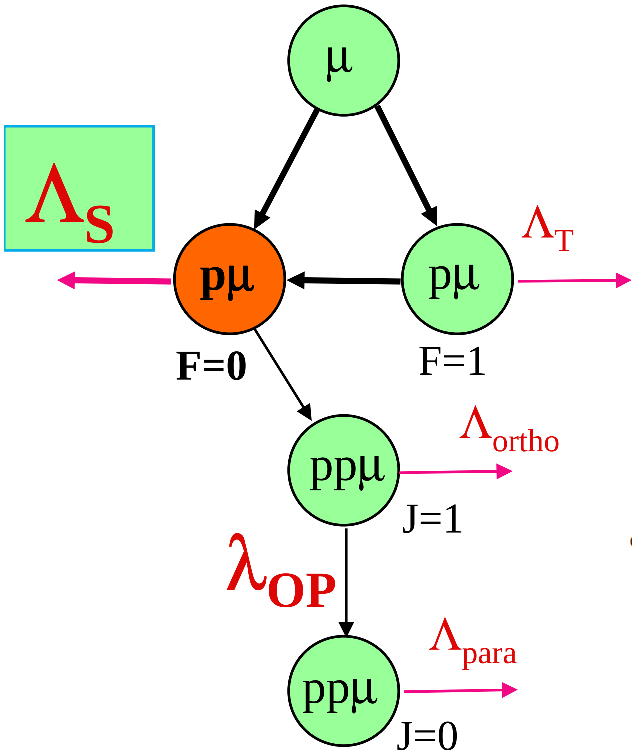
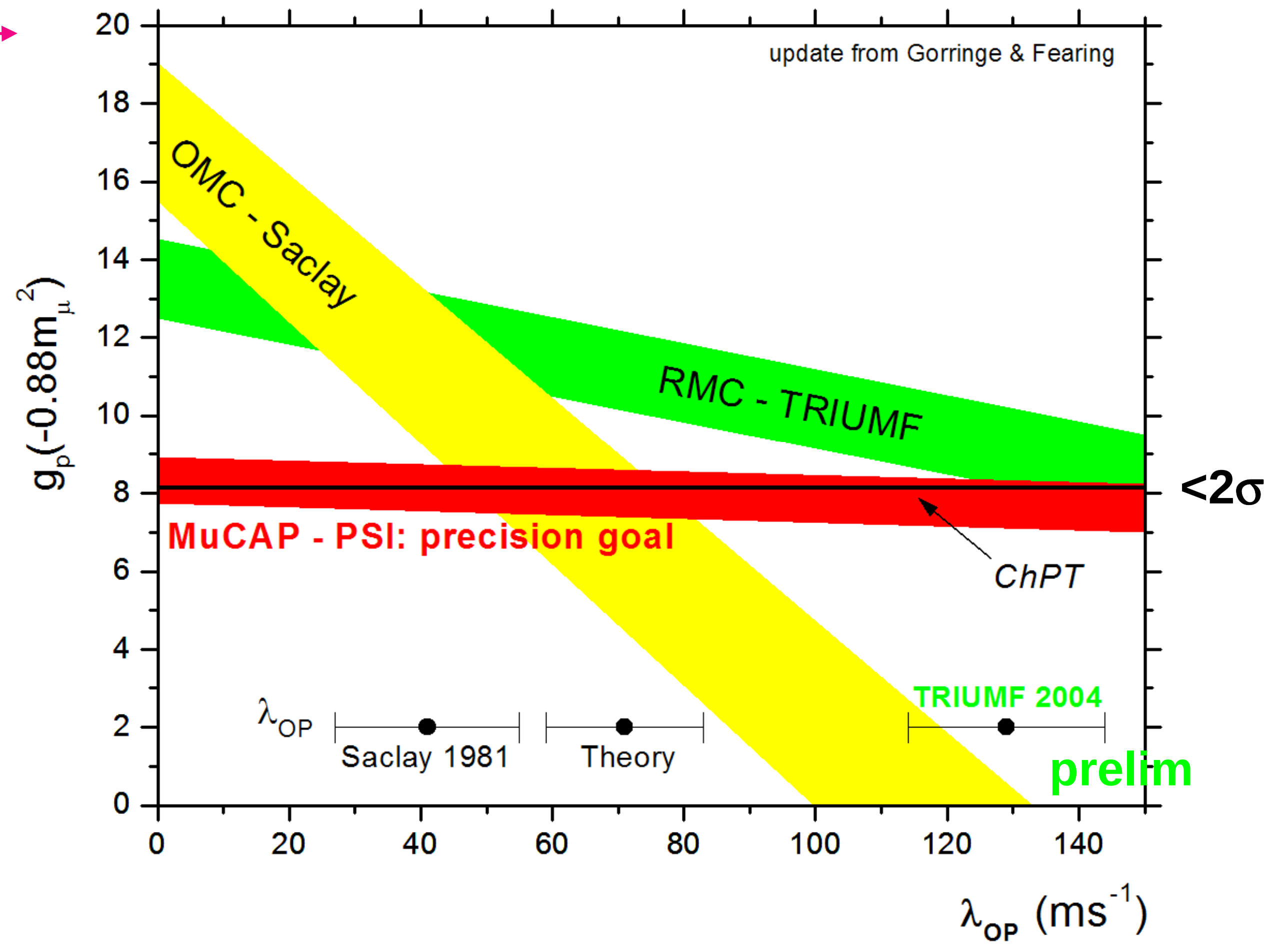
Ortho-para rate and neutron detectors





