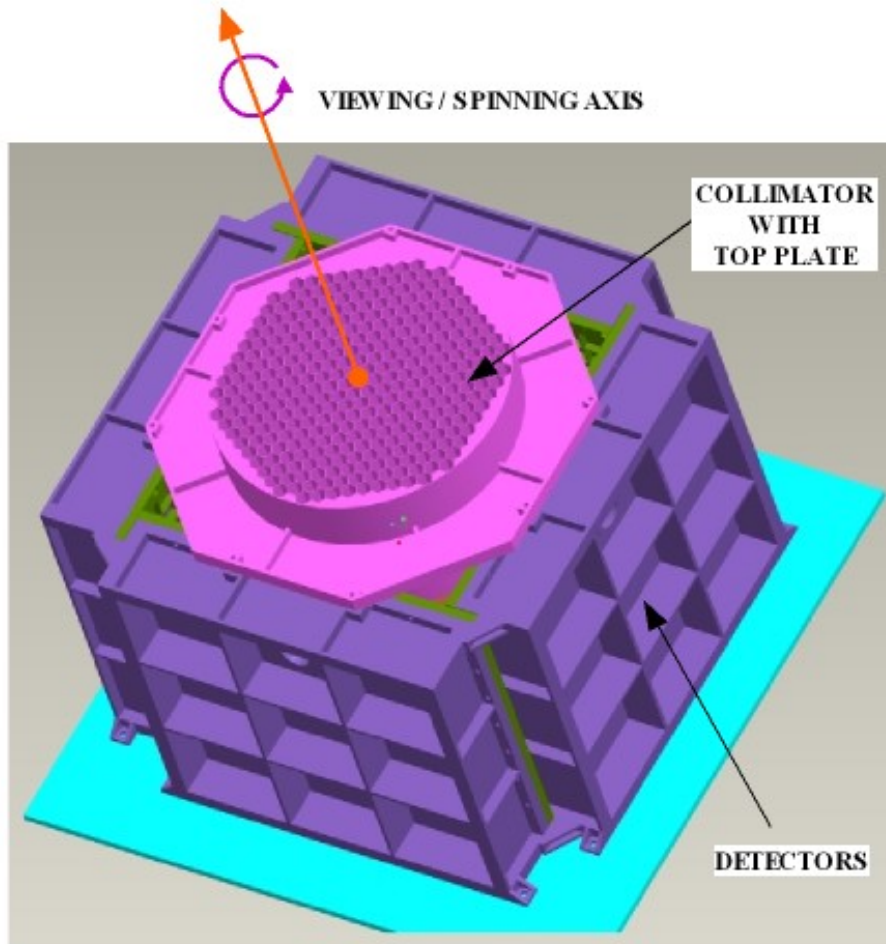


Thomson X-ray Polarimeter



•Photoelectron/Bragg: < 10 keV

•Compton :> 30 KeV

•Thomson: 5-30 keV

Biswajit Paul
Raman Research Institute
Bangalore

Thomson X-ray Polarimeter

Development History

Design, Sensitivity

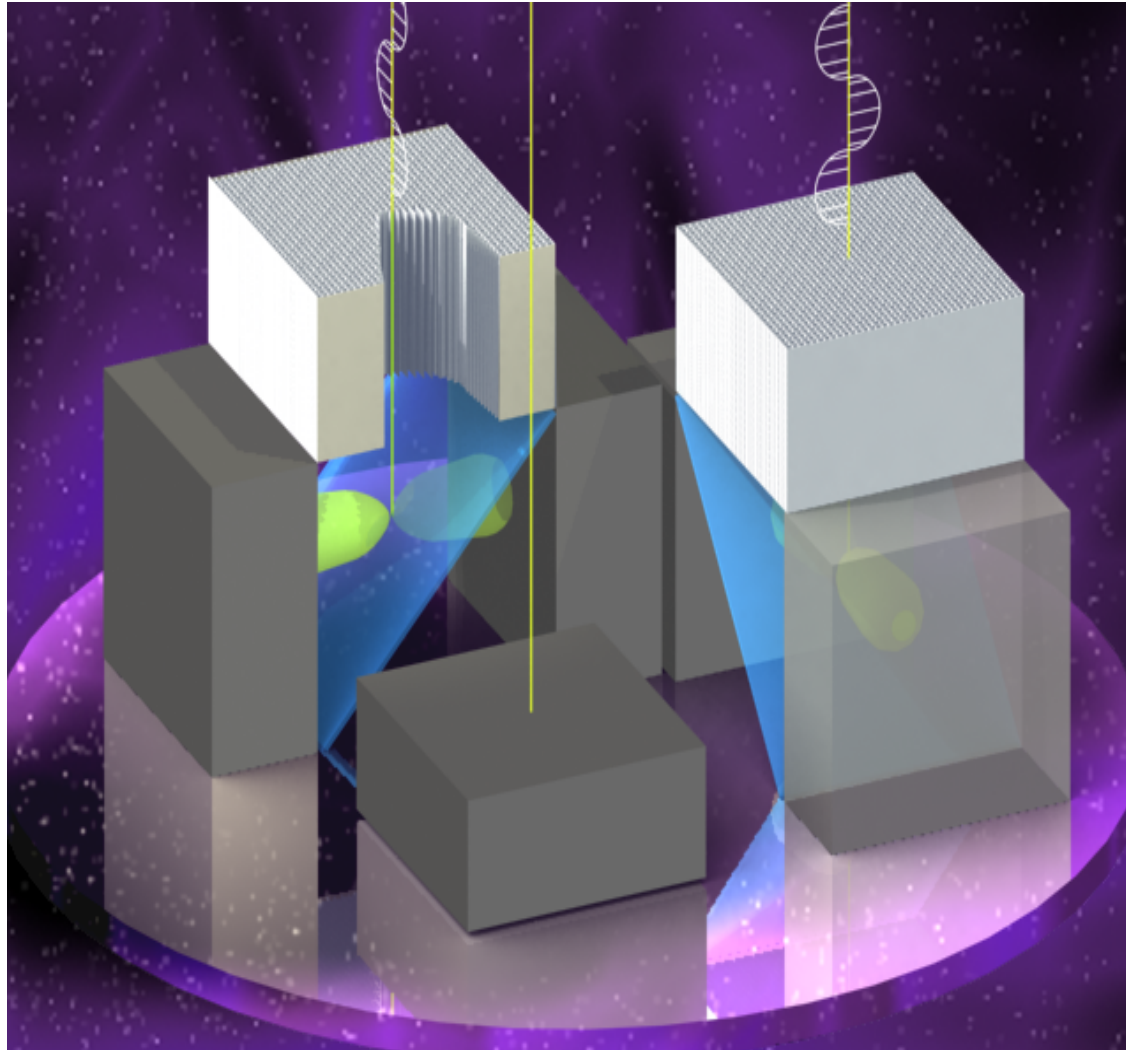
Satellite

Some Science Prospects

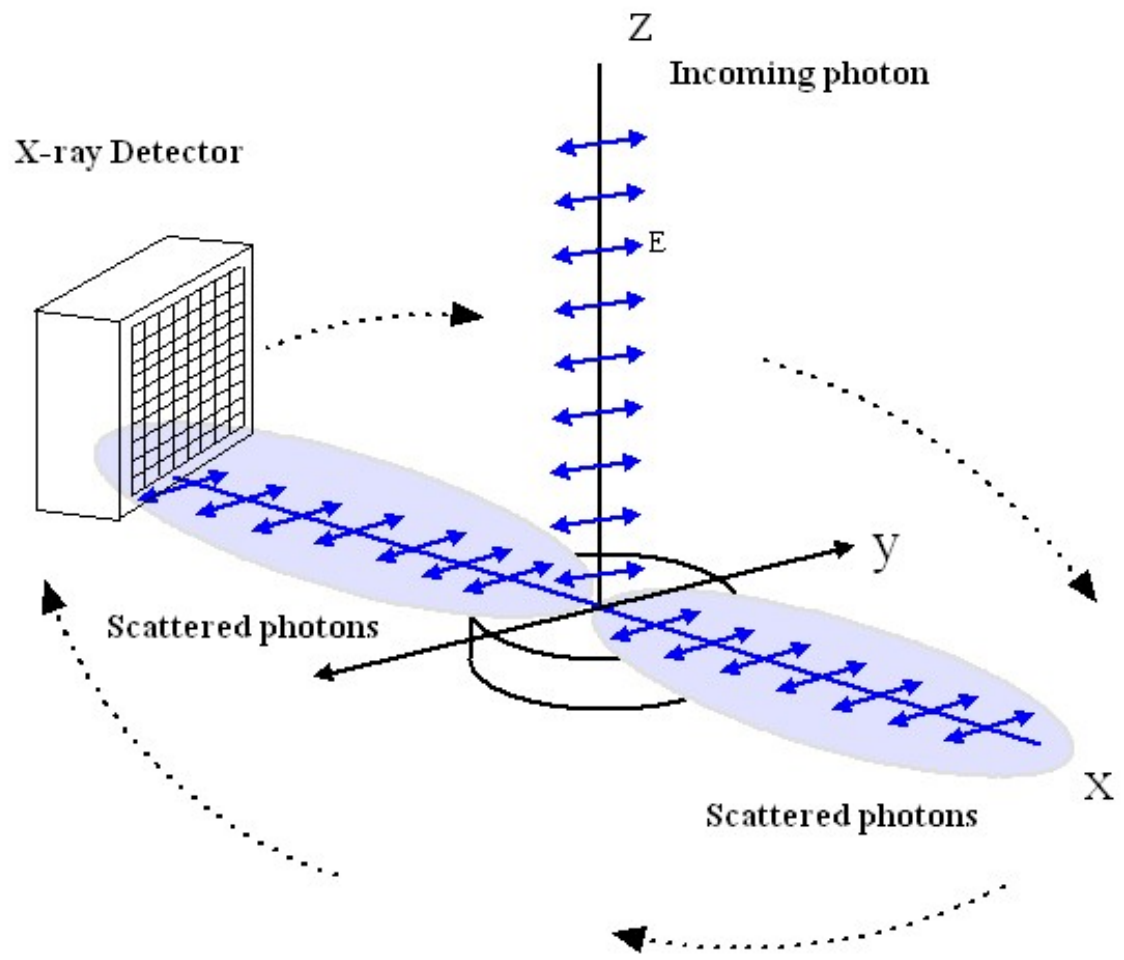
Status

Instrument

Mission



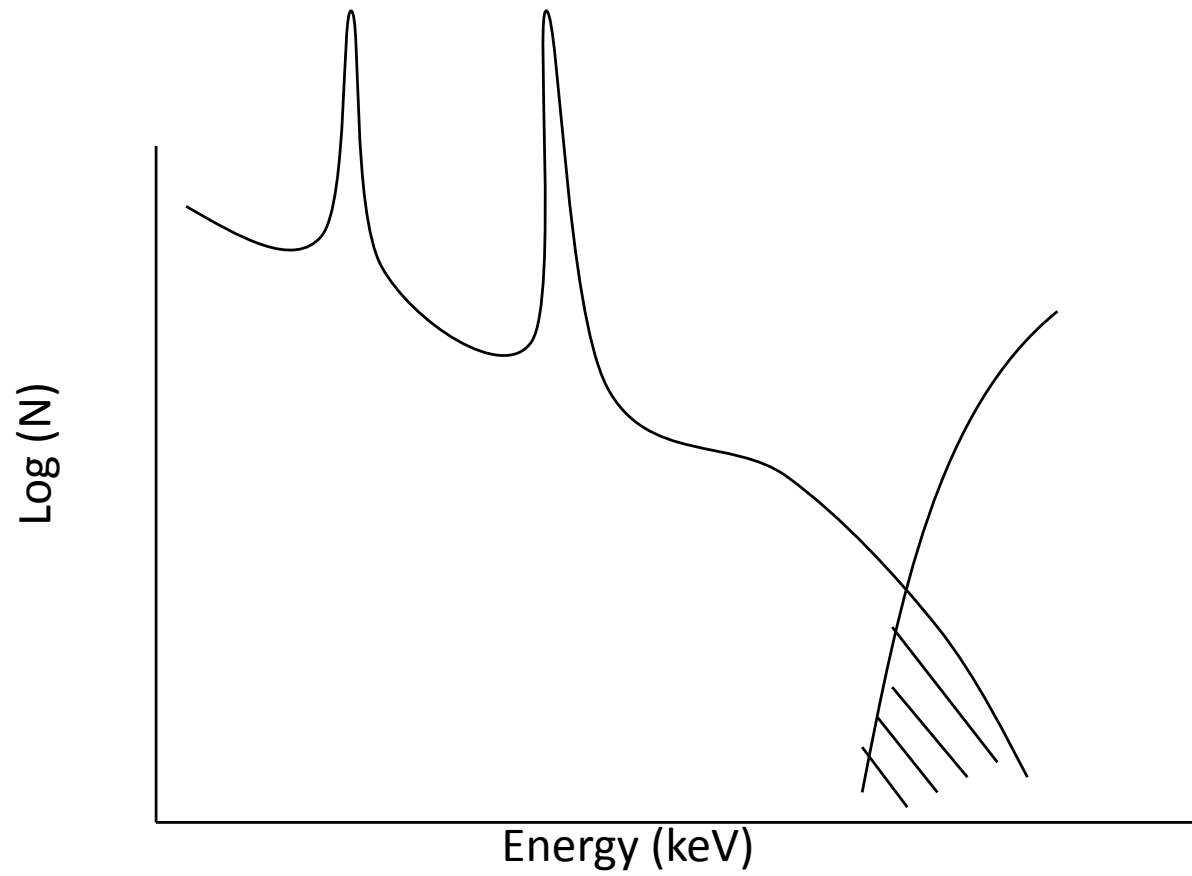
Stockholm, 26 August 2014



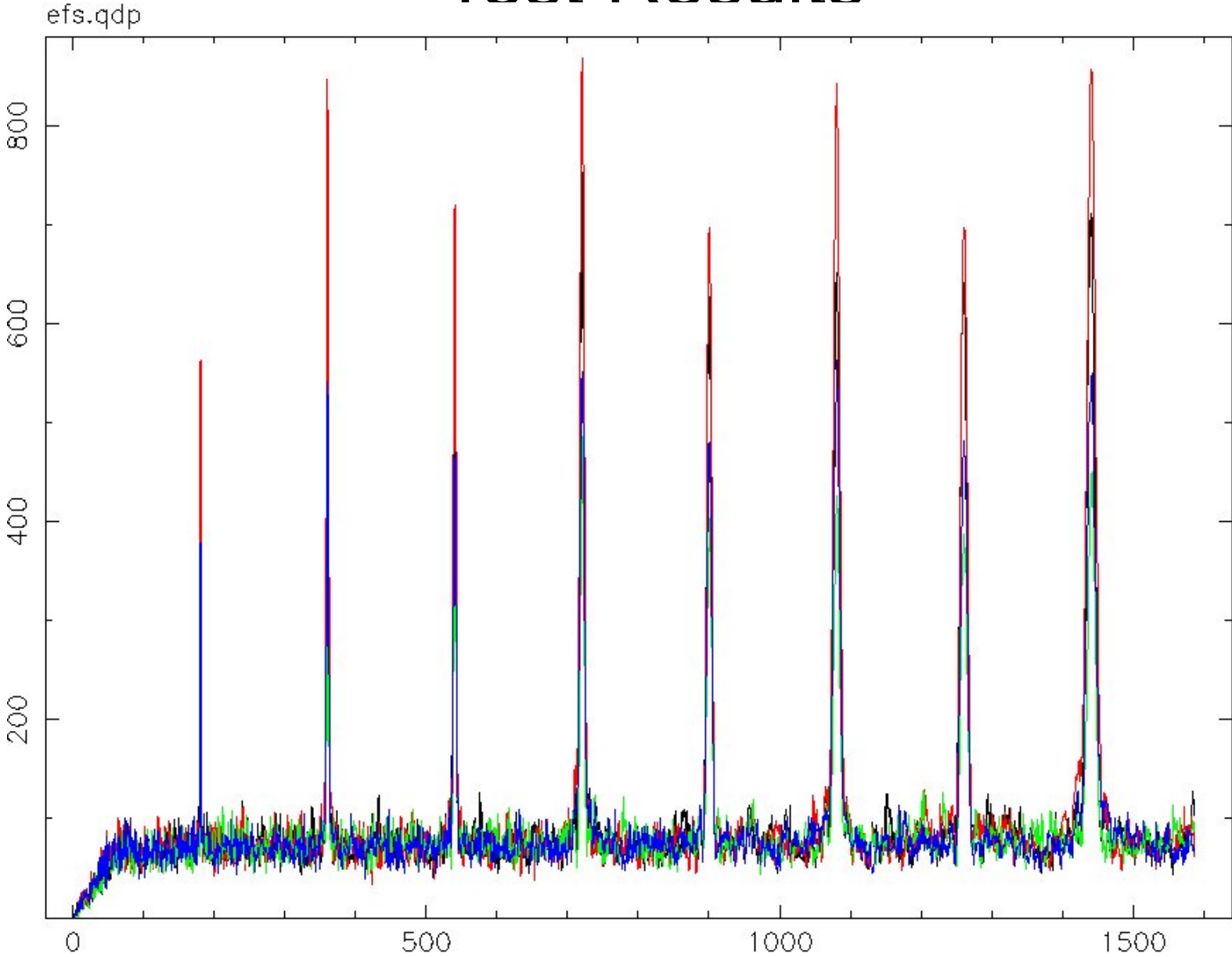
Prototype Detectors



Polarised X-ray Source



Test Results



Stockholm, 26 August 2014

New design



Stockholm, 26 August 2014

