A new C6D6 detector with SiPM readout

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The n_TOF Collaboration

nTOF

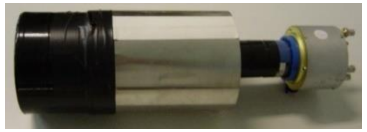
European Research Council

CSIC
Consejo Superior de Investigaciones Científicas

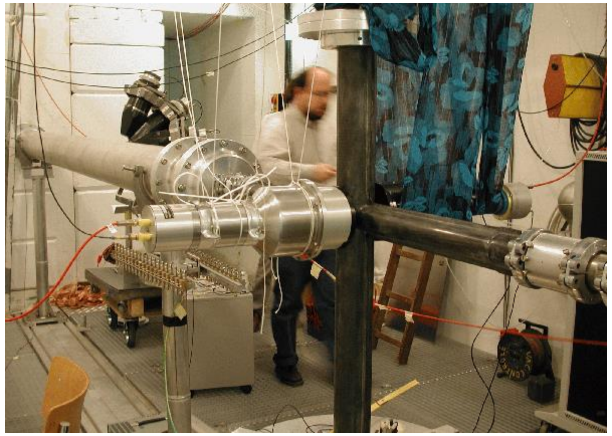
Outline:

- Brief evolution of the C6D6 zoo @ n_TOF
- Objectives of a new C6D6 design
  - Neutron sensitivity
  - Electrical signal response
  - B-field insensitivity
- Pros- and cons of the new design
- Proposed prototype development and tests

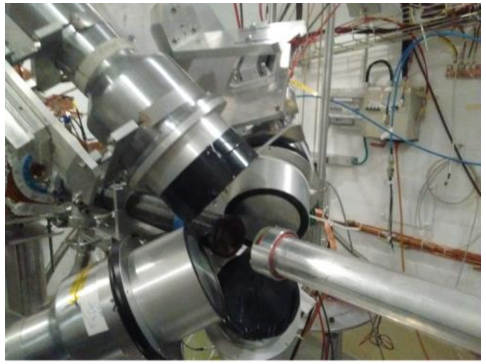
Brief evolution of C6D6 detectors at n_TOF:

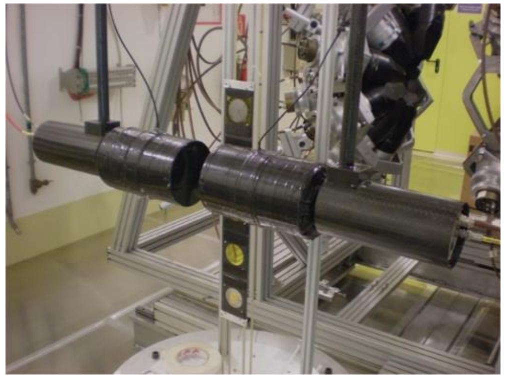


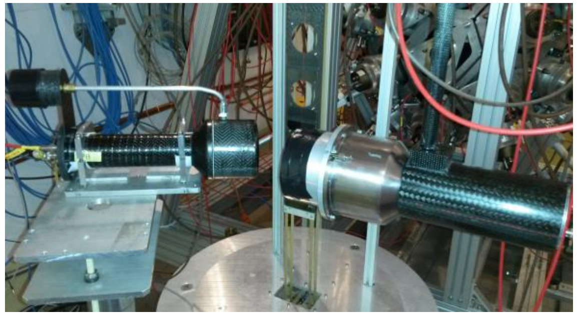
2001-2005



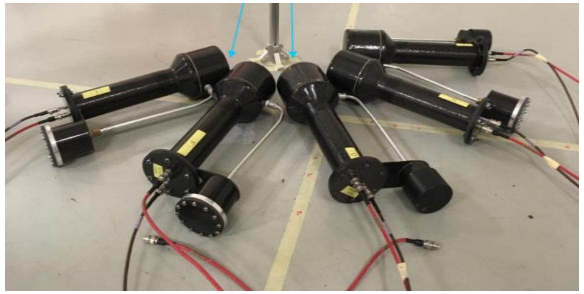
2000

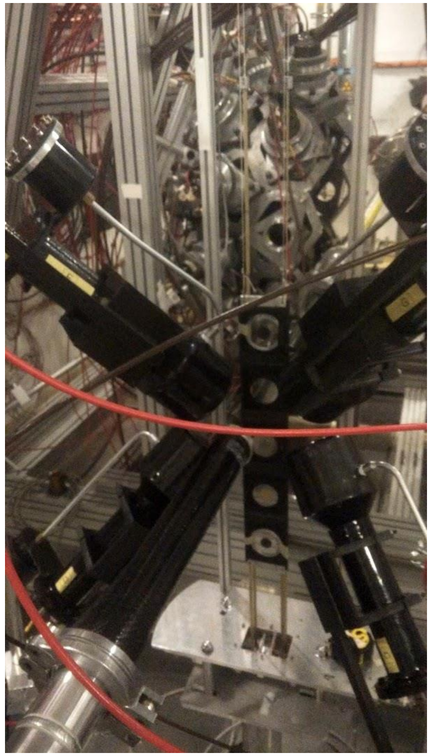


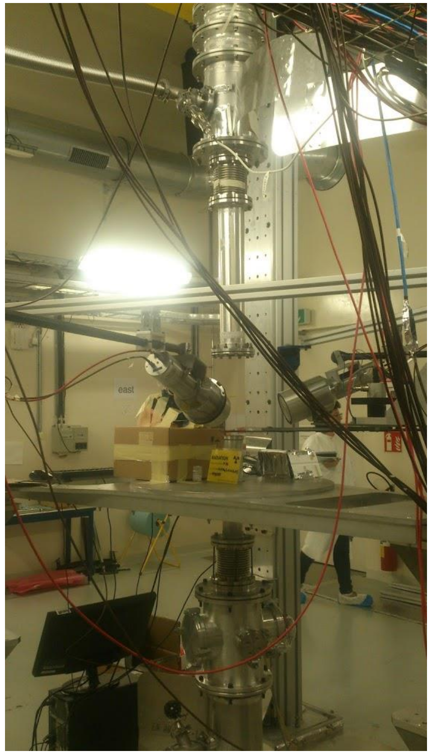




2009-2012







2015-2018

time

C6D6/SiPM goals:

→ Further **reduce the intrinsic Neutron Sensitivity** (compared to state-of-the-art C6D6)

→ Better **suited for high CRs and γ-flash (EAR2)** by reducing volume (1/4 L6D6)→ Better suited for high En-range

→ Clean electrical output signals (no VDs → no rebounds → To be tested in the lab during LS2)→ **Reliable PSA**

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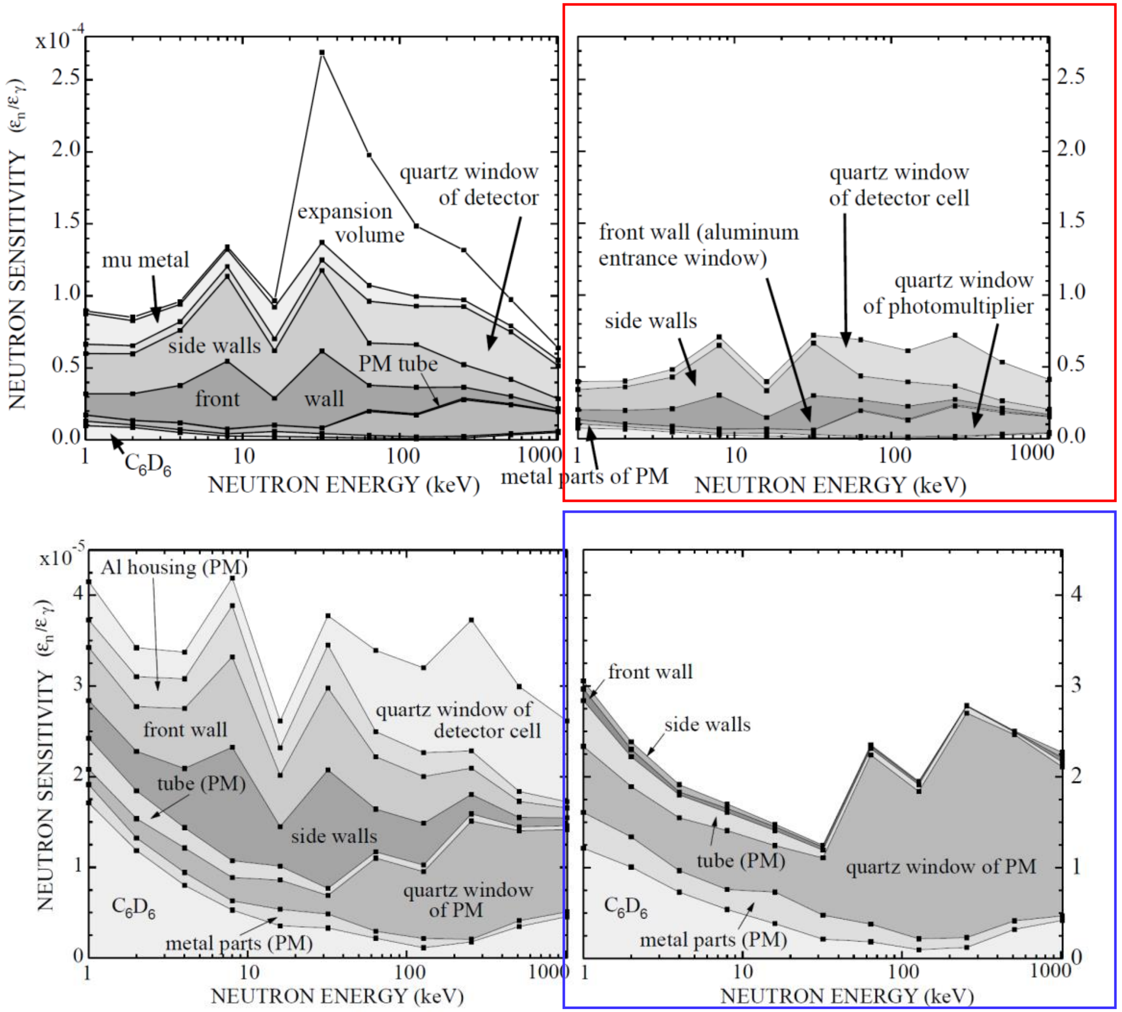
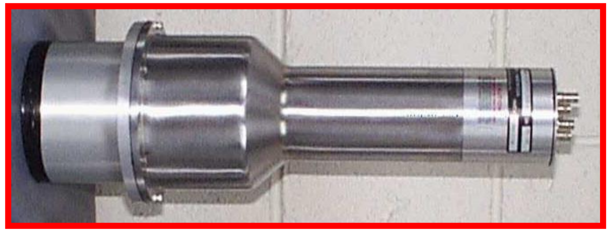
C6D6/PMT Neutron sensitivity: could it be improved further?

→ Aspect 1: neutron sensitivity





R.Plag et al. Nucl. Instr. Meth. A 496, Issue 2, p. 425-436 (2004).

C6D6/PMT Neutron sensitivity: could it be improved further?