Motivation and Goal for aux. measurement

- Convincing proof of the internal consistency of the experiment by directly checking the underlying $p\mu$ and $pp\mu$ kinetics.
  Really in situ constraint on λ_{op}, so it affects lifetime <10ppm
- **At the time of the proposal we were expecting that the TRIUMF experiment would determine λ_{op} to 0.3×10^4/s.**

year	Method	λ_{op} (10^4/s)
1981	Exp LH2	4.1(1.4)
1982	Theory	7.1(1.2)
2004 prelim.	Exp LH2	12.2-13.6 (1.5)

- **The situation is thus totally confused and not much guidance available from the literature.**
- **MuCap uses 1% of LH_2 density which, though not expected, might change λ_{op} from the measured value(s) at LH_2**

$$p\mu + H_2 \rightarrow (pp\mu)^+ pe + e$$

$$(pp\mu)^+ pe + H_2 \rightarrow [(pp\mu)^+ p2e] + H_2^+ \quad 1\ \lambda_{op}$$

$$\rightarrow [(pp\mu)^+ 2p2e]^+ + H \quad 0.78\ \lambda_{op}$$

$$\rightarrow [(pp\mu)^+ e] + e + H_2^+ \quad 0.66\ \lambda_{op}$$

rate LH_2 10^{13} s^{-1}

Experiments

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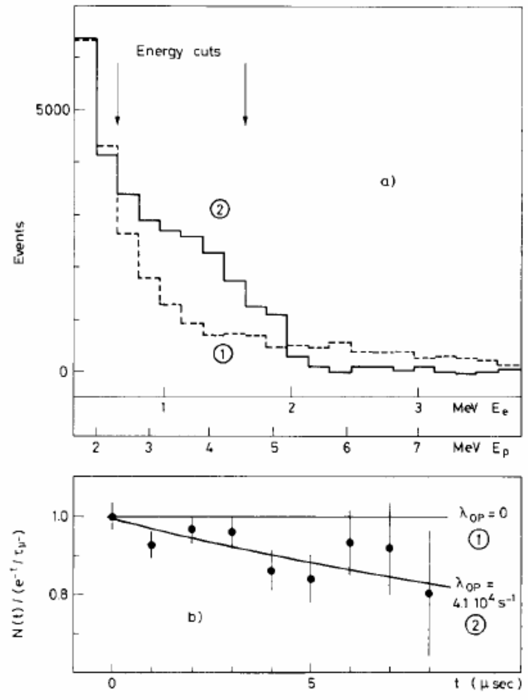
$$N(t) \propto \exp(-t/\tau_{\mu^-}) \times \{1 + [(\lambda_{OM} - \lambda_{PM})/\lambda_{PM}]\exp(-\lambda_{OP} t)\}\,. \quad (3)$$