Weisskopf et al. 2006

Design goal:

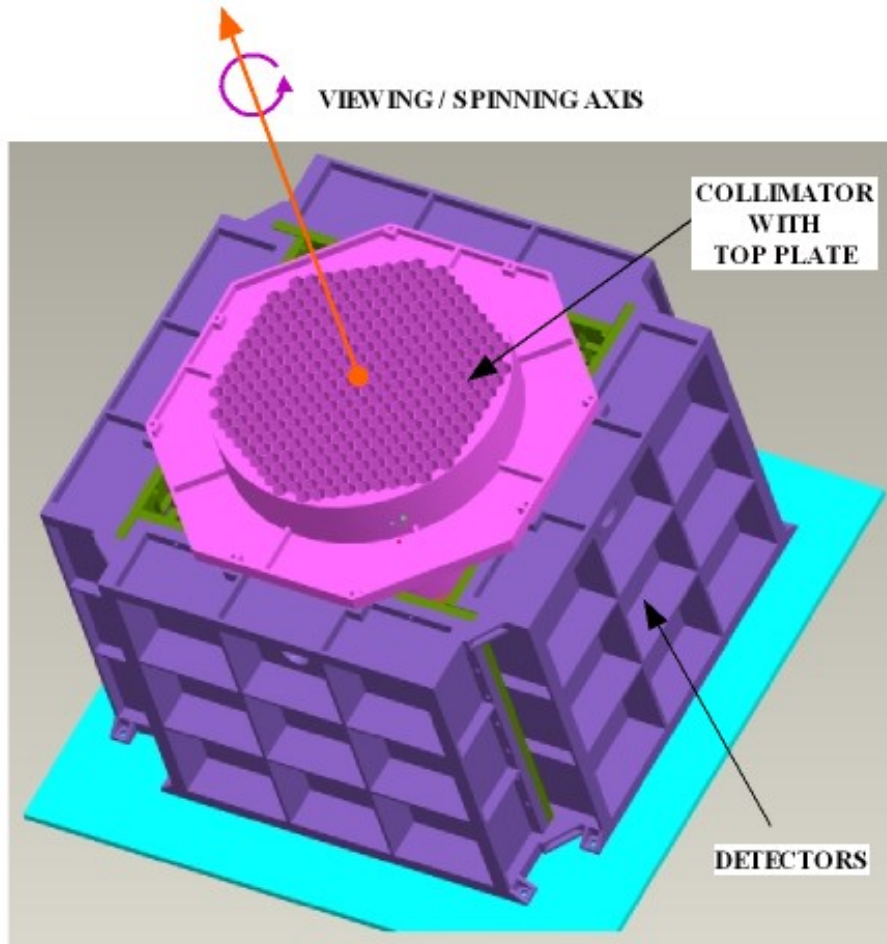
MDP of 2-3% at 5 sigma level for 1 million sec exposure of a 50 mCrab source.

Potential Sources :50

$$\text{MDP} \quad (n\sigma) \quad = \quad (n / \mu S) \quad (2(S+B)/T)^{1/2}$$

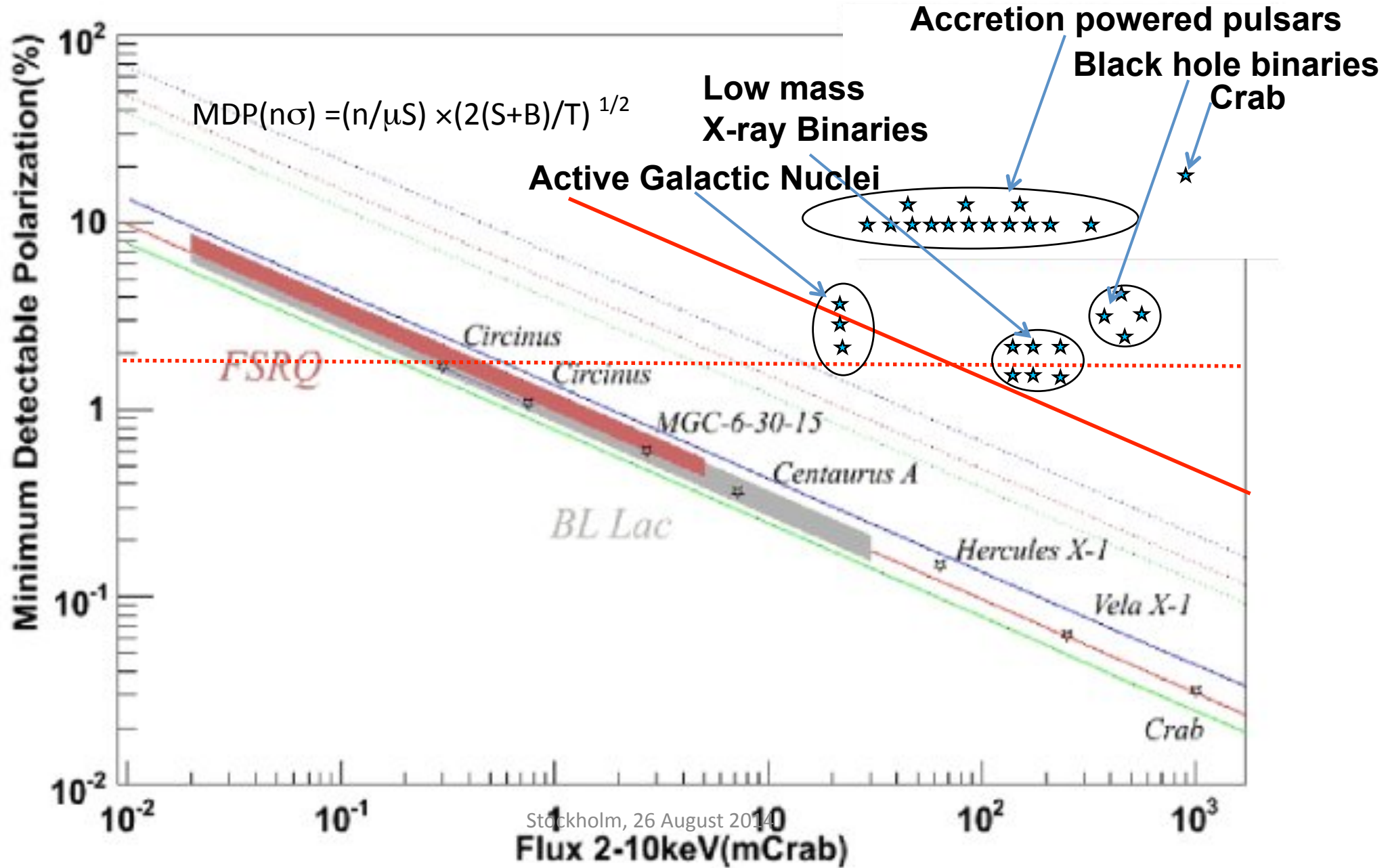
Engineering Model

The mechanical configuration

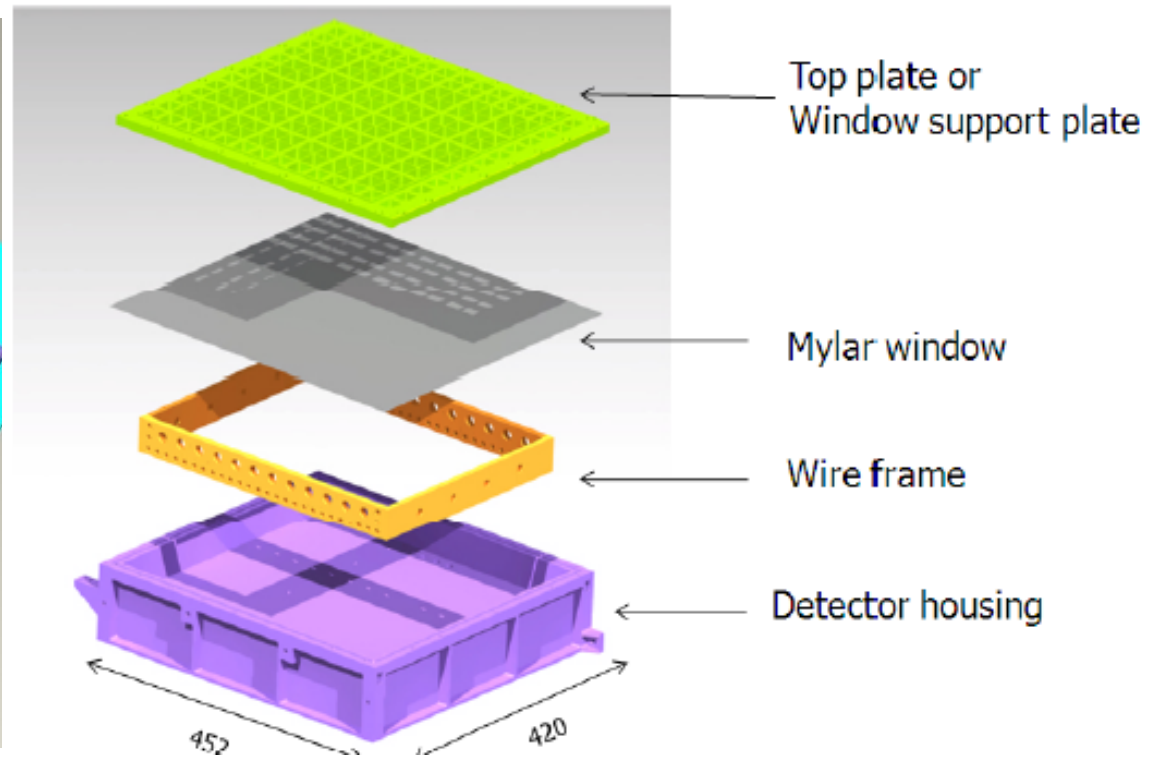
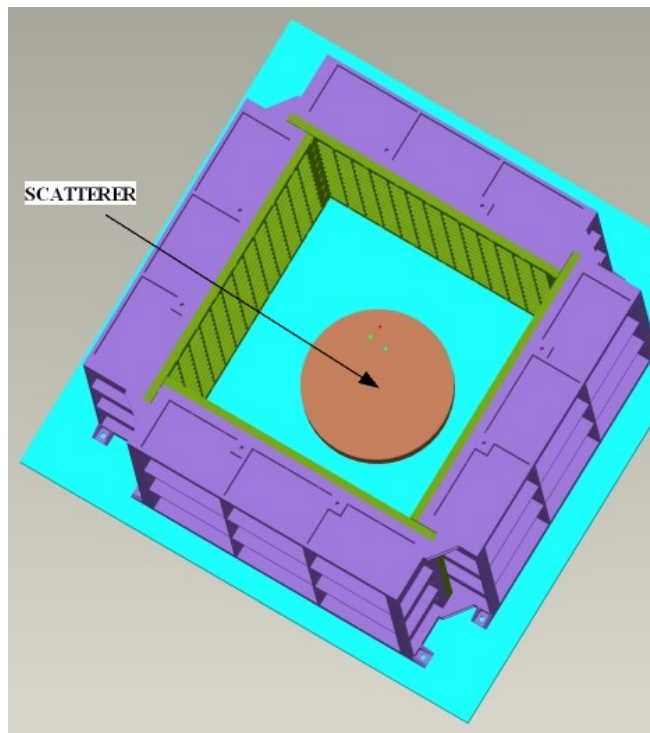


- Similar to prototype
 - > Consists of 4 detectors placed in cyclic order on all sides of the scattering element
 - > Larger area
 - > Overlapping arrangement to reduce corner dead area
 - > Detectors side-connected to increase stiffness

