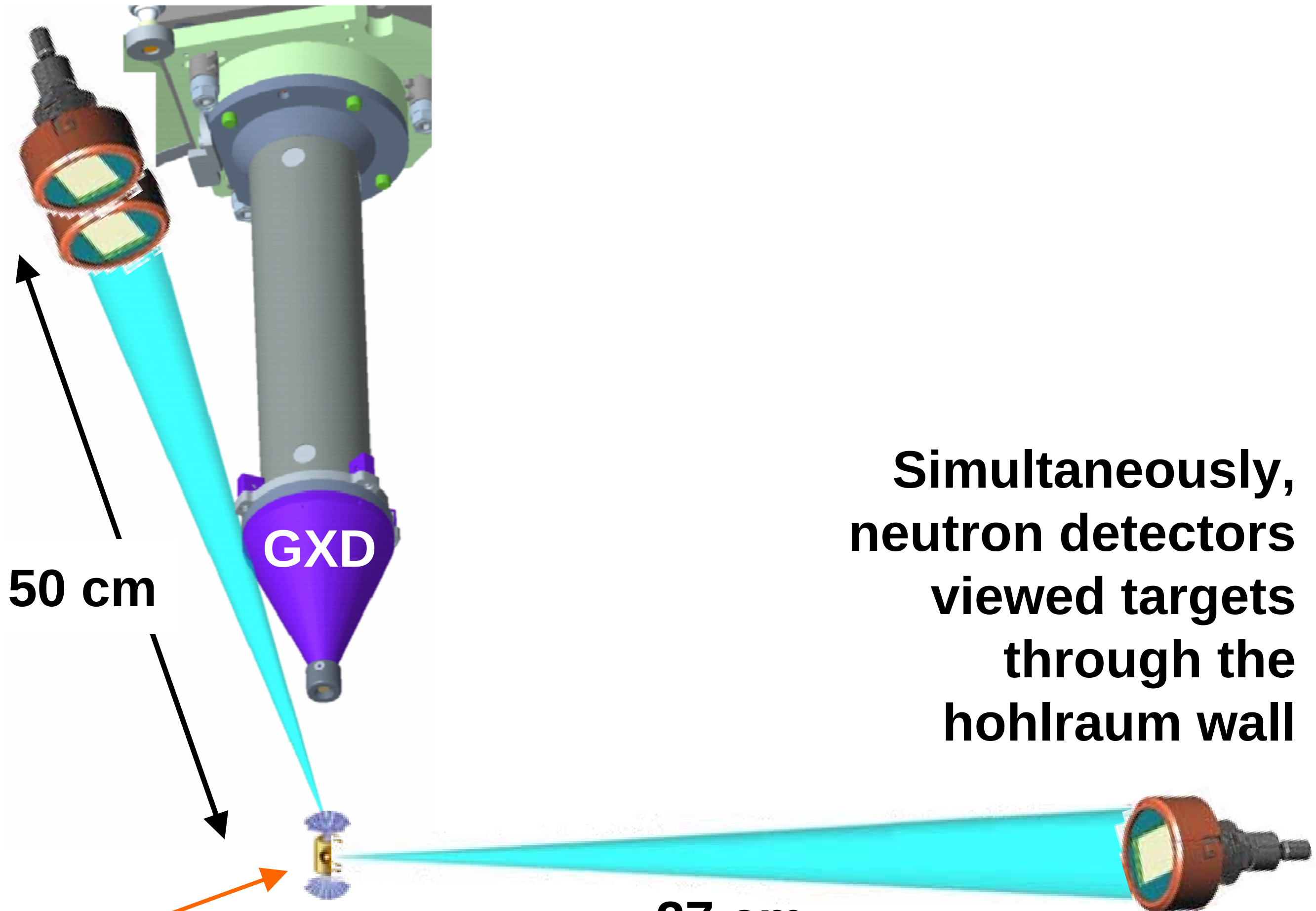
- **Passive** (no sensitivity to EMP, x or γ rays, 1/3-μm or unconverted light)
- **Compact** (~ 6 cm module size, even with addition of a proton spectrometer)
- **Multiple modules can be used** at different positions simultaneously
- **Directional**
- **Redundancy** (3 pieces of CR39 per module)
- **Wide dynamic range**:

  Fluence ~ 10^5 – 10^8 DDn cm^{-2}

  Y_{DDn}~ 10^9 – 10^{12} at 30 cm; 10^{11} – 10^{14} at 300 cm
- **Unaffected by long vacuum exposure**
- **Slow turnaround** (Minimum 9 hours to etch, scan, analyze)
- **No half-life issues**

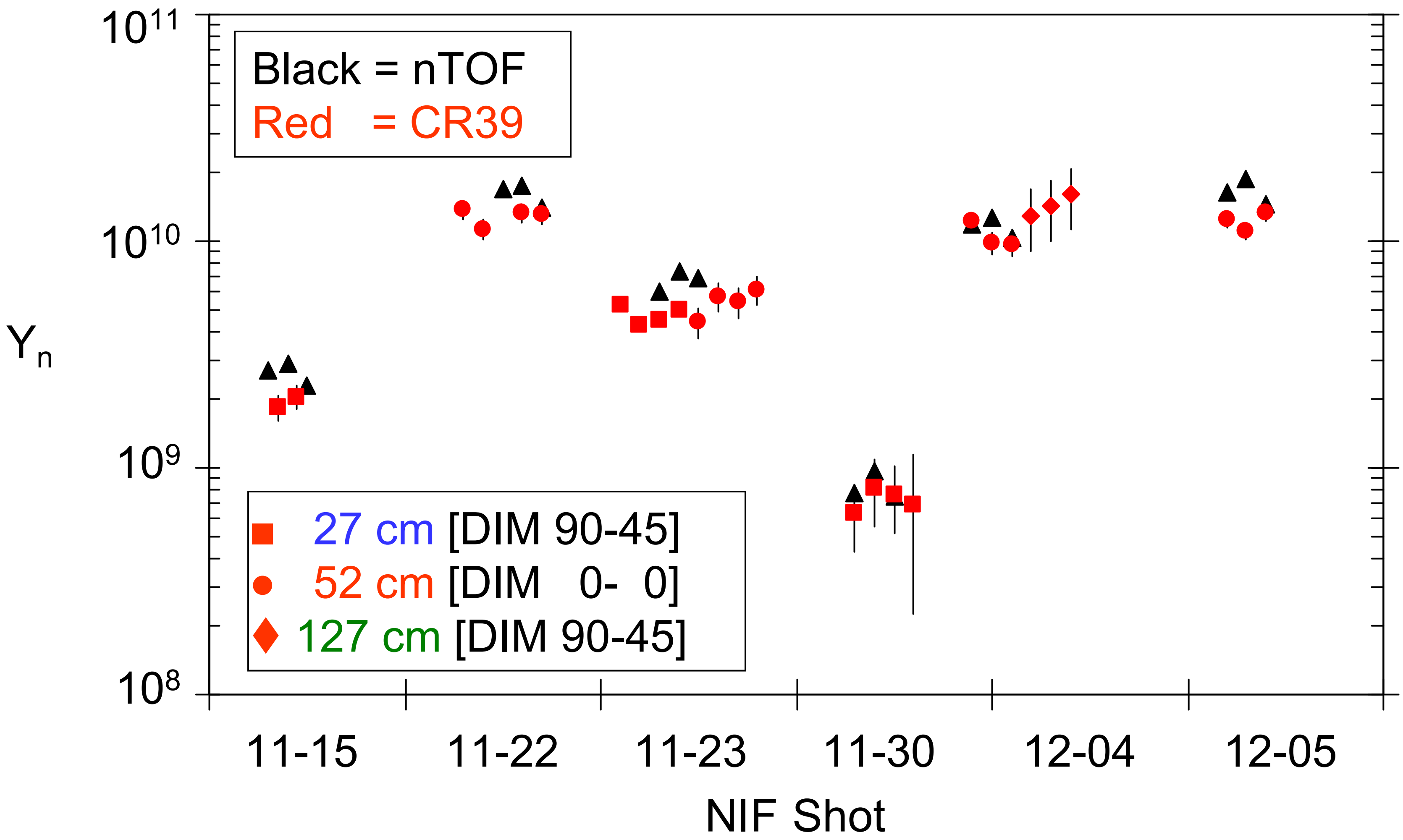
In the fall of 2009, detector modules were fielded on the NIF during low-yield shots