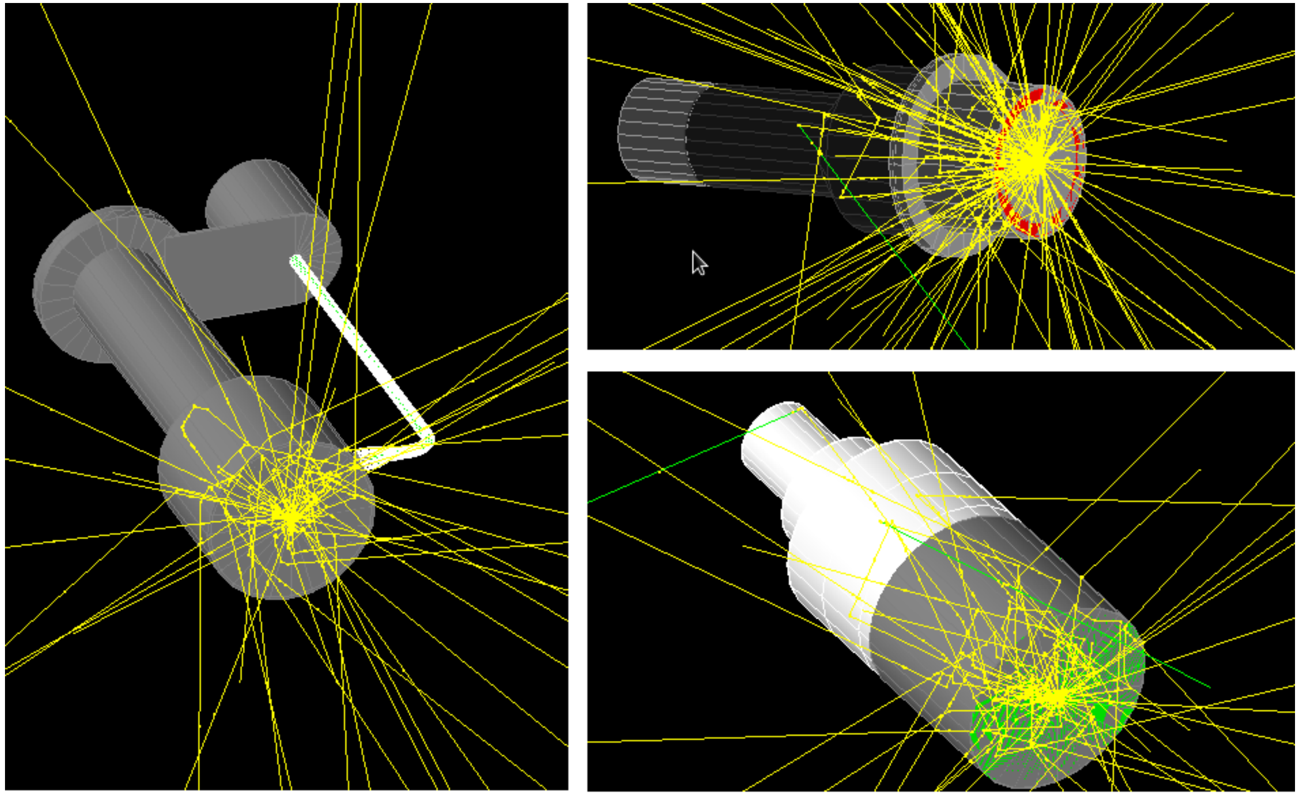
→ Aspect 1: neutron sensitivity

L6D6 Response to Neutrons (C. Guerrero & J.Lerendegui-Marco, US):

N_TOF Collaboration Meeting, 7 October 2014

- Low Sensitivity:
  - 20h-Long simulations , 10^8 neutrons
  - Maximized geometrical efficiency:

    2π emitting source at <1mm from detector



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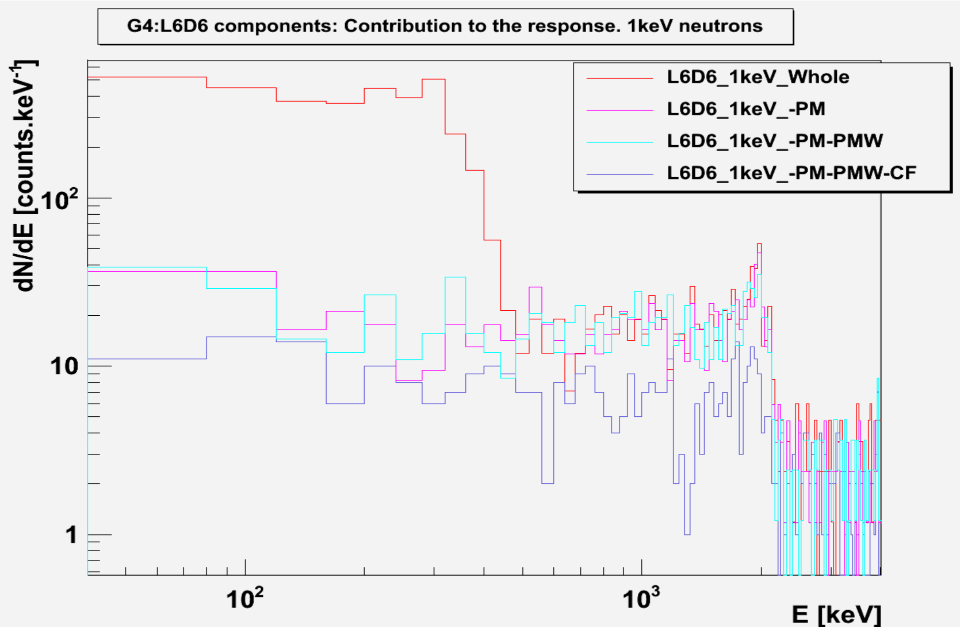
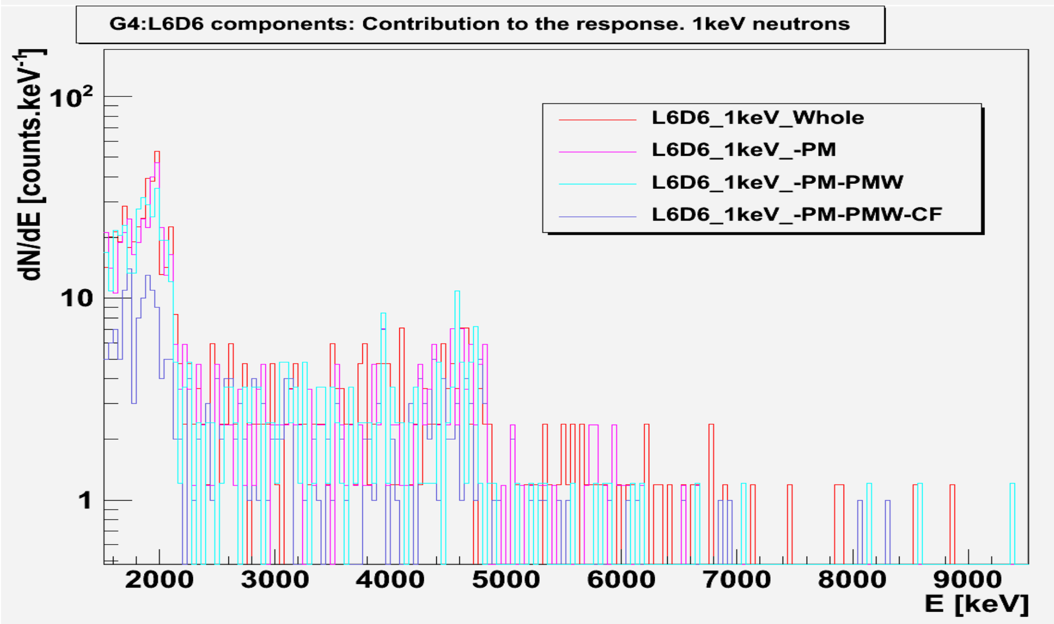
L6D6 Response to Neutrons (C. Guerrero & J.Lerendegui-Marco, US):

- Analysis of main contributions to neutron sensitivity of the L6D6 :





PMT is main contributor (E< 500keV)

CF main cotribution at ~2.2 MeV

→ Thus, avoiding PMT (thereby reducing also total amount of CF) should help to reduce NS further down(!)