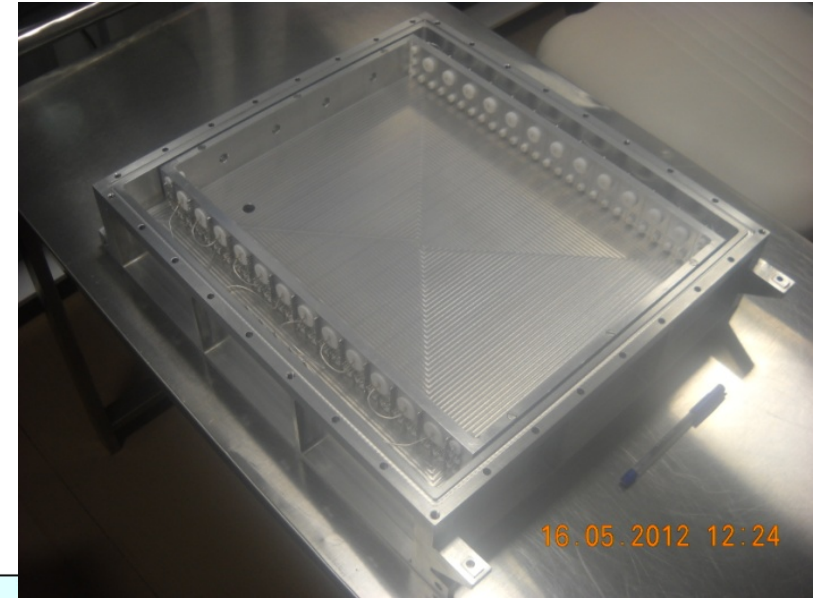
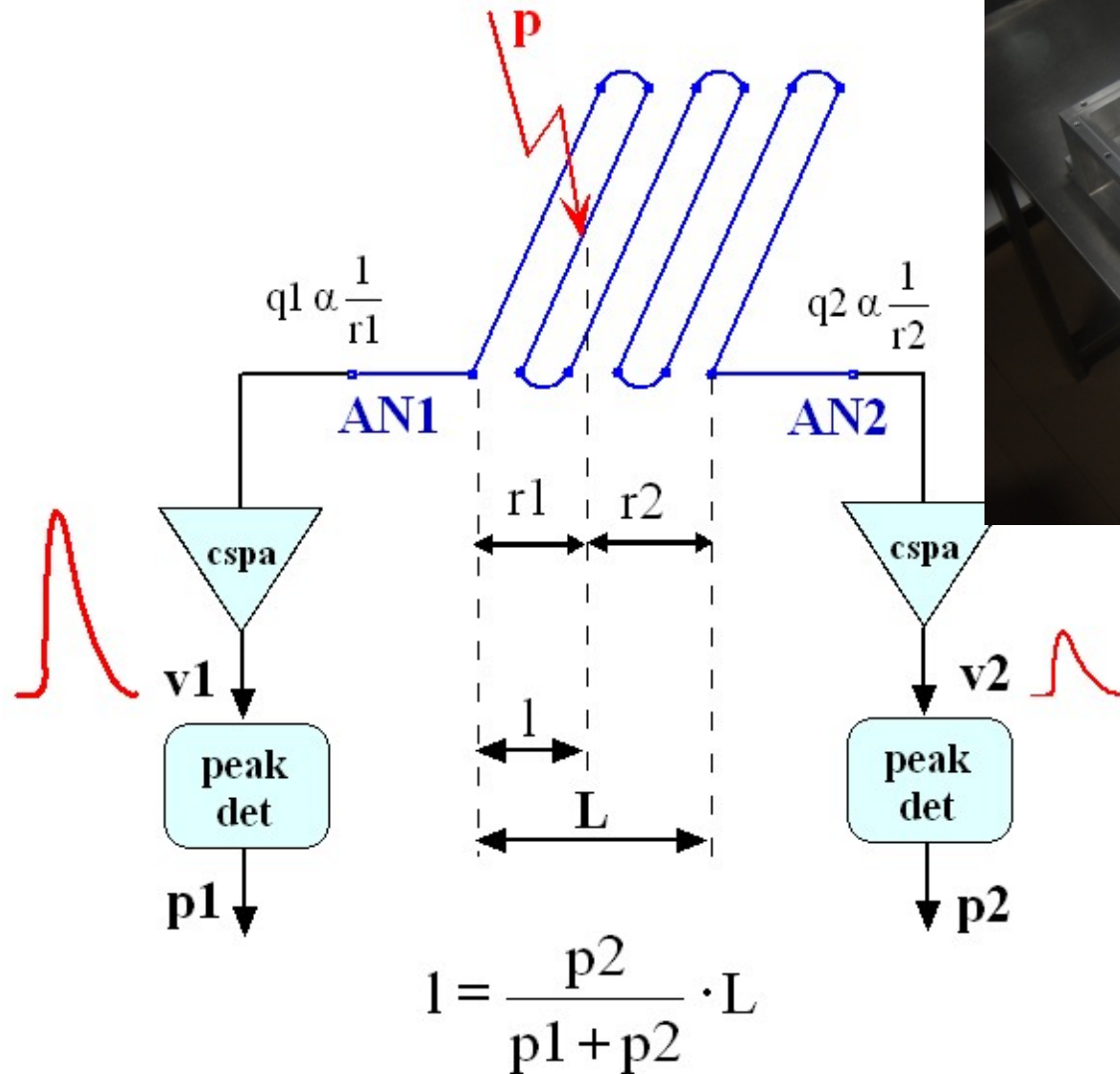
Sensitivity



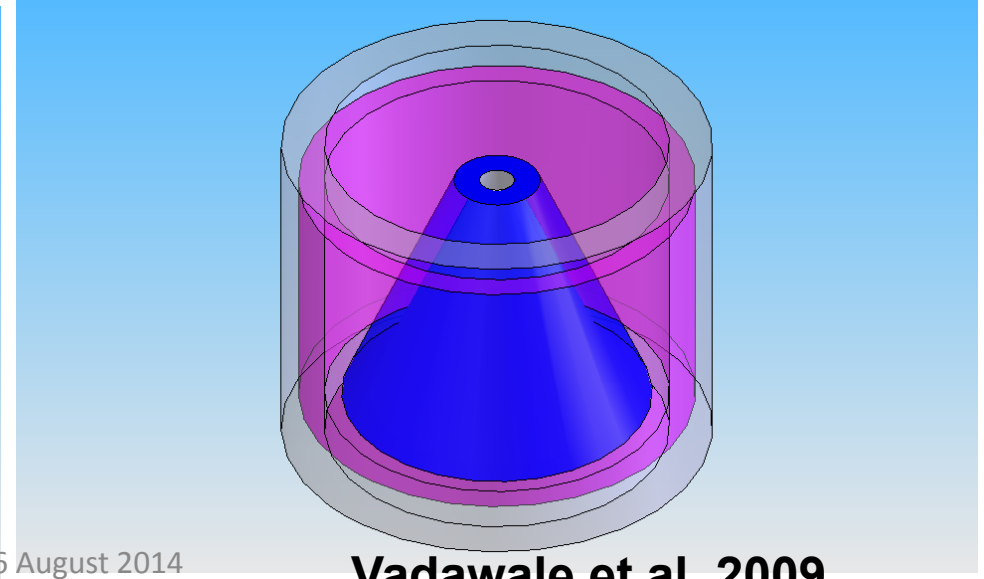
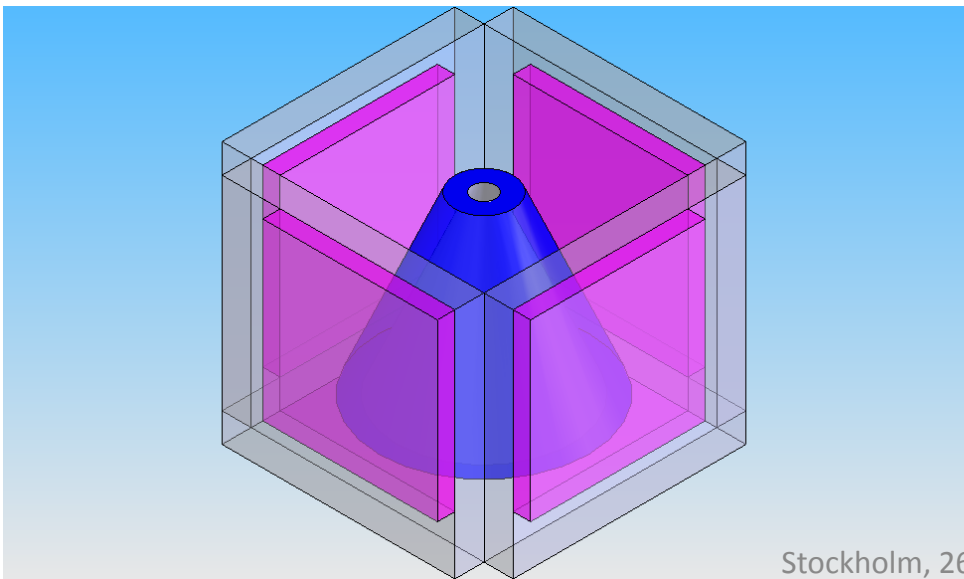
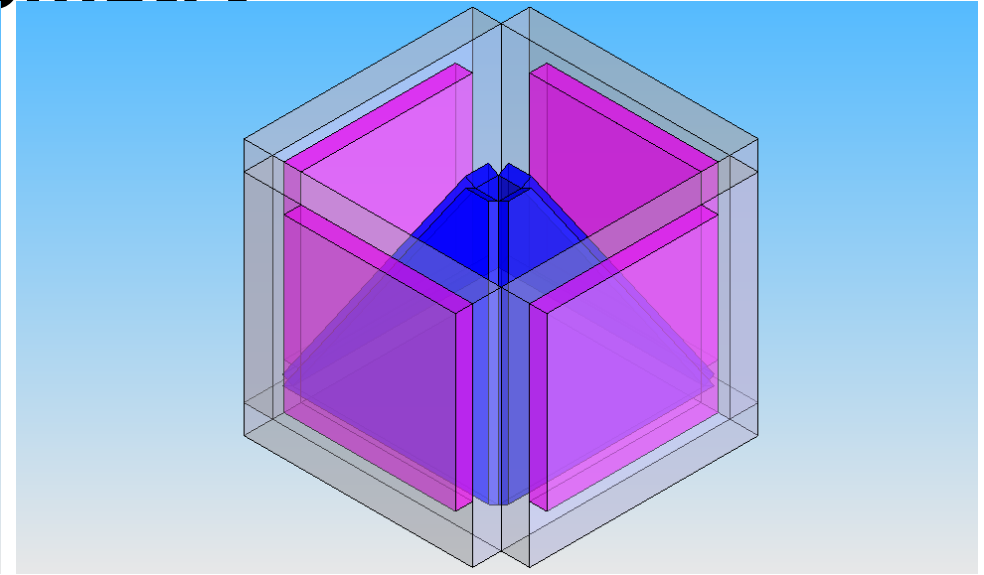
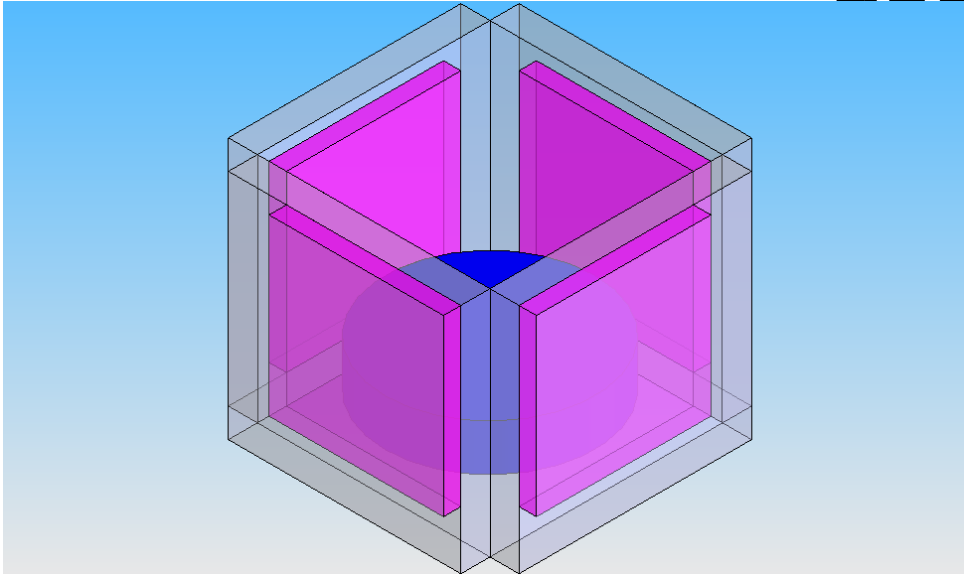
Mechanical configuration.....



Electronics



Simulations to optimise scatterer geometry



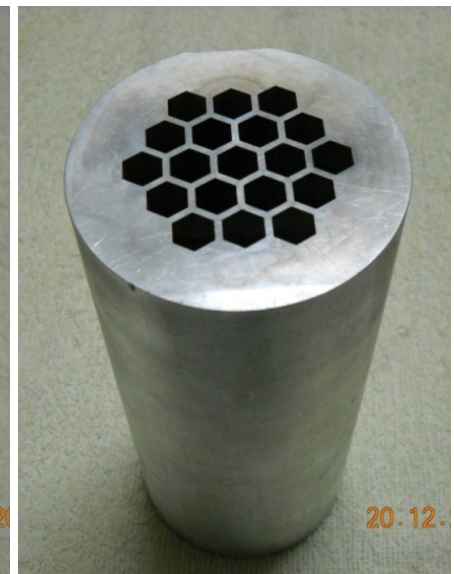
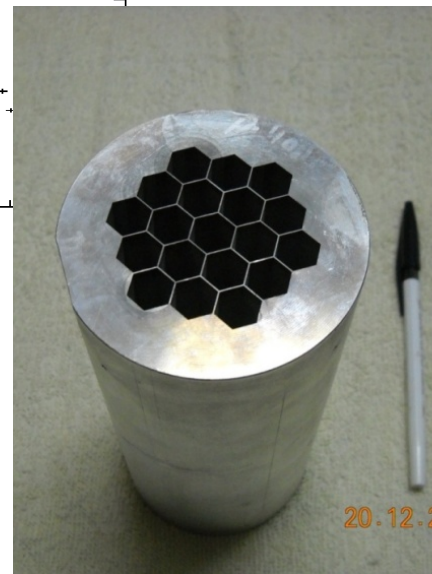
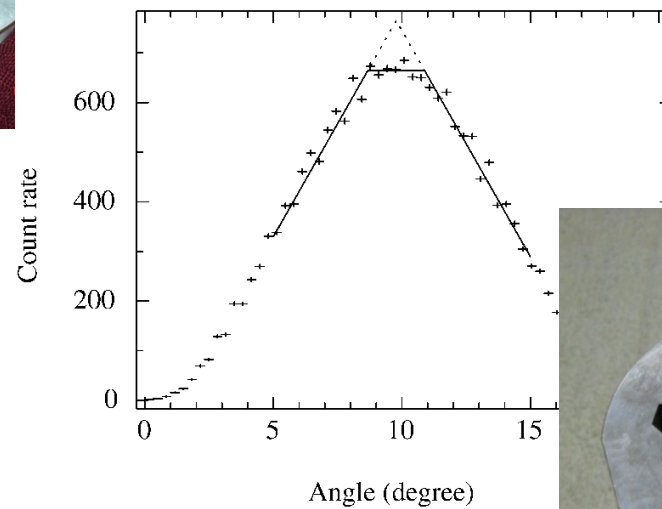
Stockholm, 26 August 2014