Saclay, TopCite 50+

Exp	Neutrons	μp Neutrons	stat. error (10^{-3})	lifetime (ns)	error (ns)	rel error (10^{-3})	efficiency
Saclay	26746	17730	9.22	2084	30.00	14.40	
TRIUMF	405000	???	1.57	1909	26.00	13.62	
MuCap	240000	???	2.00		**4.5**	**3.00**	0.02

wild !

Kinetics study

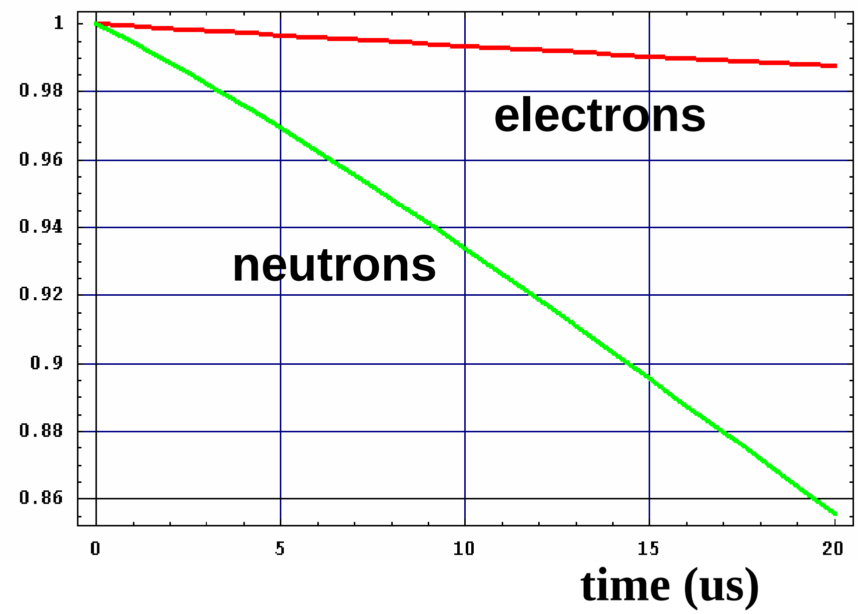
The results are summarized in the following table.

Kinetic assumption Rates in μs^{-1}	Relative change in **electron** disappearance rate (ppm)	Relative change in **neutron** disappearance rate (ppm)	
λ_{op}=0.0, λ_{pp}=2	0	0	moment method
	0	0	fit method (0.05-20 μs)
λ_{op}=0.08, fit 0.05-20us	-11	5569	moment method
	-12	5482	fit method
λ_{op}=0.20	-23	10468	moment method
	-21.6	10330	fit method
λ_{op}=0.20, fit 0.05-10us	-15	9306	fit me
λ_{pp}*1.5	-18.4	7054	mome
	-17.6	6899	fit me

We should measure λ_{pp} too

Electron and neutron time distribution devided by mu+ time distribution, normalized to identical initial point by Rs/r0

```
In[43]:= Rs / r0
         Plot[{ne[t] / ne0[t], nc[t] / ne0[t] r0 / Rs}, {t, 0, 20}];
Out[43]= 0.00145934
```



$\Delta\lambda e$= 10 ppm ≈ $\Delta\lambda n$= 5 10^{-3}

We need to measure $\Delta\lambda n$ to ~3 10^{-3}!