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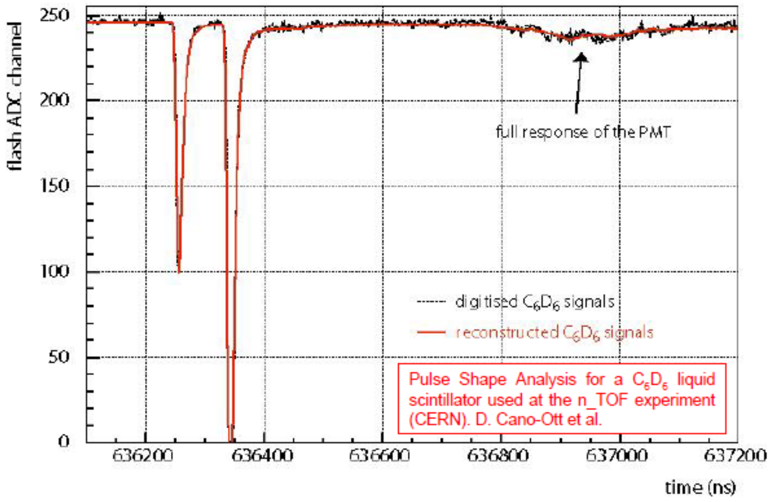
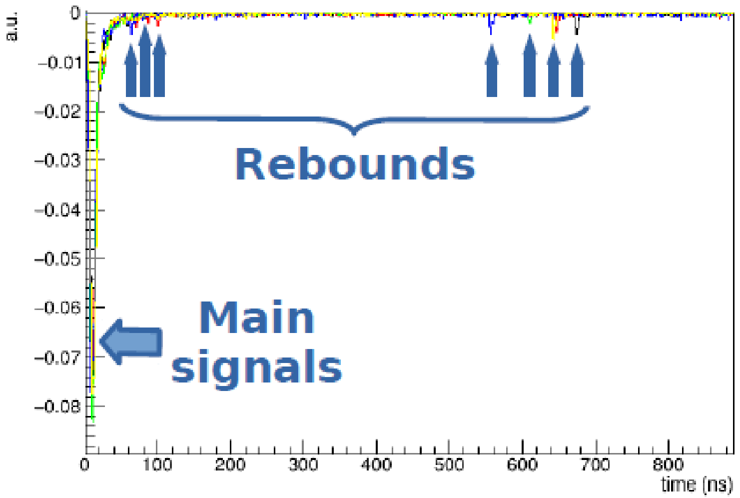
C6D6/PMT response: affected by artifacts (rebounds) probably arising from PMT’s Voltage Divider:

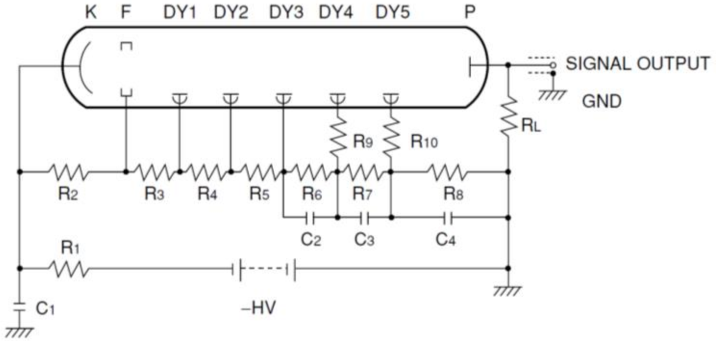
→ Aspect 2: ringing and rebounds produce a “dirty” electrical response

PMT + Voltage Divider:

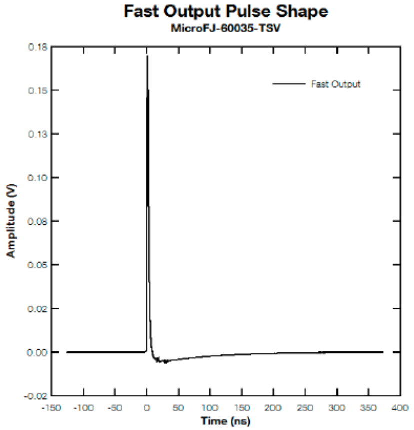


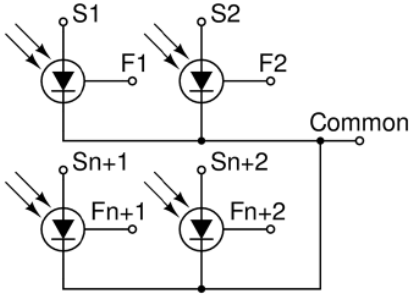


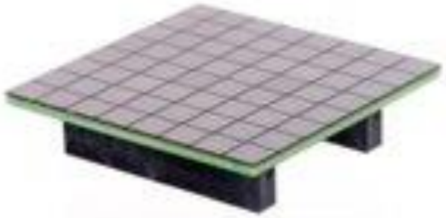
impedance missmatch issues due to voltage divider



SiPM:







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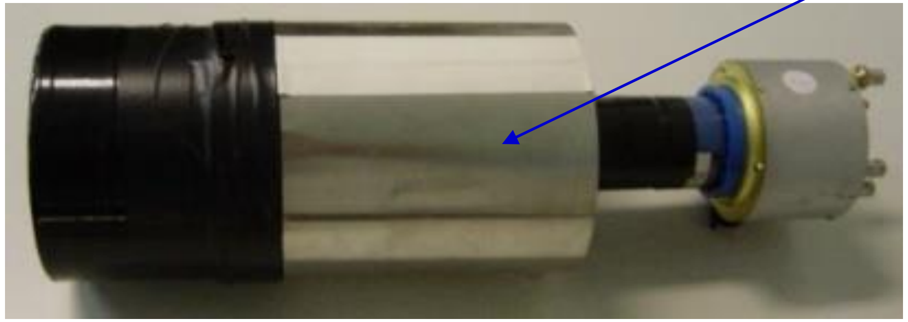
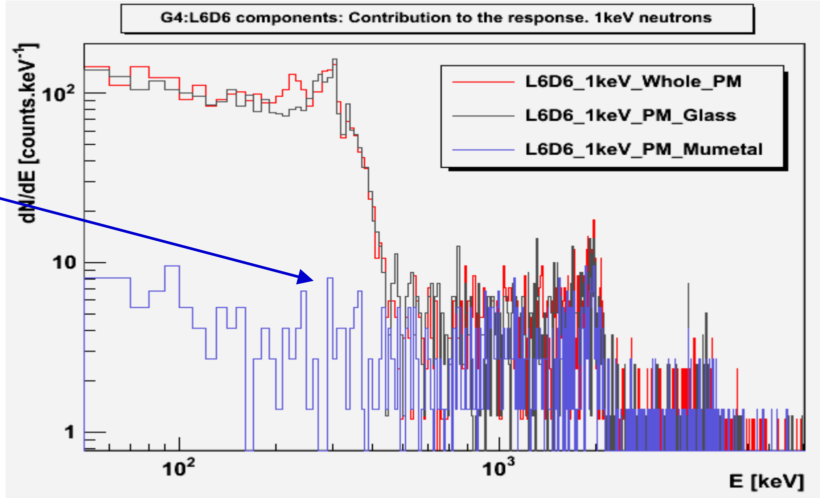
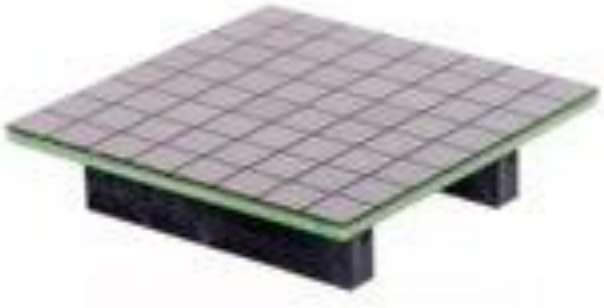
C6D6/PMT B-field sensitivity: can we avoid it?

→ Aspect 3: mu-metal & magnetic fields screening

mu-metal



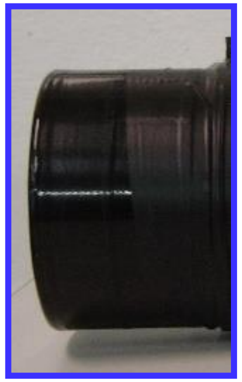


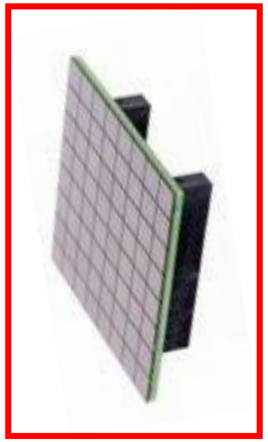


From conventional C6D6/PMT towards C6D6/SiPM: the proposal to develop a new C6D6

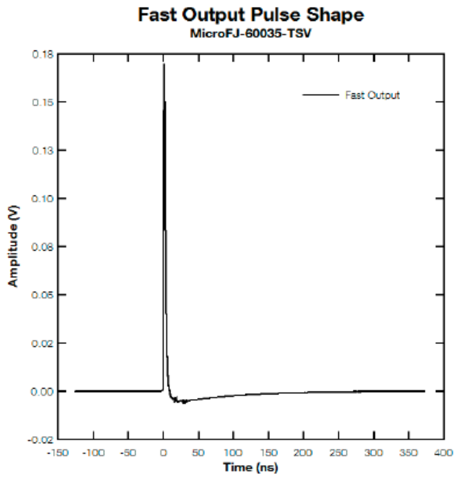
→ Aspect 1: “dirty” signal response
→ Aspect 2: neutron sensitivity (PMT)
→ Aspect 3: B-field sensitivity (mu-metal)

Replace PMT+VD by SiPM





“Mock” prototype of IFIC-C6D6: i6D6
→ 250 ml C6D6
→ SiPM Sensl 50x50mm^2
→ 1/4th of L6D6 volumen (four of these make one L6D6)



C6D6/SiPM Project summary: Pros & Cons, Next steps

Pros:

- → Further **reduce the intrinsic Neutron Sensitivity** (compared to state-of-the-art C6D6)
- → Better **suited for high CRs and γ-flash (EAR2)** by reducing volume (1/4 L6D6)→ Better suited for high En-range
- → Clean electrical output signals (no VDs → no rebounds → To be tested in the lab during LS2)→ **Reliable PSA**
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Cons:

- → Need 4 channel Digitizers per 1L volumen (4 times the # channels than same efficiency with L6D6)
- → Needs some development, in particular a customized C6D6 Carbon Fiber cell
- → Thermal dependency of the SiPM – gain (there are simple solutions)