Vadawale et al. 2009

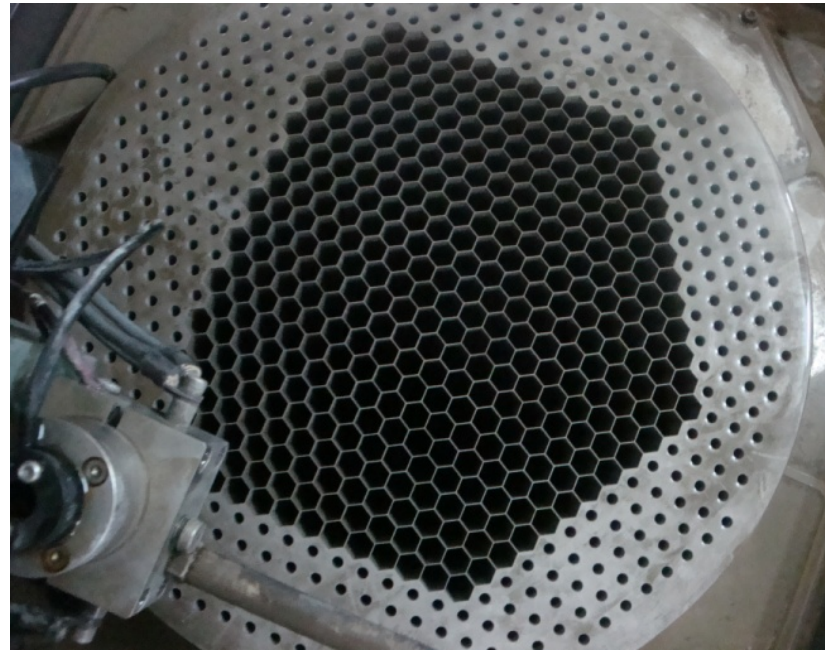
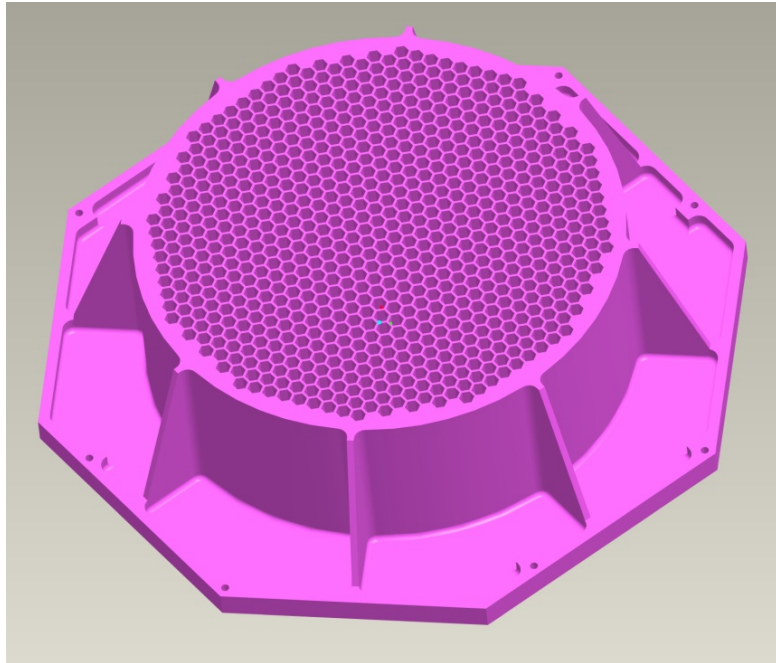
Collimator



Angular response of honeycomb collimator with copper plates on both sides

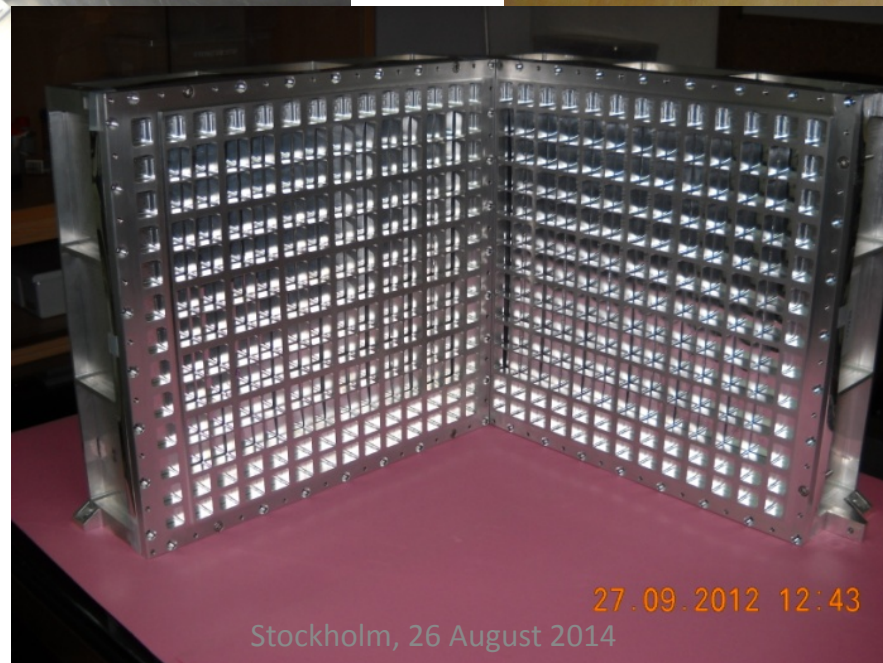
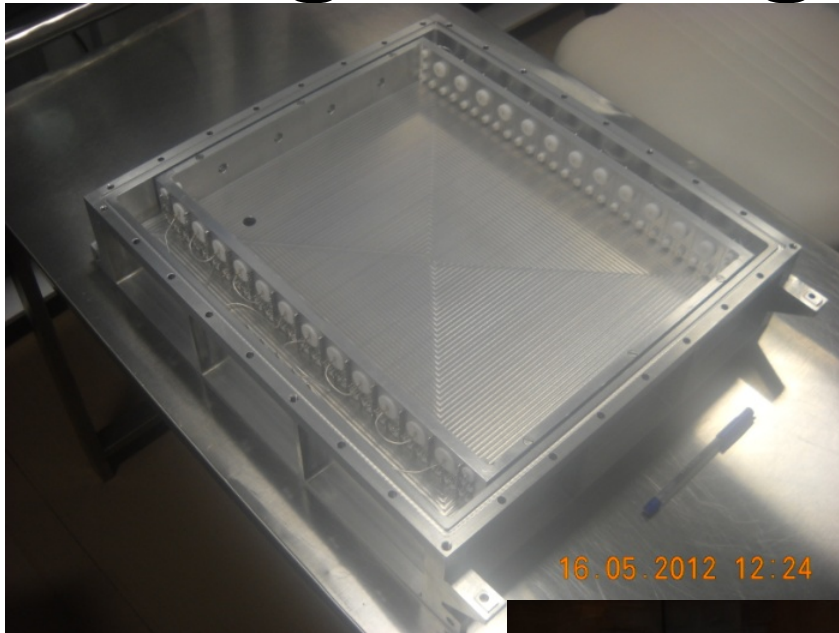


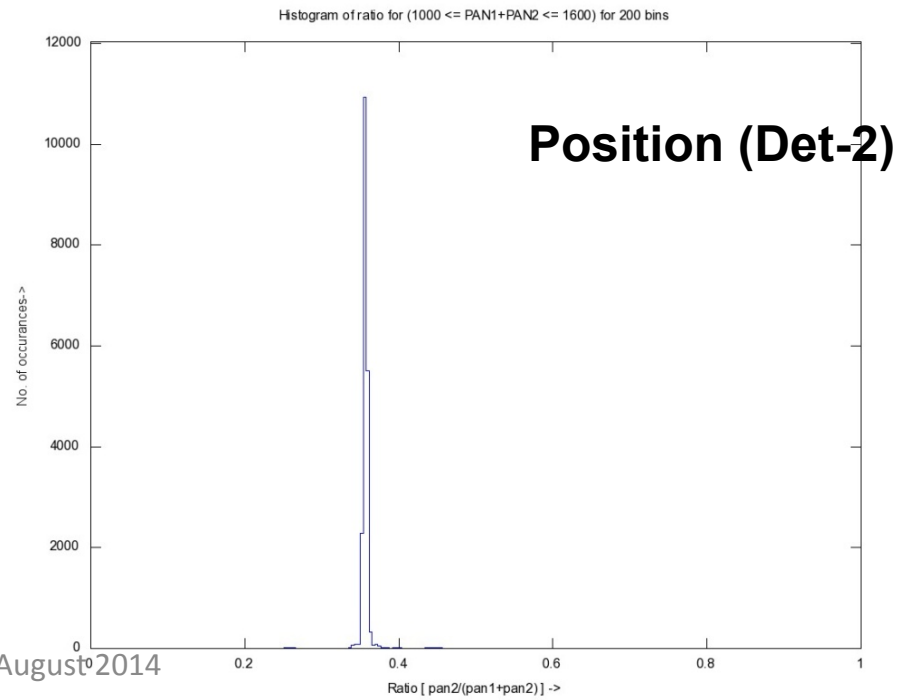
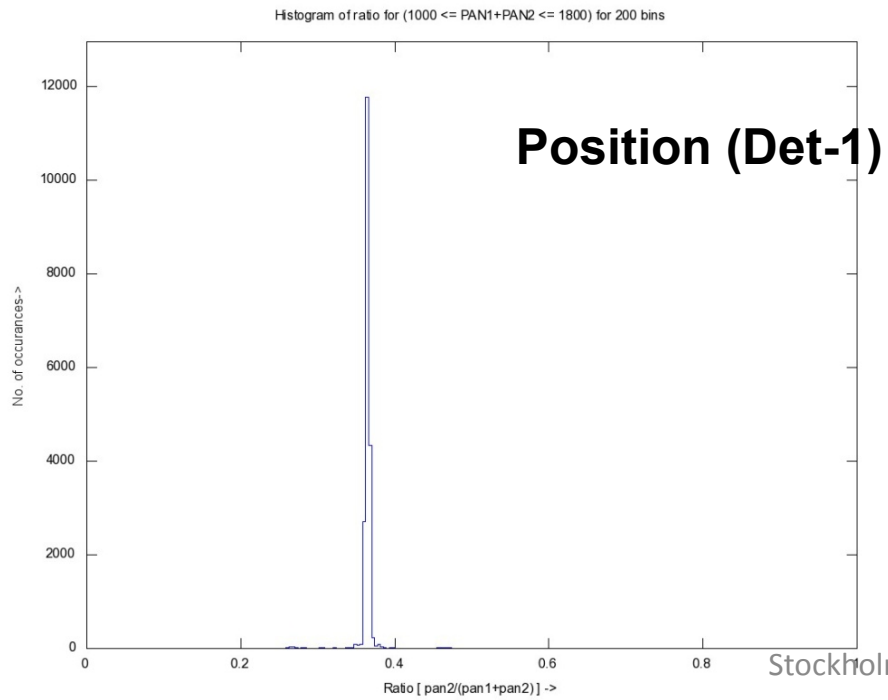
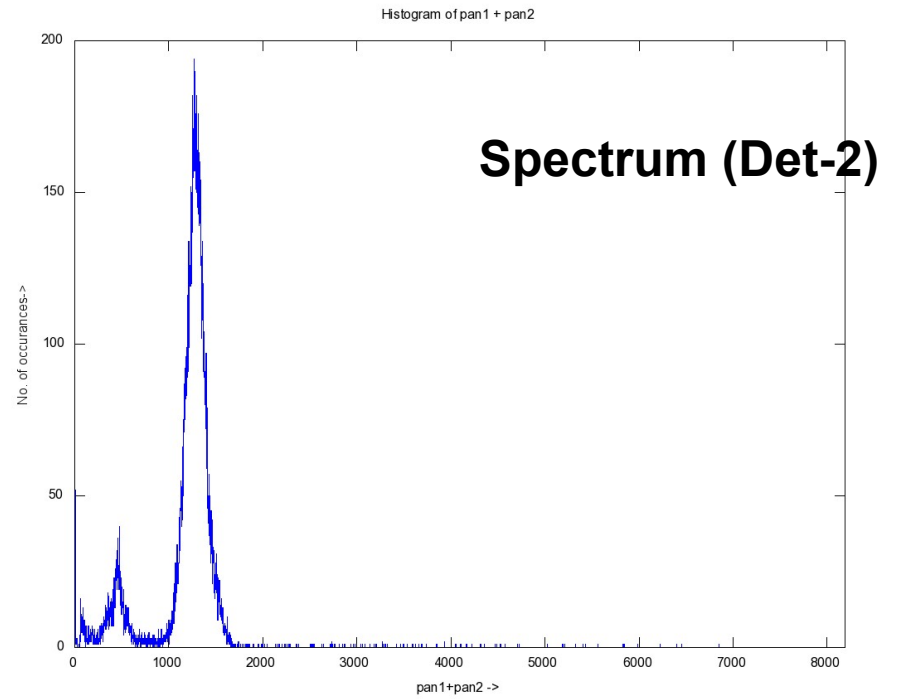
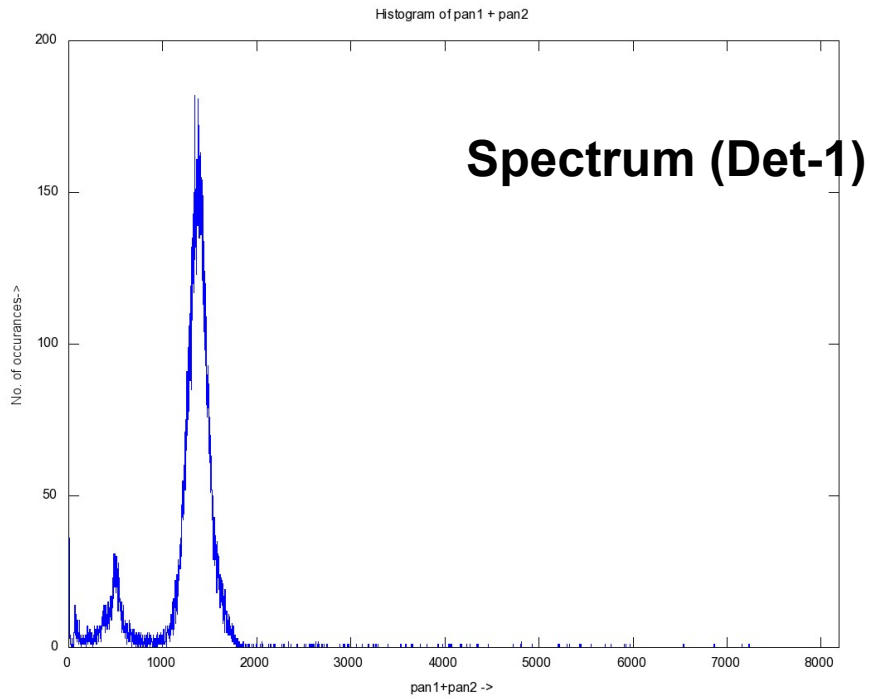
Collimator