(At present $\Delta\lambda n$= 14 10^{-3})

Statistics and systematics

Statistics

- should be ok for 10^{10} μ, if BG small

Systematics

- accidental BG
  - accept only n with no decay electron, 0.7 accidental suppression ?
  - fit can start at t=0, but detectors further away than Saclay, TRIUMF
  - shielding difficult (tent)
- other BG (wall stops etc)
  - much better than previous experiments
- Distortions due to n-det deadtime?

Depending on success, we will decide

- 8 detectors 2006 (3 in 2005)
- special high density run?

Technique

- start with classic PulseShape circuit (borrow more?)
- implement FADC once they are available

Demon detectors from Rene

NIM A 365 (1995) 446-461

Each DEMON cell is a cylinder of 16 cm diameter and 20 cm length, designed with an expansion volume and painted with TiO_2 white reflector. A cell contains 4 liters of liquid scintillator NE213 in an aluminium container having a 6.35 mm thick front entrance and a 21.5 mm thick wall. The cell back window of 10 mm thick glass is directly coupled to a 130 mm diameter XP4512B magnetically shielded fast PM. The tube is supplied with a grounded anode divider which, for the recommended supply voltage (V) of 1700 V, typically ensures a gain of 5.0×10^6. The standard anode pulse rise time is 2.1 ns, the intrinsic PM pulse duration at half maximum is 3 ns and the signal transit time is (49 ± 1.3) ns for full cathode illumination. The manufacturer gives a slope of log(gain)/log(supply voltage) = 7.5. A lead absorber of 5 mm thickness is used in front of the cell to lower the exposure to low energy γ-rays, thus allowing a reduction of the n–γ discrimination threshold.

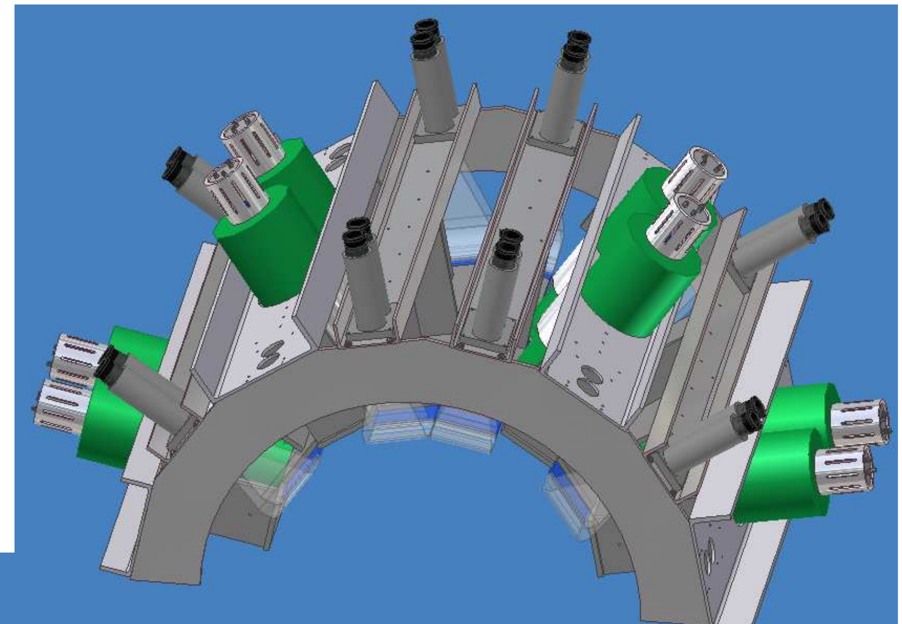
The neutron mean free path λ as a function of neutron incident energy $\lambda(\mathrm{NE213})=21.3(\mathrm{cm})/(K\sigma_H+\sigma_C)$, with ρ (volumic mass)=0.874 g/cm^3, K=1.213, the (H/C) ratio, σ_H and σ_C the *total* reaction cross sections of neutron interactions with hydrogen and carbon media. Next columns display Monte Carlo simulations of the mean "minimum" distance-of-penetration $\bar{x}$ along the cell axis and the mean response time-of-flight ($\bar{t}_d$) of a DEMON cell and their corresponding standard deviations σ_x and σ_{td}. The last column displays the calculated intrinsic efficiencies at 0.2 MeVee detection threshold [11]