Neutron detectors & proton spectrometers viewed D^3He-filled targets through the LEH

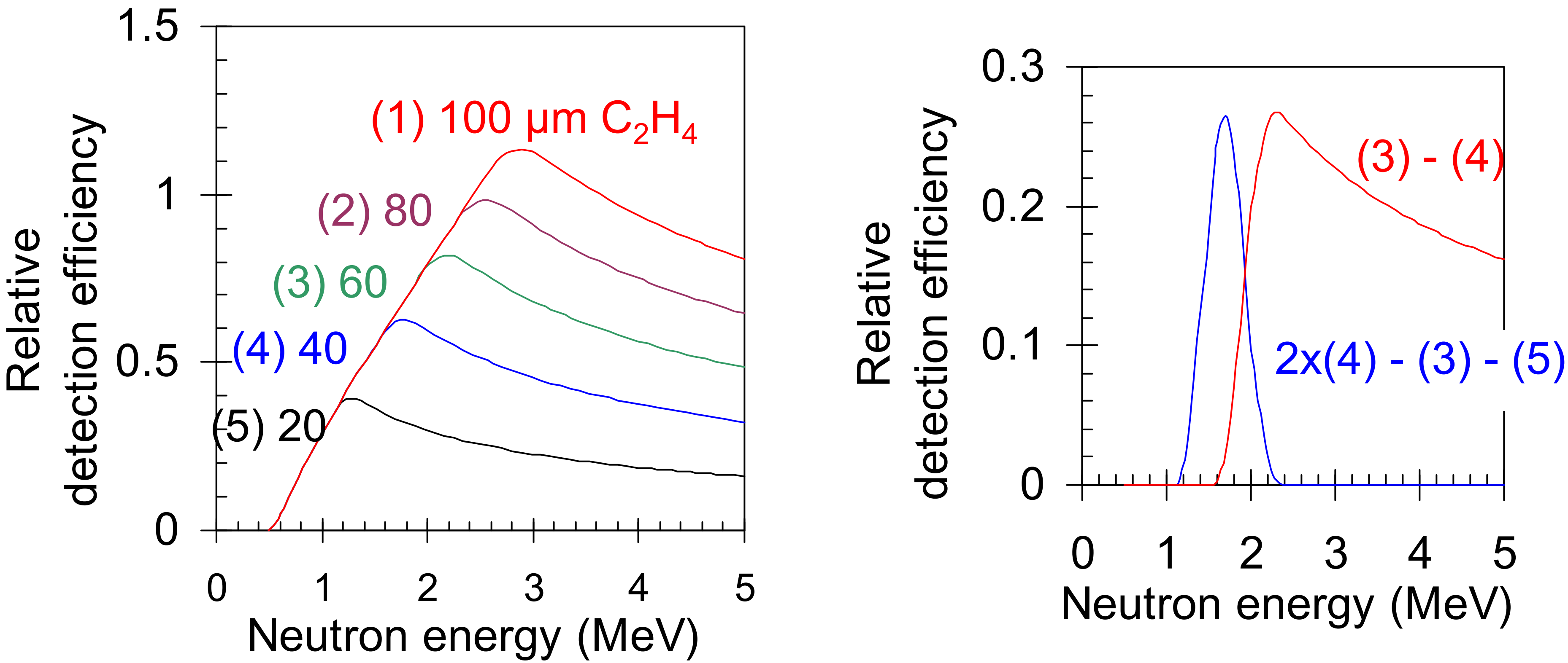


Simultaneously, neutron detectors viewed targets through the hohlraum wall

CR39-based neutron detectors provided an independent measurement of NIF DD-neutron yields



Spectrometry may be possible, using a C_2H_4 step filter



A similar approach is being developed for DT neutrons

See the next poster by Mario Manuel.