Stockholm, 26 August 2014

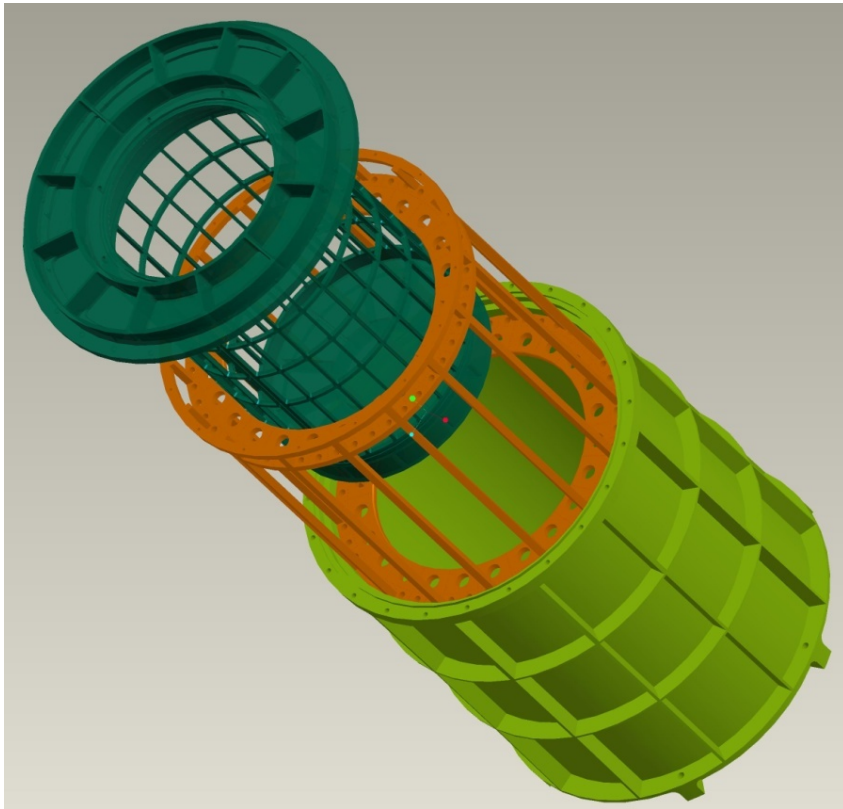
Engineering Model Detectors





Cylindrical detector

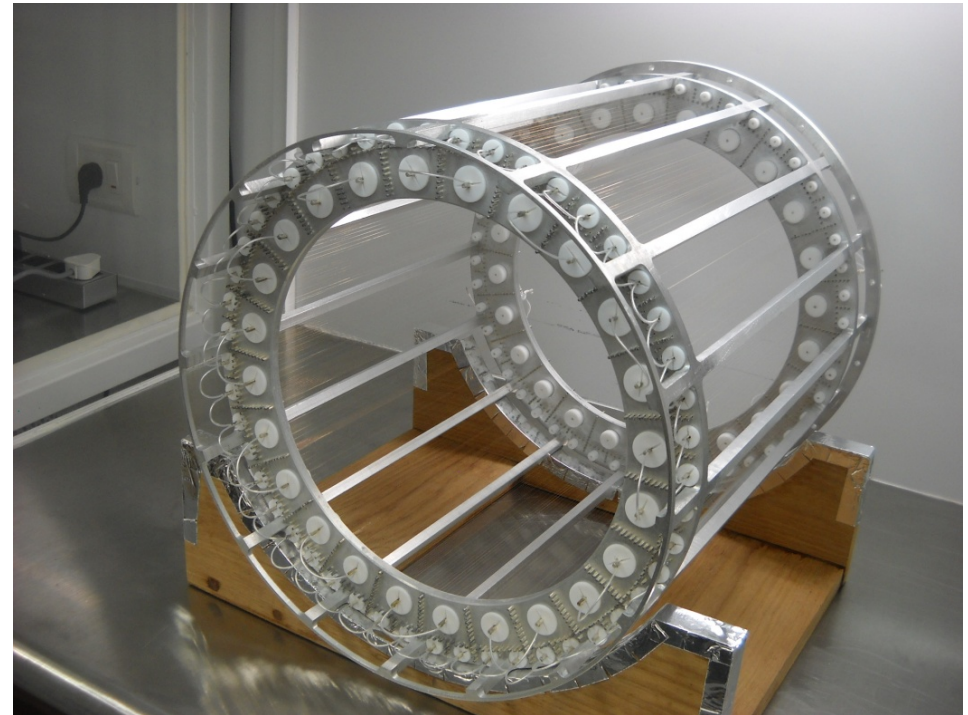
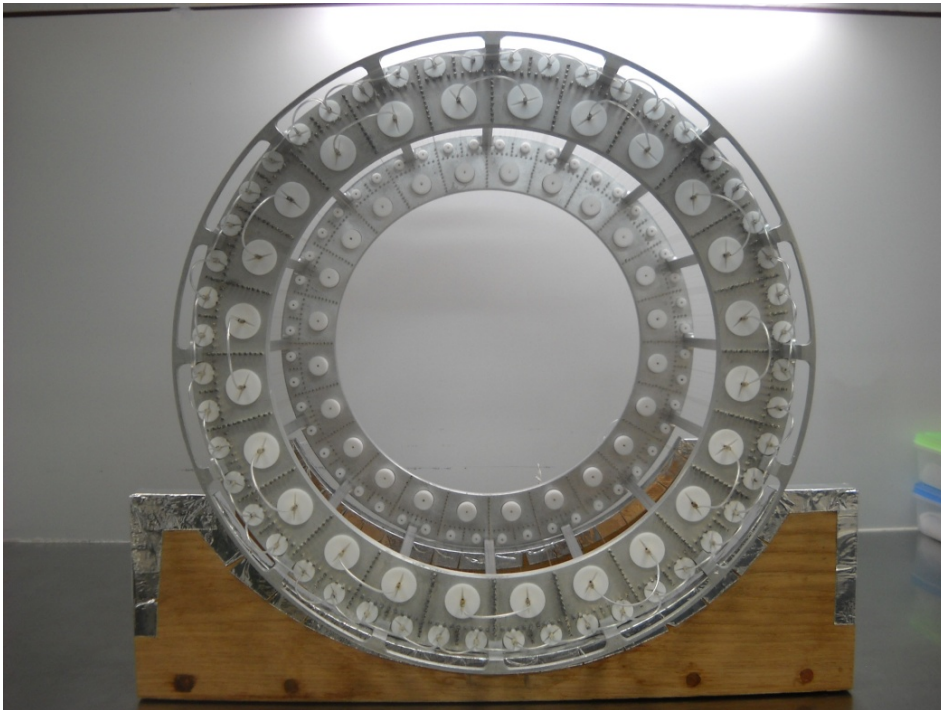
- **An alternative approach**



- **No dead area at corners**
- **Uniform gain and quantum efficiency in all directions**
- **Less systematic uncertainties**

Cylindrical detector

- Wire-frame



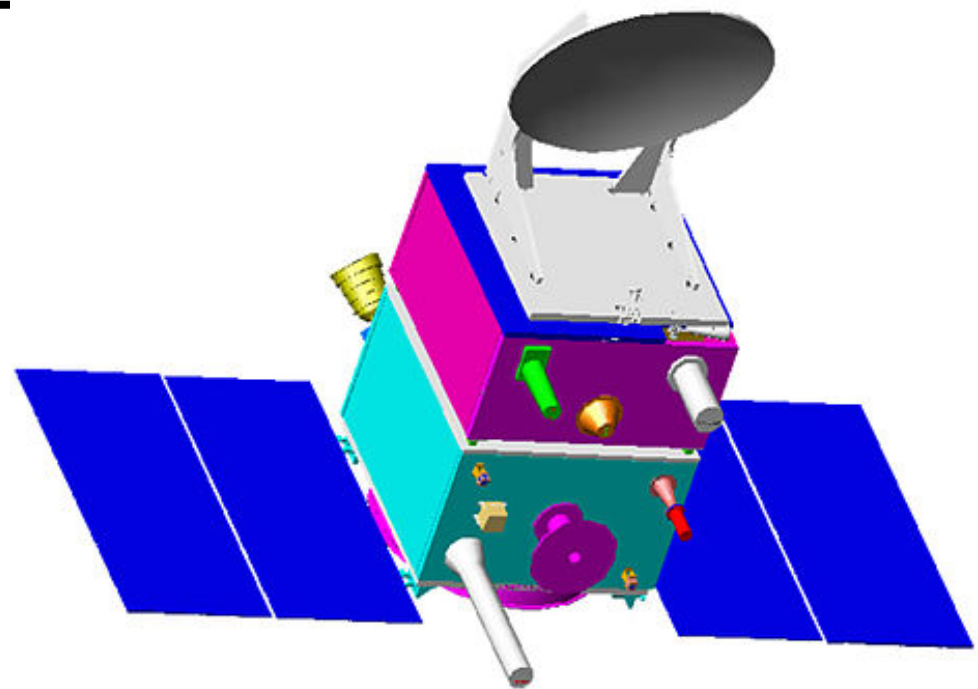
The Satellite Bus

- **Satellite with ARgos and ALtiKa (SARAL) ISRO/CNES (Feb 2013)**
400 kg
- **3 Axis Stabilised**
- **200 kg Payload**
- **800 W power**

0.1 degree pointing

Spin (power generation??)

Reorientation, Long staring



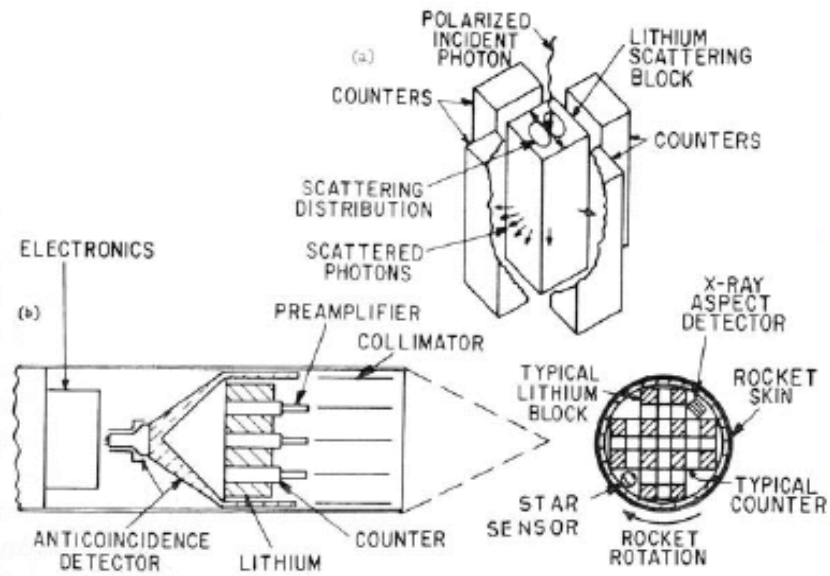
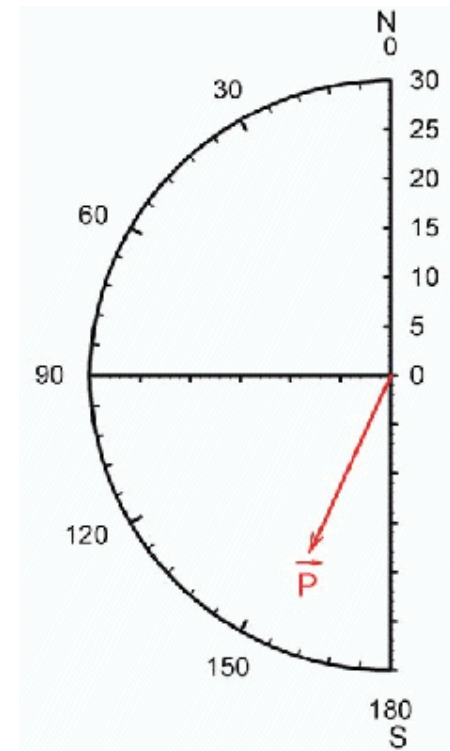
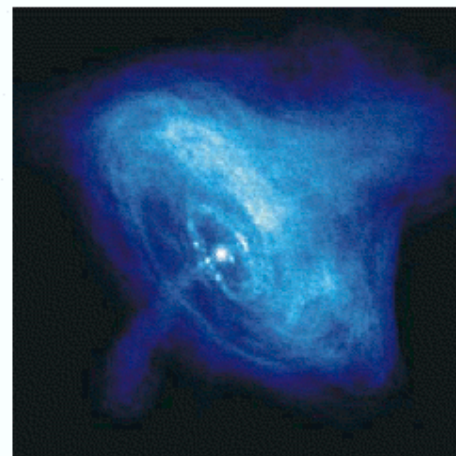


Fig. 1. (a) Schematic representation of the polarimeter concept. (b) Mounting of the polarimeter and ancillary equipment in the rocket.

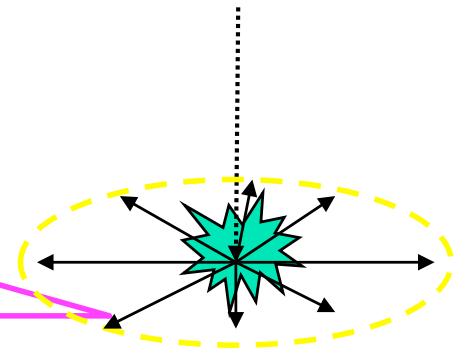


X-ray Polarisation

Polarisation is unexplored in High Energy Astrophysics

X-ray emission from the following processes should be polarised

- Cyclotron
- Synchrotron
- Non-Thermal Bremsstrahlung
- Scattering from non-spherical plasma

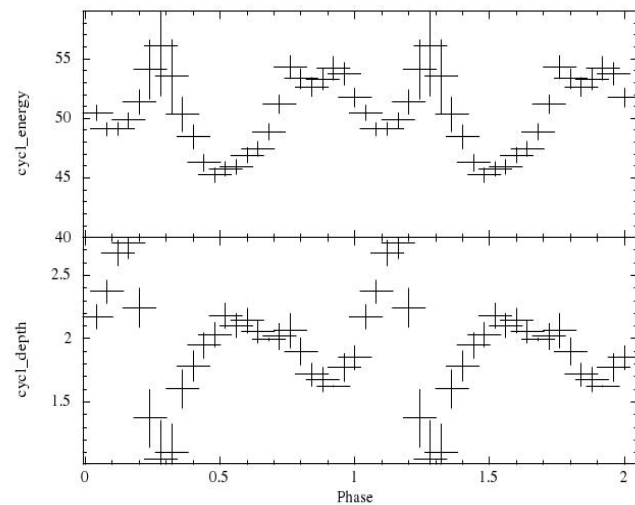
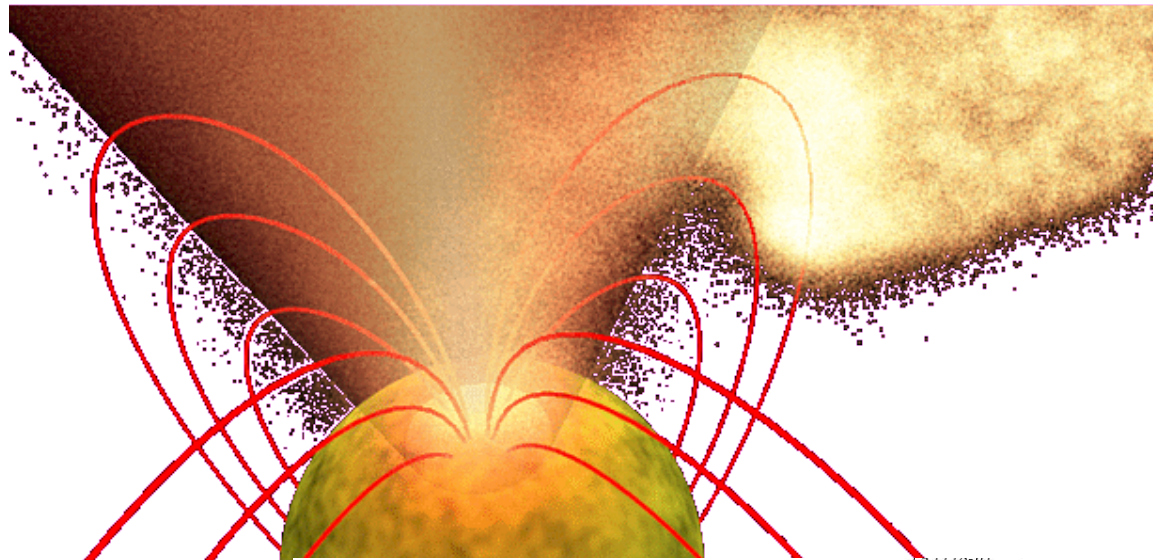