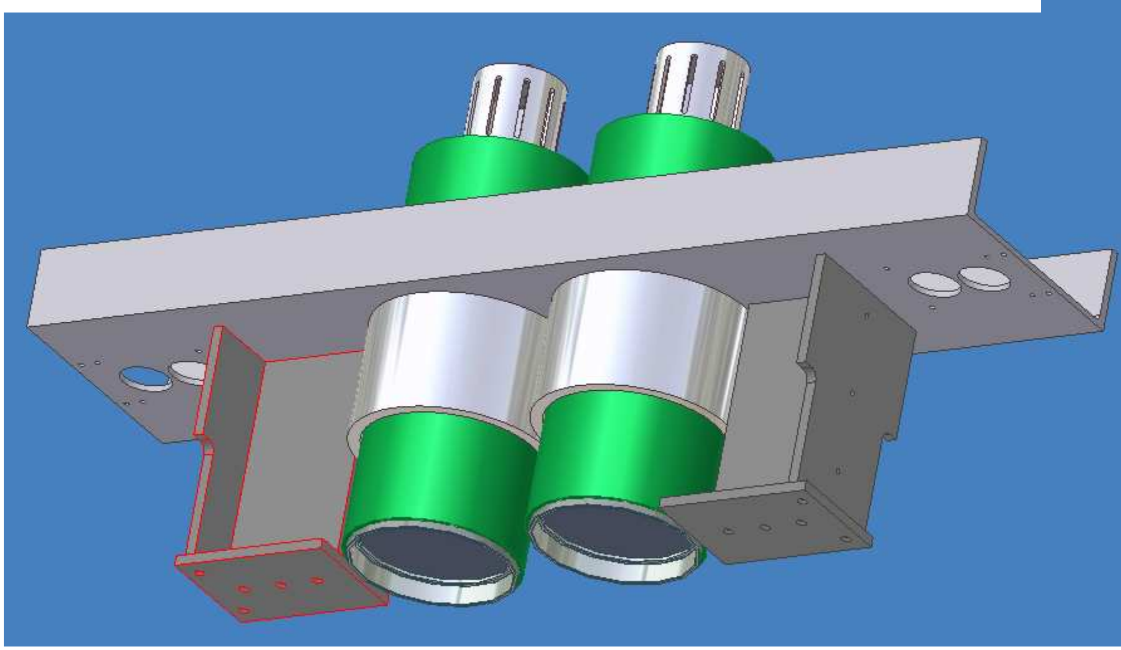
E_n [MeV]	λ [cm]	$\bar{x}$ [cm]	σ_x [cm]	$\bar{t}_d$ [cm]	σ_{t_d} [ns]	Intrinsic efficiency [%] $\epsilon_{n+\gamma}$
5	7.94	7.07	5.33	3.30	1.83	71.94
10	11.02	7.77	5.55	2.47	1.36	58.18

~0.65 @ 5.2MeV

Mounting structure and plan

-outer detector diameter: 216 mm
-length of the detector: 500 mm
+ 120 mm for base
-diameter of the base: 110 mm
-inner frame ring diameter: 218.6 mm
for non strictly circular outer detector tube
-length of the frame ring : 150 mm
-thickness of the frame ring : 15 mm