C6D6/SiPM development: next steps

- → **Prototype** replacing Bicron PMT by SiPM and tests with sources (IFIC/CERN) for:
  - → gain-stability, resolution, count-rate capability
- → Neutron sensitivity study at CNA using n-beam
- → Study of the neutron-sensitivity via MC (US/C.Guerrero,J.Lerendegui)

backup stuff

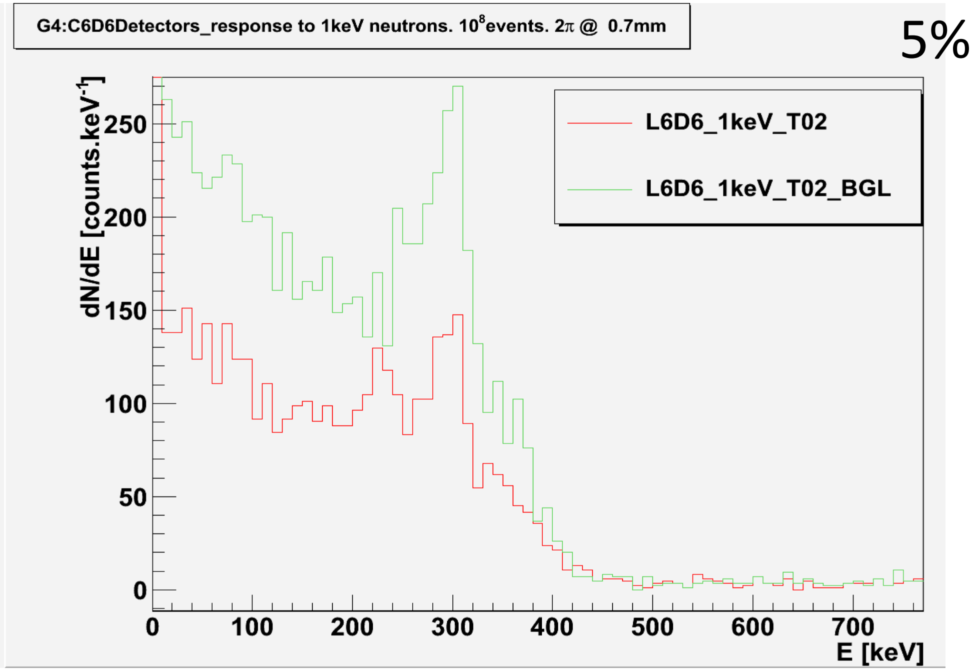
C6D6/PMT Neutron sensitivity: could it be improved further?

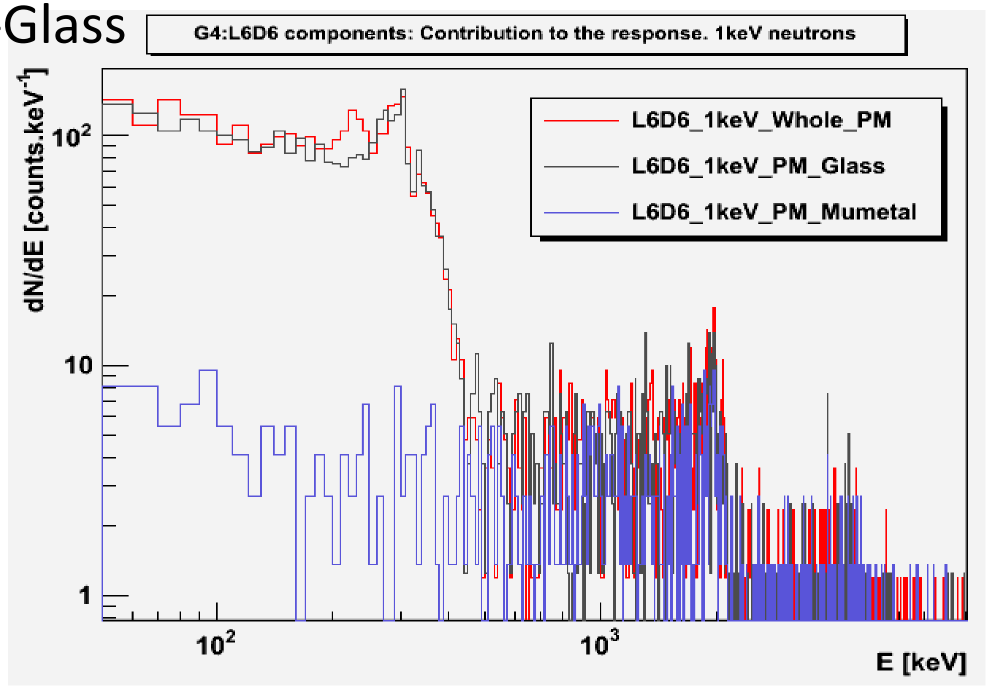
→ Aspect 1: neutron sensitivity

L6D6 Response to Neutrons (C. Guerrero & J.Lerendegui-Marco, US):