These objects should produce polarised X-ray radiation

- Accretion powered pulsars
- Rotation powered pulsars
- Magnetars
- Pulsar wind nebulae
- Non-thermal supernova remnants
- Black holes, micro-quasars and active galactic nuclei

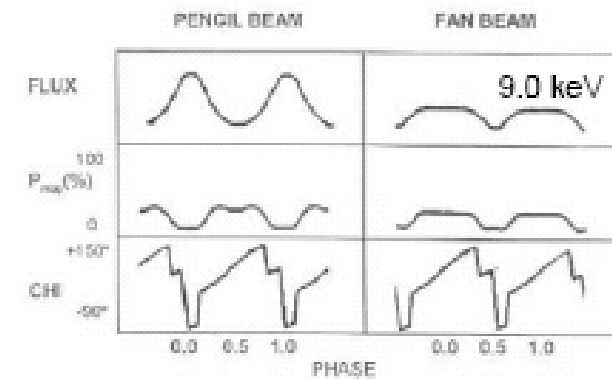
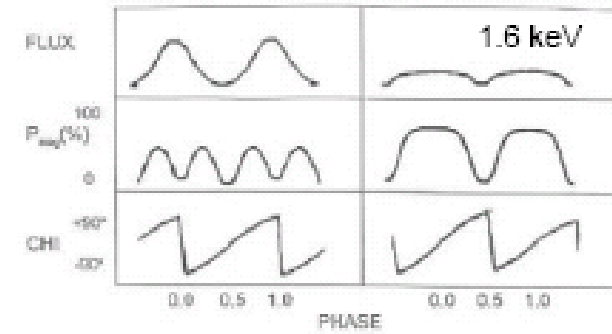
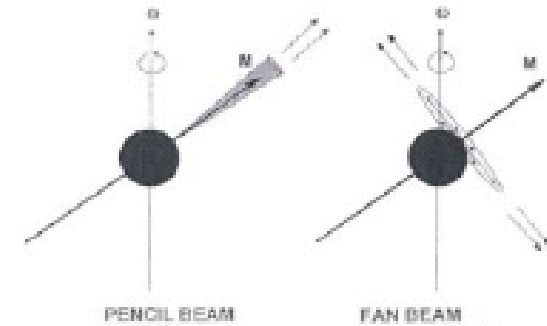
Crab nebula is the only source for which X-ray polarisation measurement exists with high s/N.

Accreting X-ray Pulsars



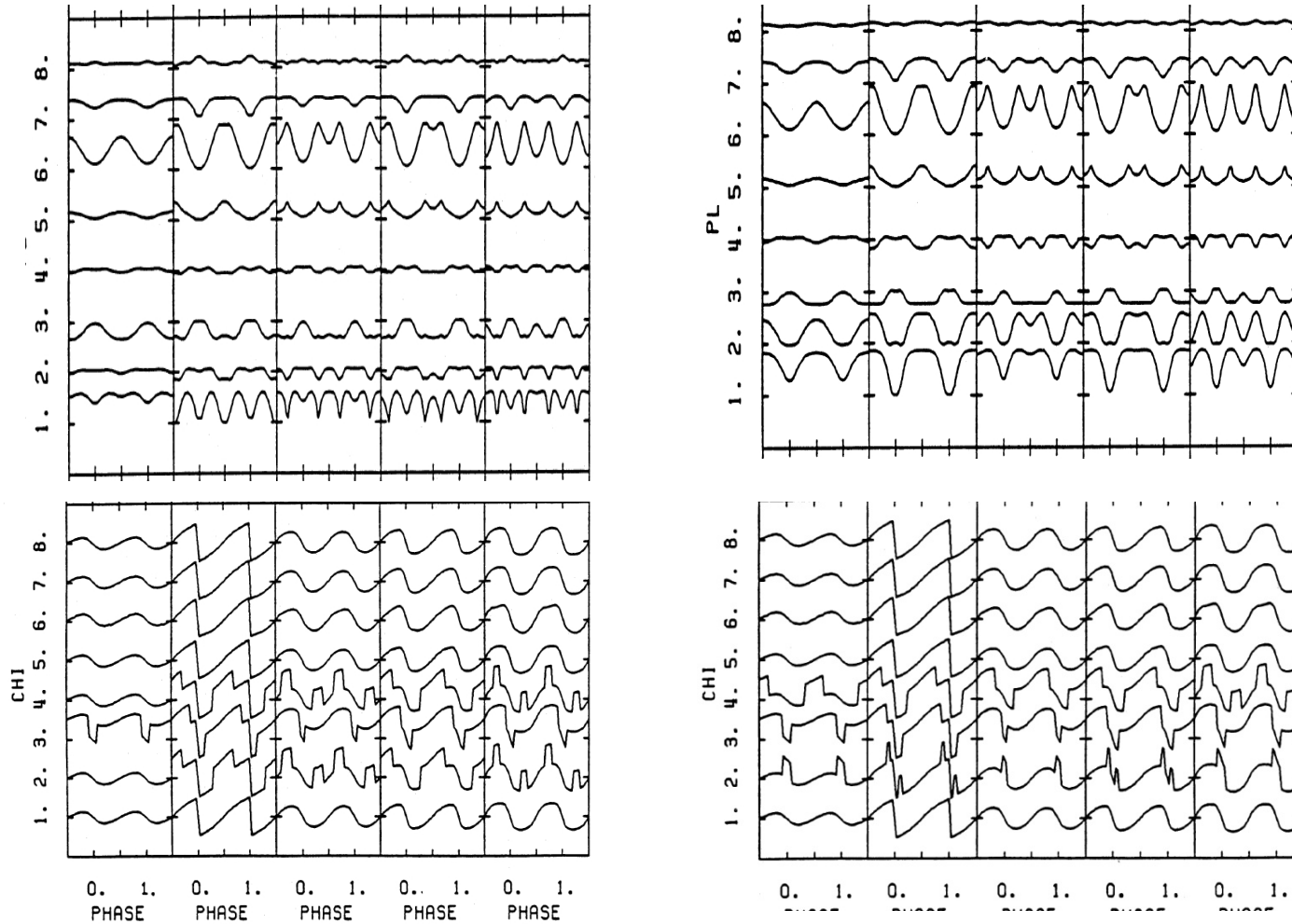
Ima

2014



Meszaros et al. 1988

Accreting X-ray Pulsars



Degree and angle of polarization with pulse phase for Pencil beam and Fan beam (left and right) for (i₁,i₂=45,75)
E_{cycl}=38 keV and K_T=8 keV (Meszaros et al. 1988)

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Accreting X-ray Pulsars

Table 1: 9 keV: Time is in secs.

Source name	Pencil Beam		Fan Beam	
	Li	Be	Li	Be
GX 301-2	259.91	590.08	733.09	1664.39
1A 1118-61	596.82	1479.82	1683.37	4173.89
Vela X-1	831.34	2130.61	2344.84	6009.46
A0535+26	725.44	1834.52	2046.14	5174.35
XTE J1946+274	1073.60	2818.43	3028.15	7949.50
4U 1907+09	14184.56	43580.18	40008.16	122919.75

Table 2: 18 keV: Time is in secs.

Source name	Pencil Beam		Fan Beam	
	Li	Be	Li	Be
GX 301-2	830.97	1030.74	399.69	495.97
1A 1118-61	2548.35	3256.87	1225.73	1567.21
Vela X-1	1864.65	2360.77	896.88	1135.99
A0535+26	2799.52	3588.41	1346.54	1726.76
XTE J1946+274	7639.06	10113.55	3674.32	4866.96
4U 1907+09	134099.43	189406.98	64500.69	91158.66