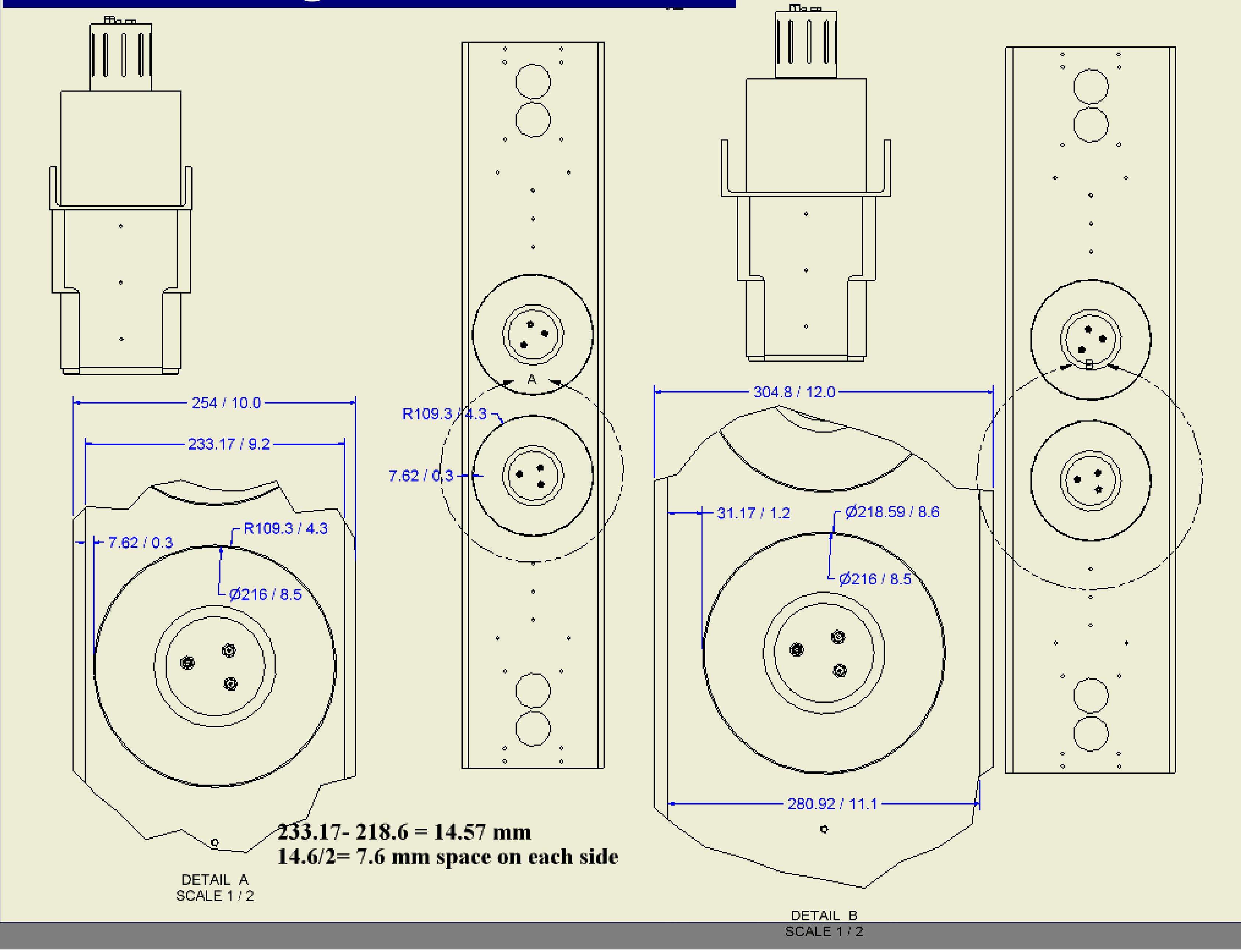
Questions

- **10” or 12” bars ?**
- **2 detectors per bar ok?**
- **symmetric arrangement?**

Proposed installation

- **dismount upper barrel**
- **n detectors upper barrel only**
- **inventor**

Mounting structure



233.17- 218.6 = 14.57 mm
14.6/2= 7.6 mm space on each side


14 4 2005