- PMT : empty glass bottle surrounded by a thin Mumetal layer

Impact of Boron
5%(BGL) vs 2% B-Glass



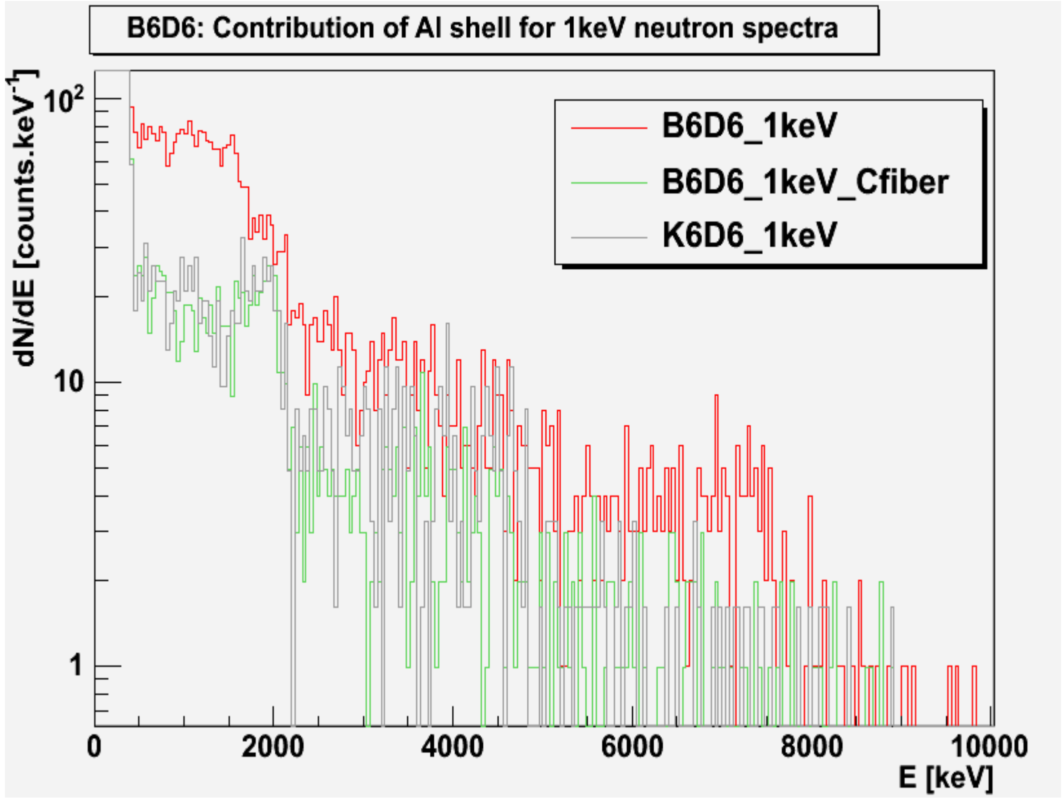


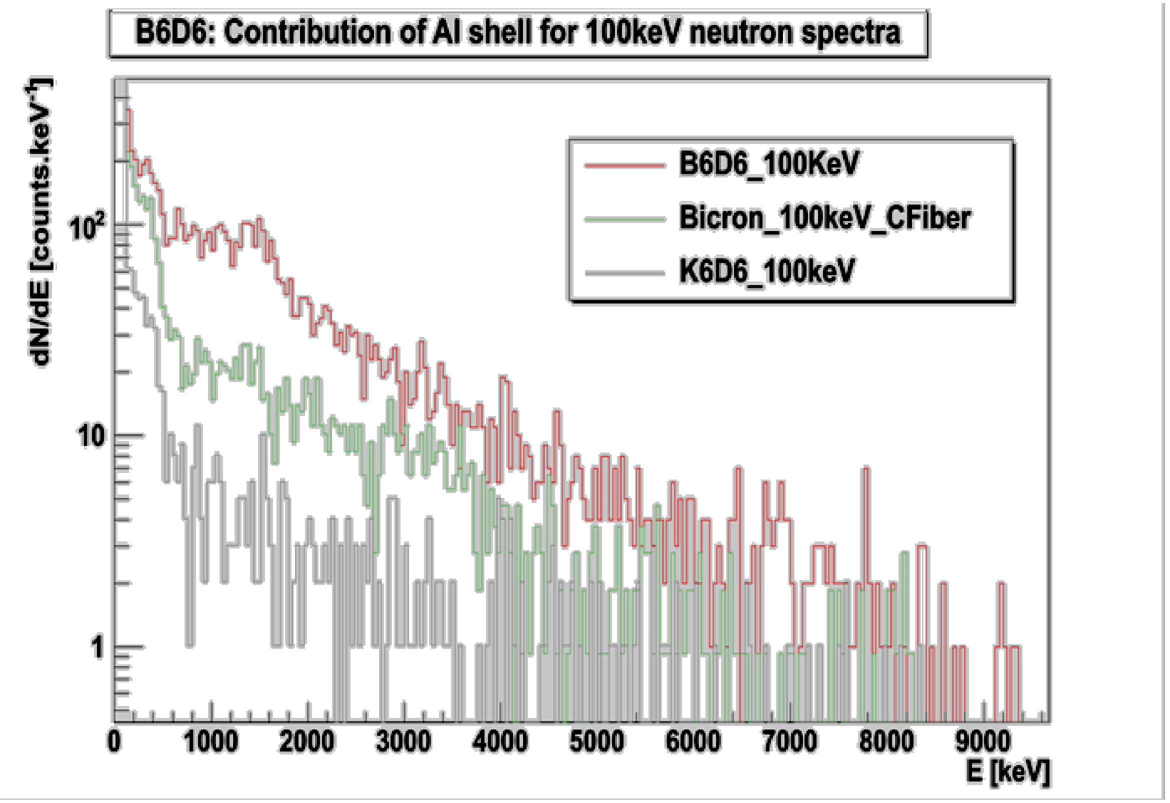
→ Thus, avoiding PMT (thereby reducing also total amount of CF) should help to reduce NS further down(!)

→ Aspect 1: neutron sensitivity

L6D6 Response to Neutrons (C. Guerrero & J.Lerendegui-Marco, US):