Jets & Motion in Accretion Disk around Black Holes

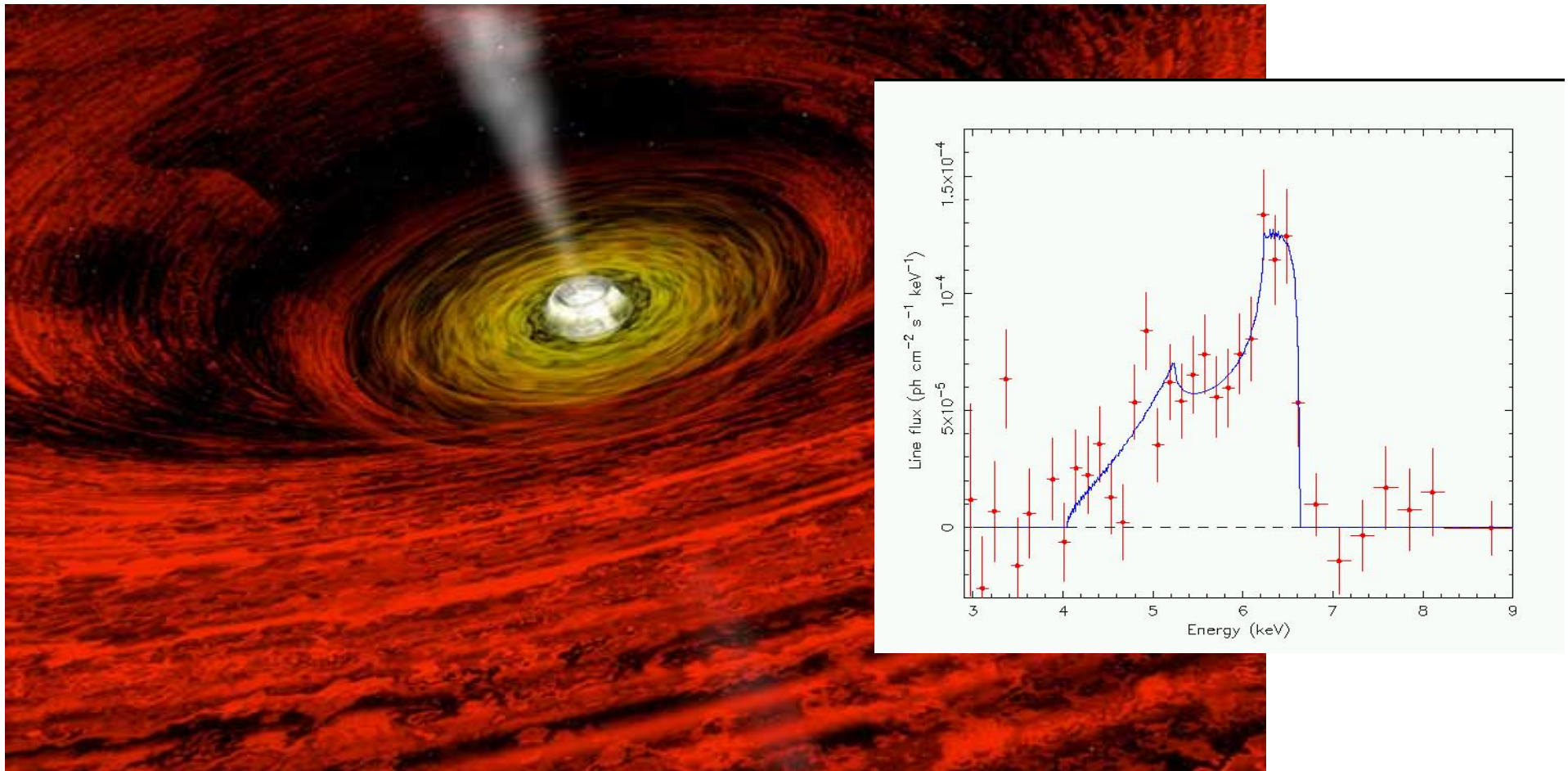


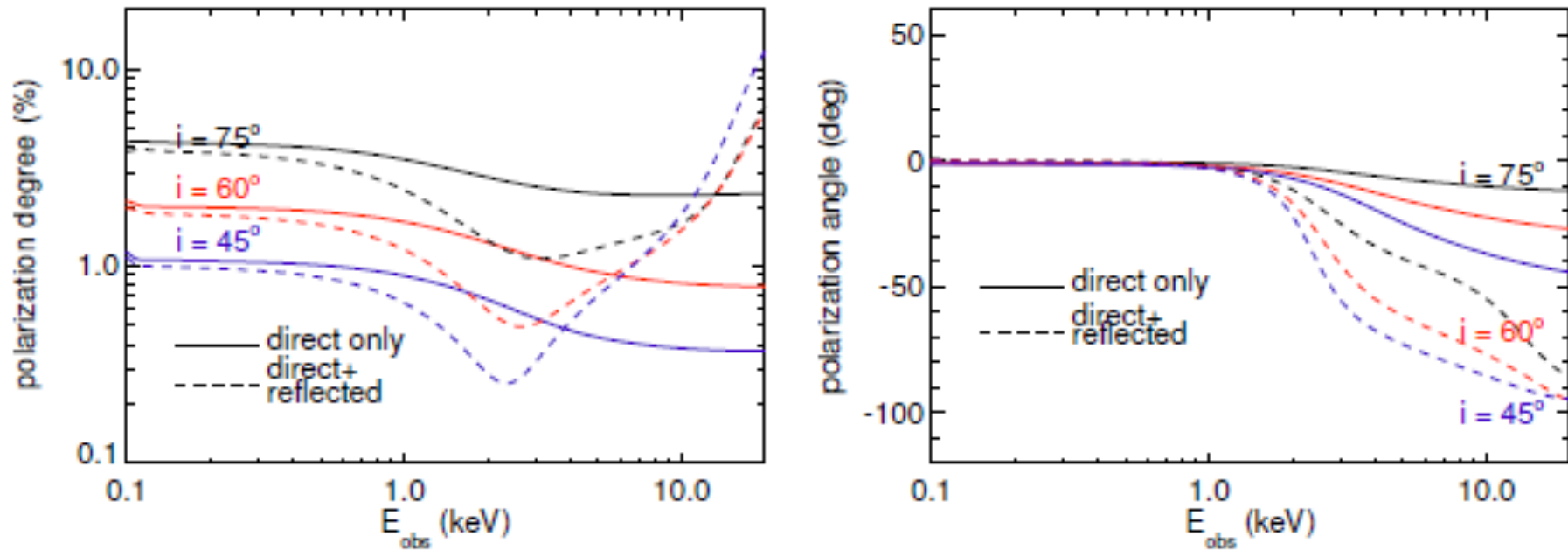
Image: NASA

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Tanaka et al. 1995

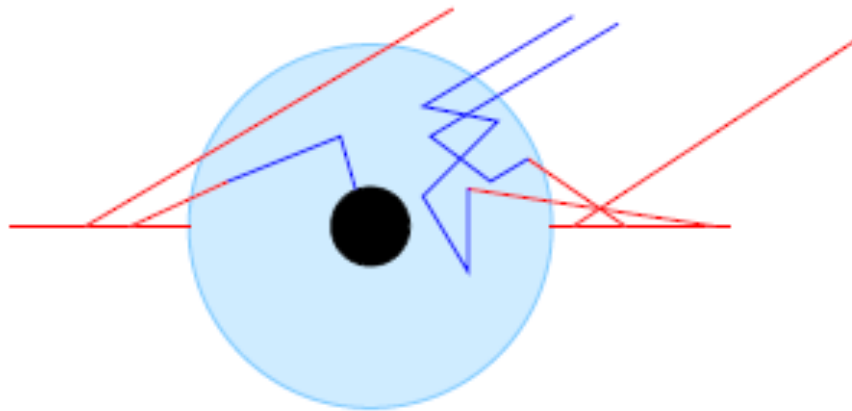
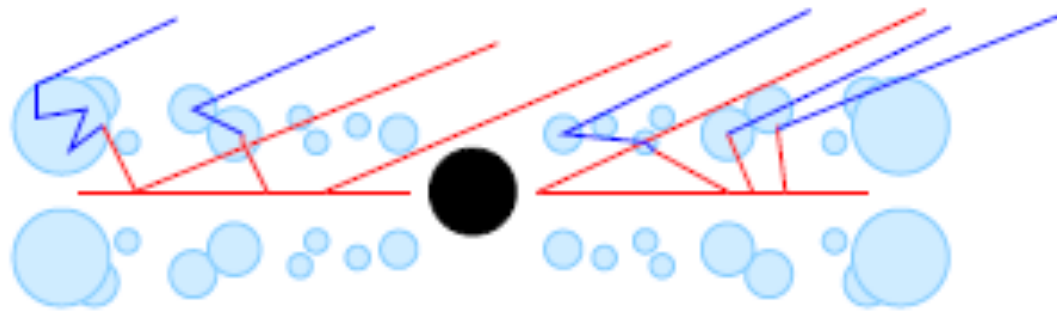
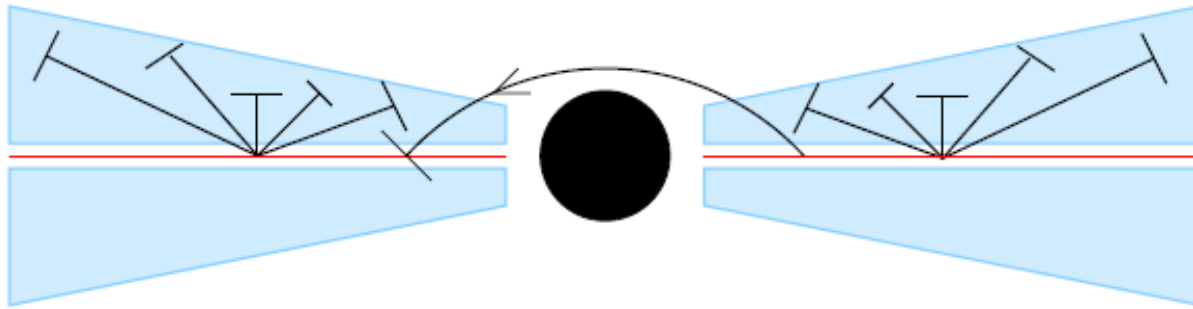
X-ray Polarisation in Black Holes

$$M = 10M_{\odot} \quad a/M = 0.9 \quad L = 0.1L_{\text{Edd}}$$

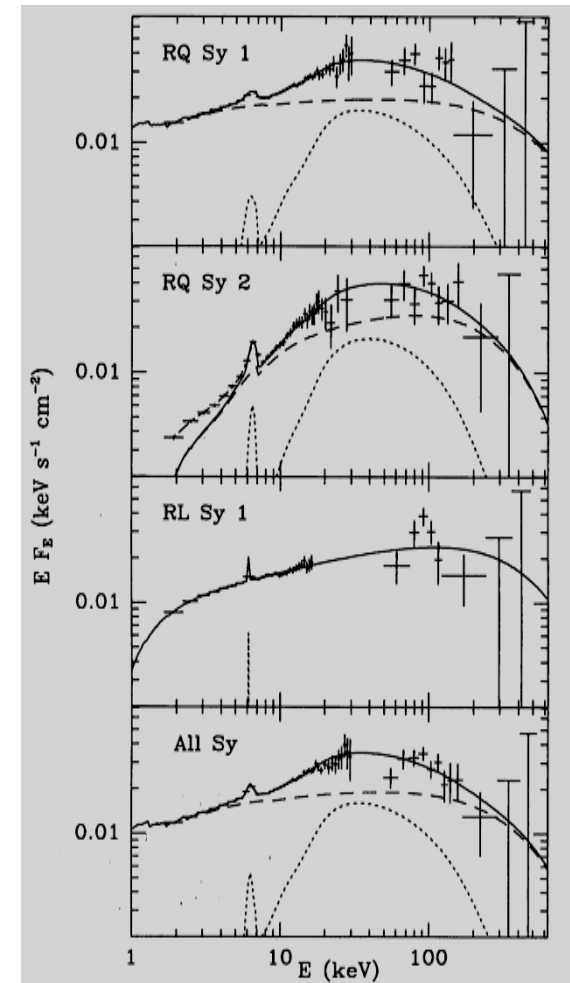
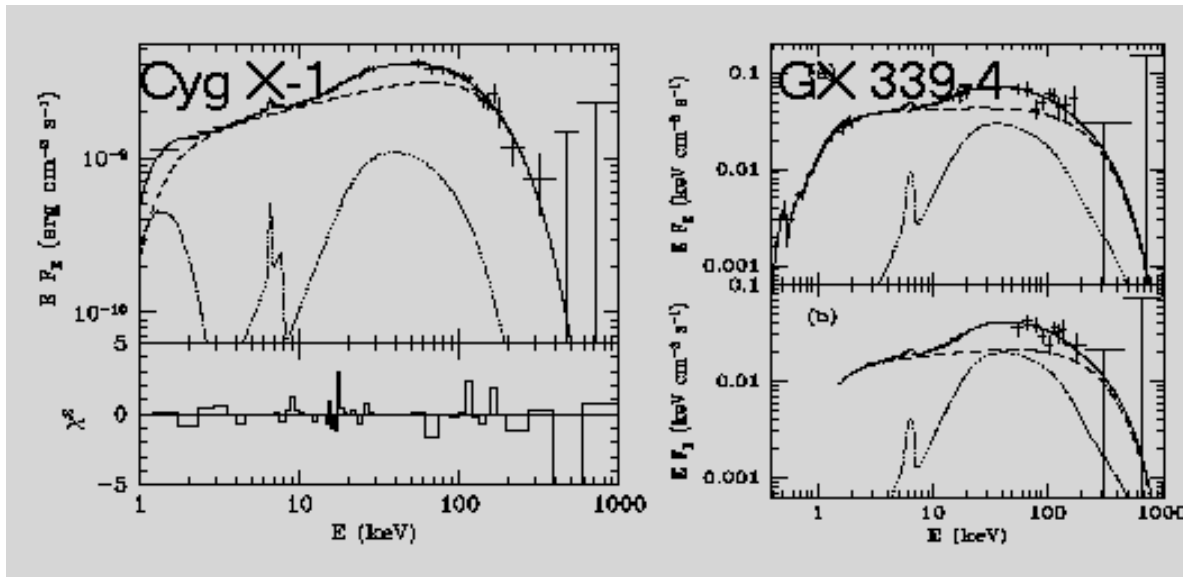


Dovchiak et al, Schnittmann et al.

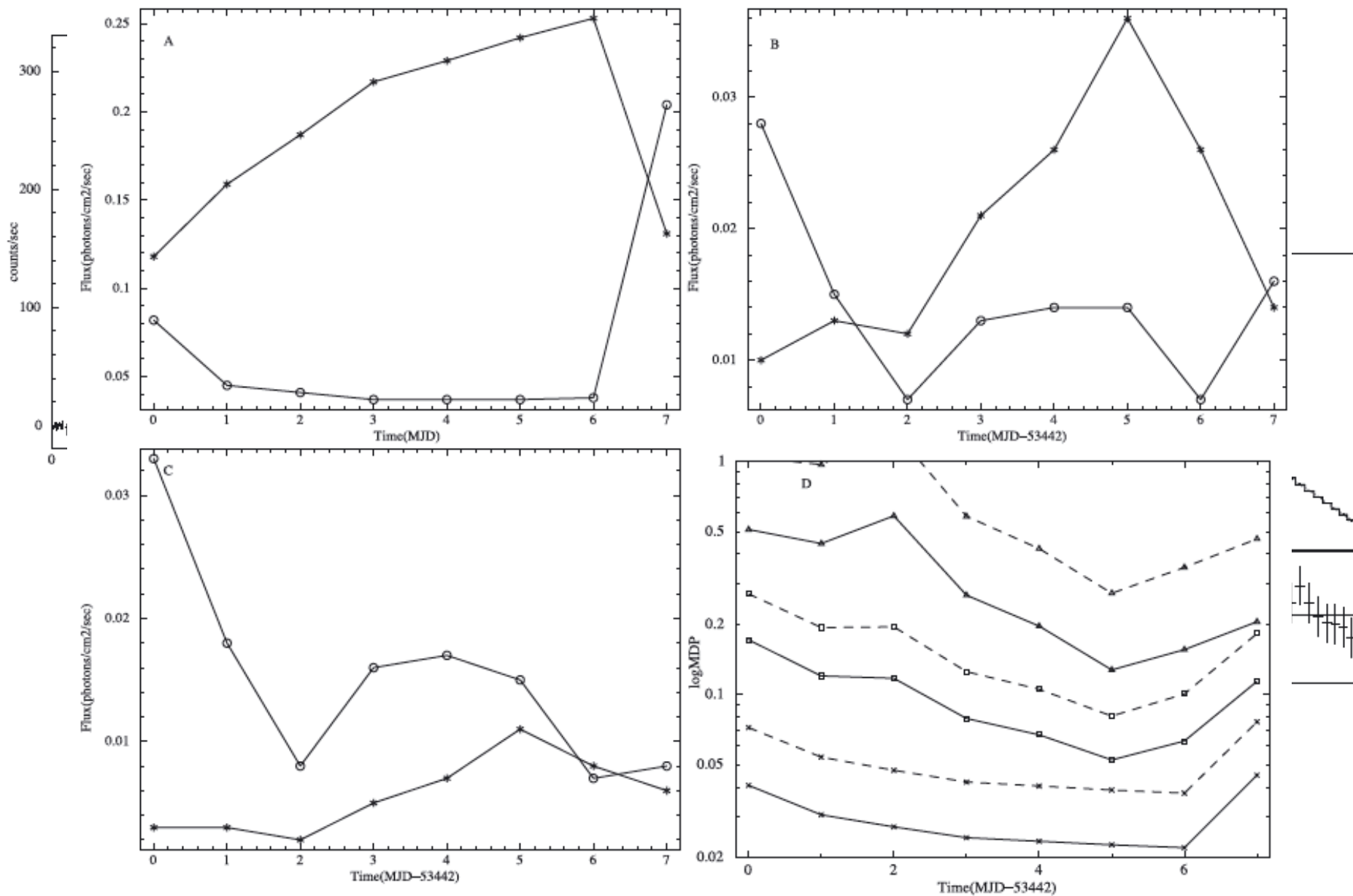
X-ray Polarisation and Corona



X-ray Reflection from BH Accretion Disk



Polarisation from BHCs in disk Dominated state

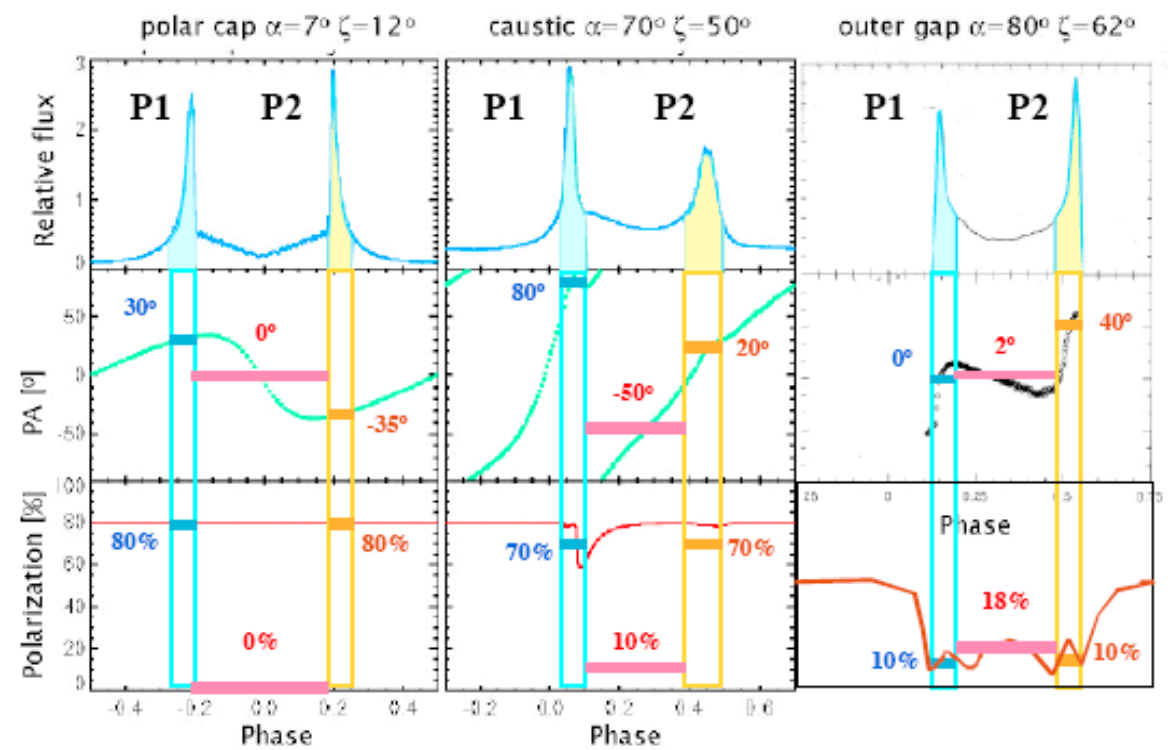
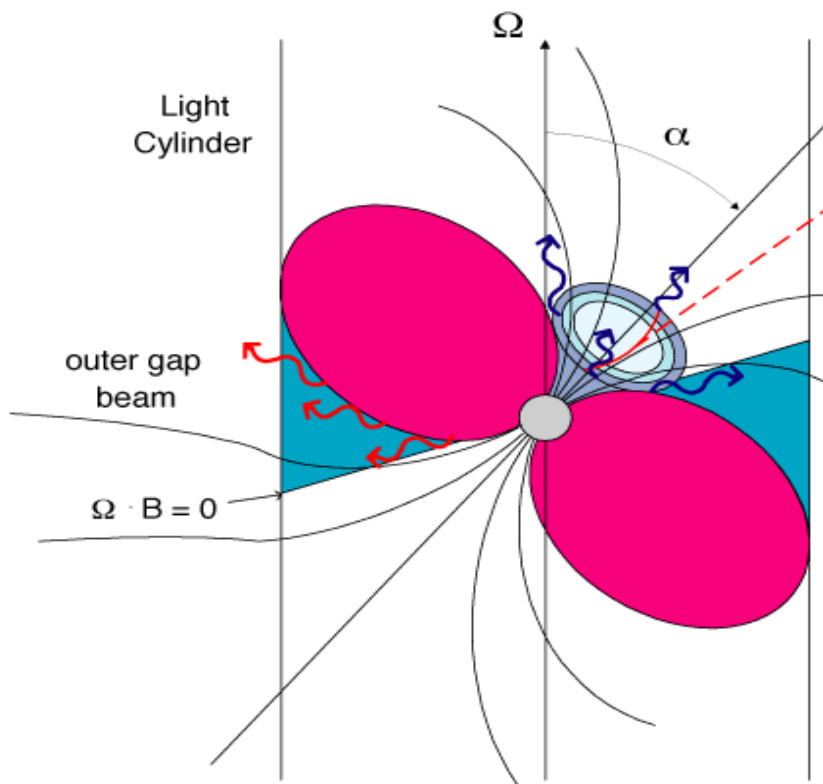


Polarisation from BHCs in disk Dominated state

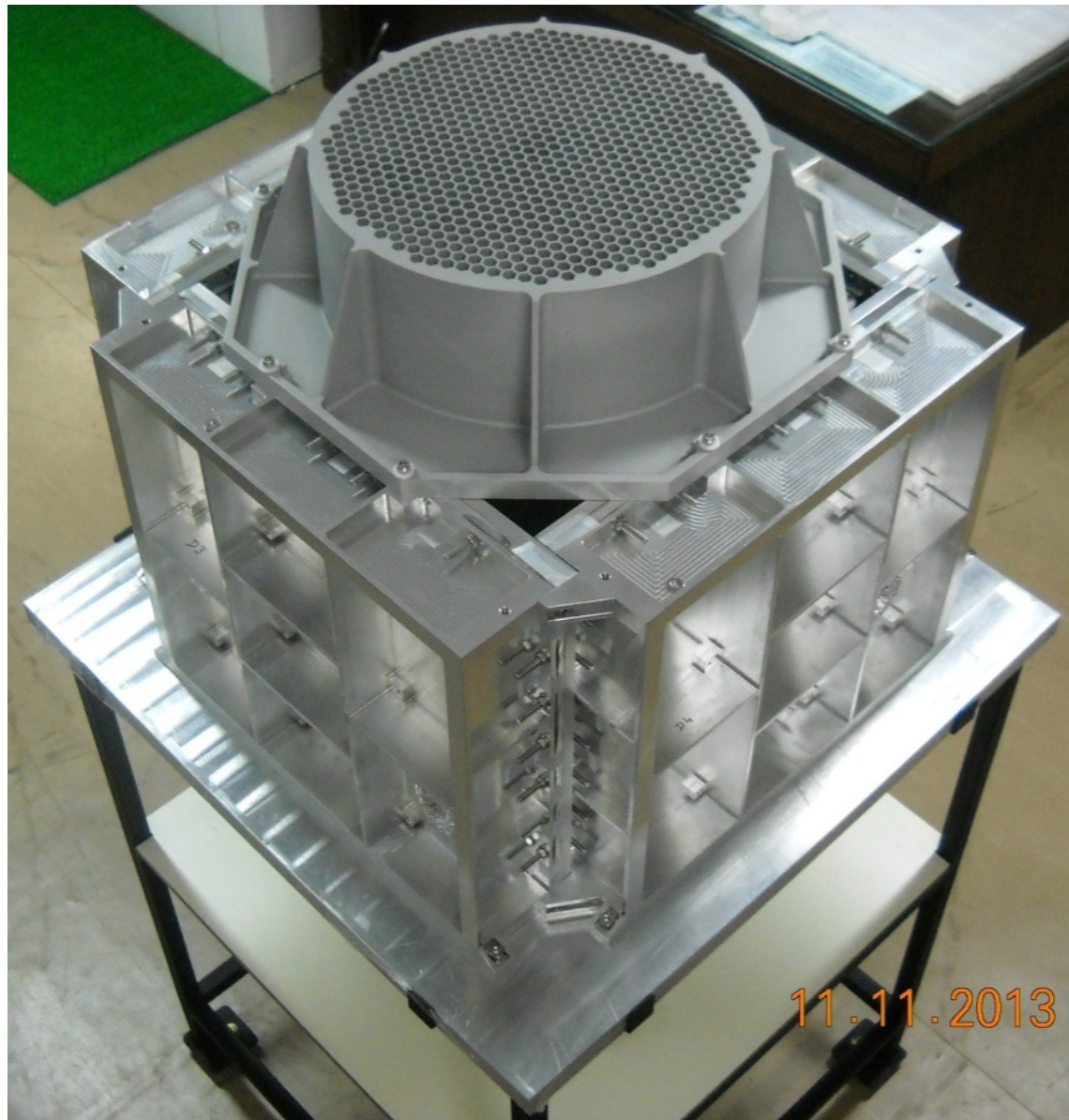
Source name (MJD range)	Net MDP 6–9 keV		Net MDP 9–11 keV		Net MDP 11–15 keV		Net MDP 11–15 keV	
	5σ		5σ		5σ		3σ	
	Li	Be	Li	Be	Li	Be	Li	Be
GRO J1655–40 (53442–53449)	0.97	1.69	2.96	4.71	8.37	11.63	5.37	7.47
GRO J1655–40 (53511–53525)	0.52	0.88	1.77	2.69	4.43	5.94	2.85	3.81
GX 339–4 (52472–52518)	0.36	0.62	2.92	4.67	18.10	25.10	11.62	16.11
Cygnus X-1 (50225–50242, 50250–50252)	1.57	2.70	15.16	23.84	–	–	–	–
H1743–322 (52823–52843)	1.42	2.89	6.25	11.10	35.94	53.63	23.08	34.43
XTE J1817–330 (53765–53780)	1.21	2.26	08.28	14.14	55.76	–	35.79	51.64

Maitra and Paul 2011

Rotation Powered Pulsars & Magnetars



Instrument Status



Stockholm, 26 August 2014

Mission Status

Advisory Committee for Space (ADCOS)

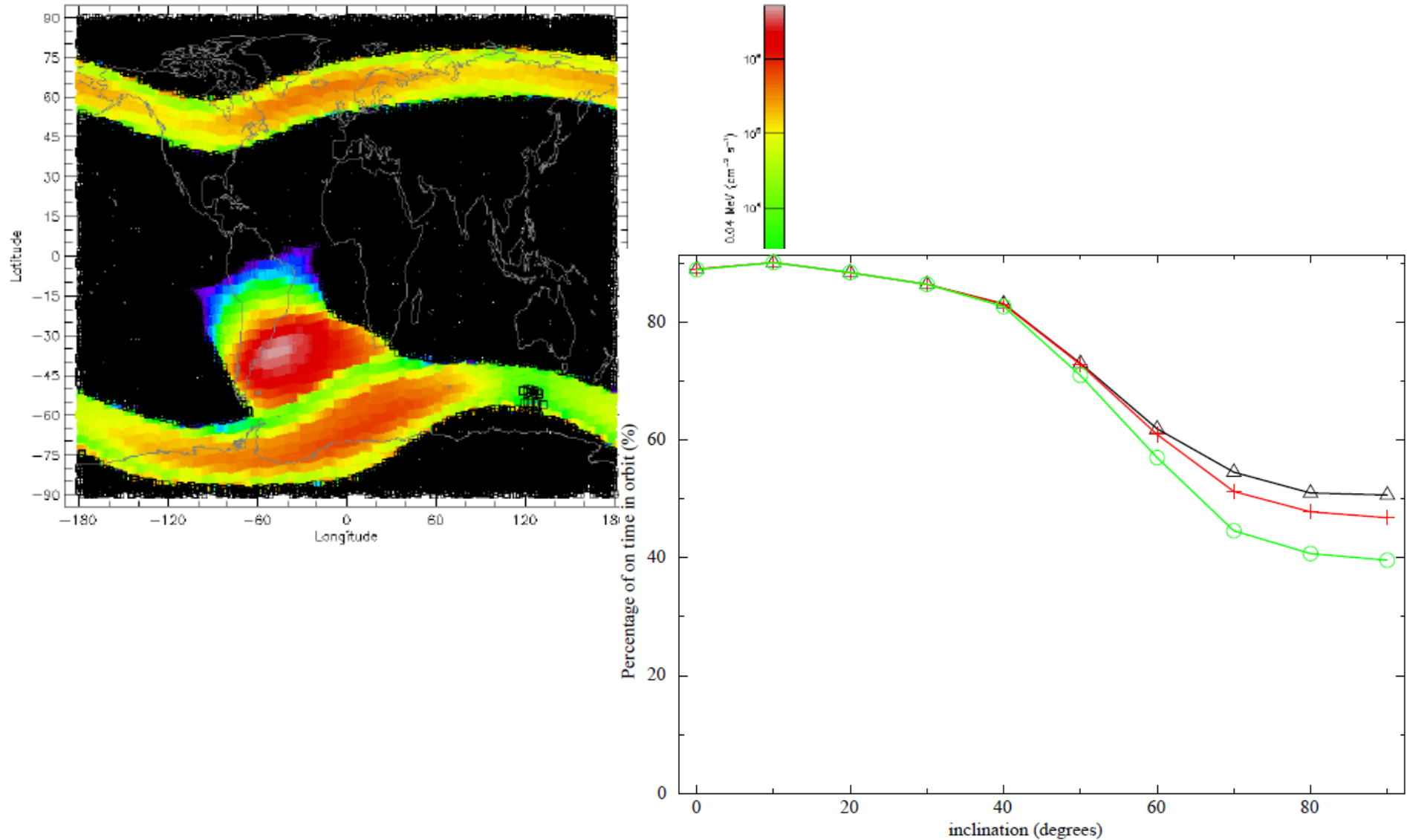
Recommended in Dec 1012

Satellite compatibility etc. worked out

May 2014: Mission Planning

Equatorial / Polar ?

Polar vs Equatorial

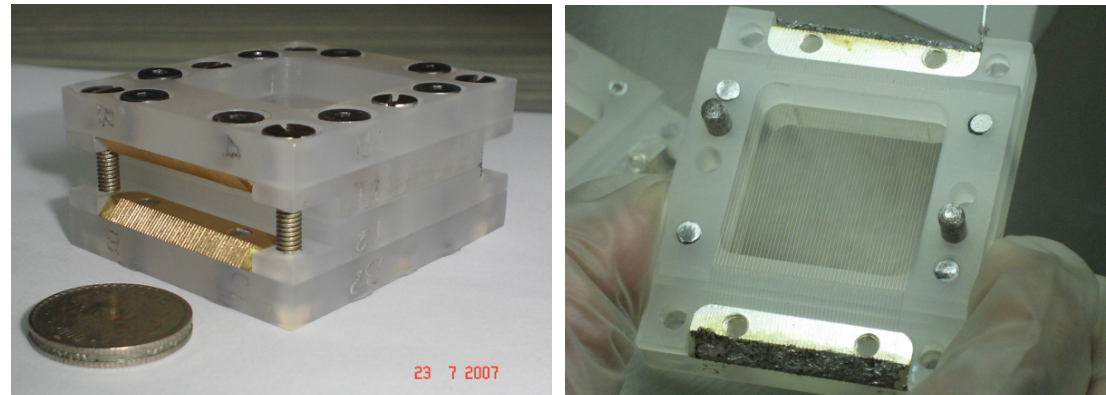
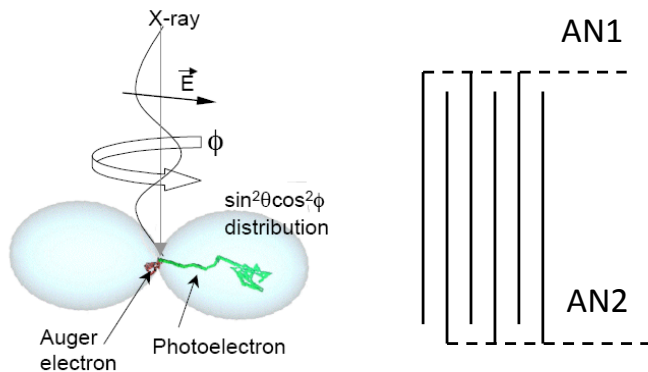
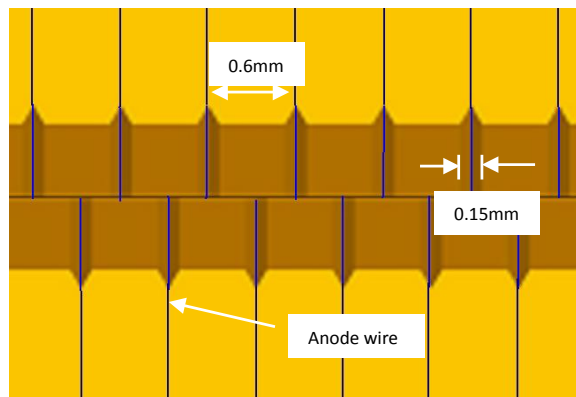
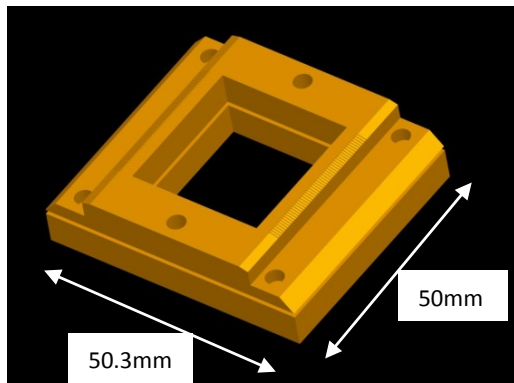


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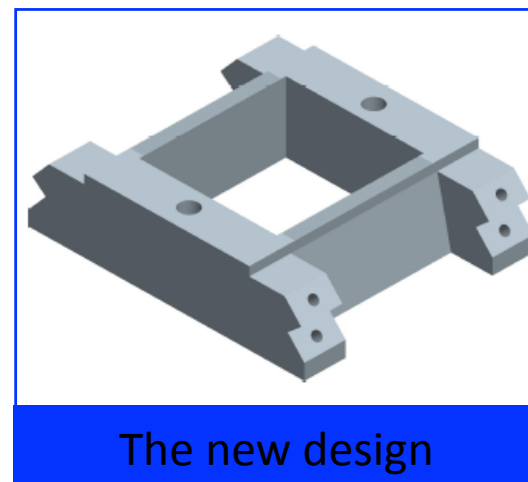
New Development/

Technique

Photoelectron polarimeter with proportional counters



Initial two piece design



The new design

Photoelectron Polarimeter with Proportional Counter