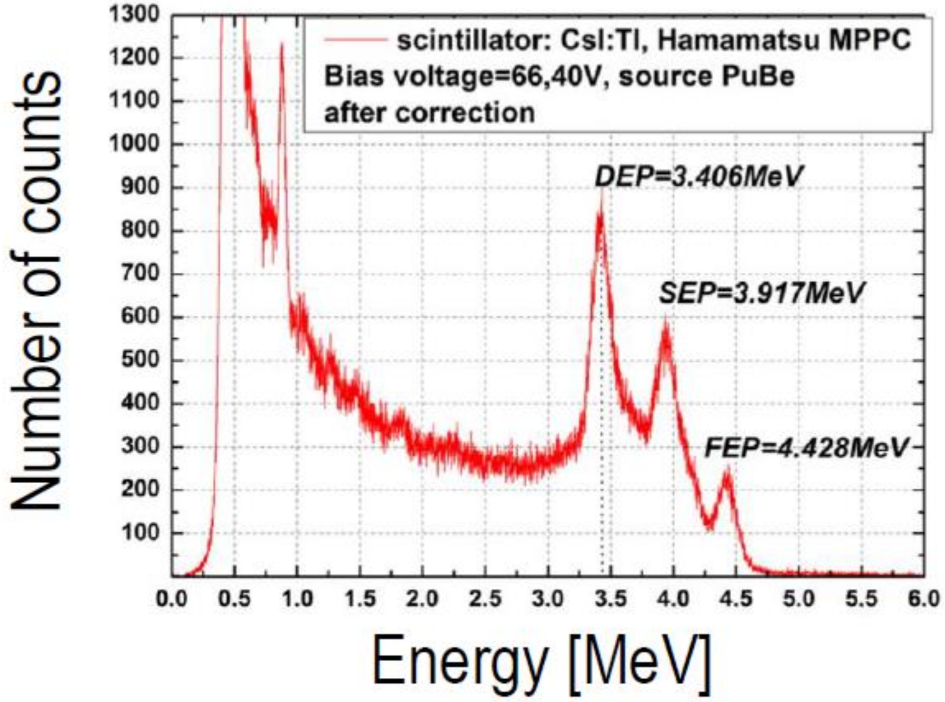
Influence of Al/Carbon Fiber



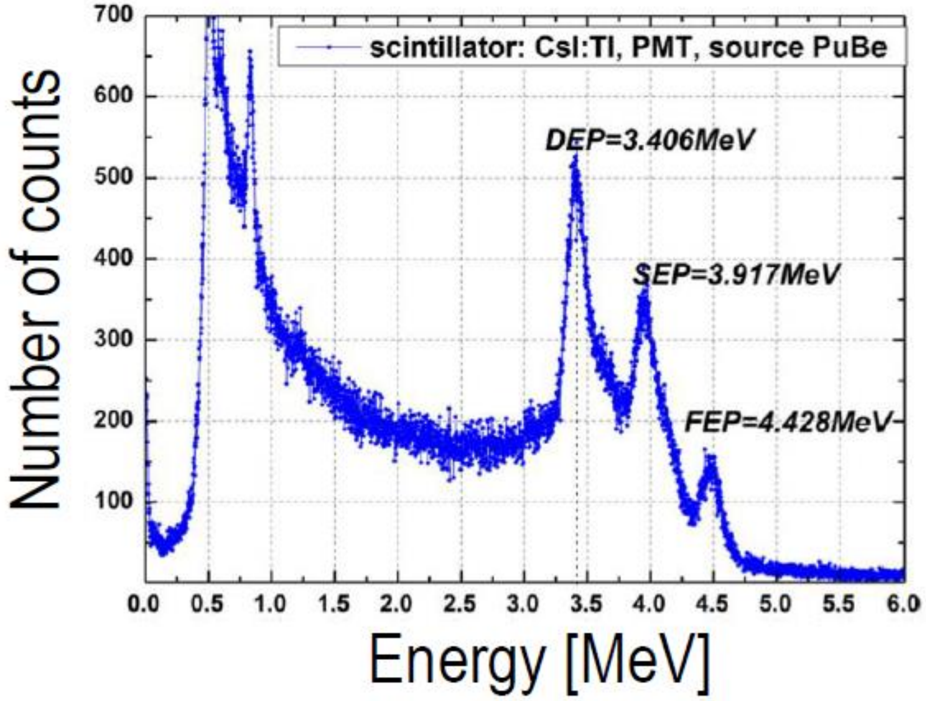


SiPM vs. PMT in γ-ray detection

SiPM

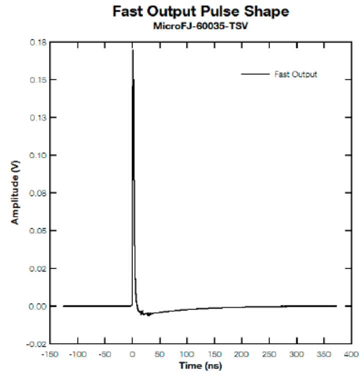


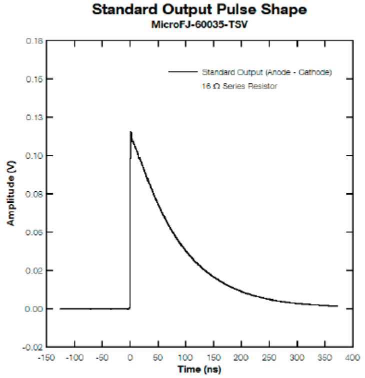
PMT



Example of energy spectra from Grodzicka et al. 2017 [Nuclear Inst. and Methods in Physics Research, A 874 (2017) 137–148]

Sensor Size	Microcell Size	Parameter	Overvoltage	Min.	Typical	Max.	Units
3mm	20µm	Gain (anode-cathode)	Vbr + 2.5V		$9.1x10^5$		
	35µm				$2.9x10^6$		
	20µm		Vbr + 6.0V		$1.7x10^6$		
	35µm				$6.3x10^6$		
6mm	35µm		Vbr + 2.5V		$2.9x10^6$		
			Vbr + 6.0V		$6.3x10^6$		
3mm	20µm	Dark Current	Vbr + 2.5V		0.2	0.3	µA
	35µm						
	20µm		Vbr + 6.0V		1.1	1.6	µA
	35µm						
6mm	35µm		Vbr + 2.5V		0.9	1.3	µA
			Vbr + 6.0V		4.1	6.8	µA
3mm	20µm, 35µm	Rise time [6] - anode-cathode output			100		ps
6mm	35µm				300		ps
3mm	20µm	Microcell recharge time constant [7]			12		ns
	35µm				37		ns
6mm	35µm				48		ns
3mm	20µm	Capacitance [8] (anode output)	Vbr + 2.5V		TBD		pF
	35µm				1000		pF
6mm	35µm				4000		pF
3mm	20µm	Capacitance [8] (fast terminal)	Vbr + 2.5V		TBD		pF
	35µm				50		pF
6mm	35µm				200		pF
3mm	20µm	Fast output pulse width (FWHM)			1.4		ns
	35µm				1.4		ns
6mm	35µm				3.0		ns
3mm	20µm	Crosstalk	Vbr + 2.5V		5		%
	35µm				7		%
	20µm		Vbr + 6.0V		10		%
	35µm				22		%
6mm	35µm		Vbr + 2.5V		7		%
			Vbr + 6.0V		22		%
3mm	20µm, 35µm	Afterpulsing	Vbr + 2.5V		0.1		%
	20µm, 35µm		Vbr + 6.0V		1.0		%
6mm	35µm		Vbr + 2.5V		0.1		%
			Vbr + 6.0V		1.0		%
3mm	20µm, 35µm	Temperature dependence of Vbr [9]			<21.5		mV/°C
6mm	35µm						





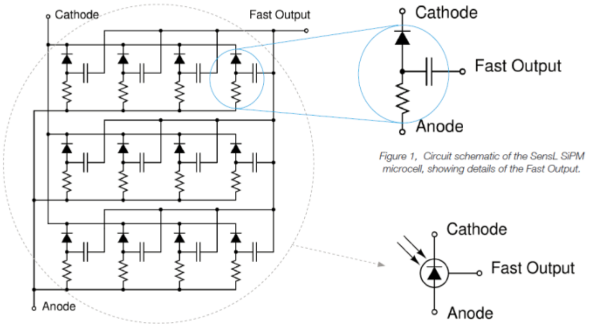


Figure 1, Circuit schematic of the SensL SiPM microcell, showing details of the Fast Output.