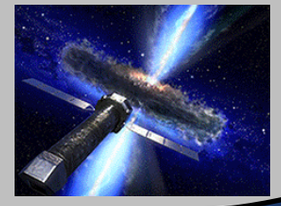
X-IFU bright source studies with SIXTE

Philippe Peille

on behalf of the X-IFU E2E simulations team

SXTE workshop, IRAP, April 21 2016

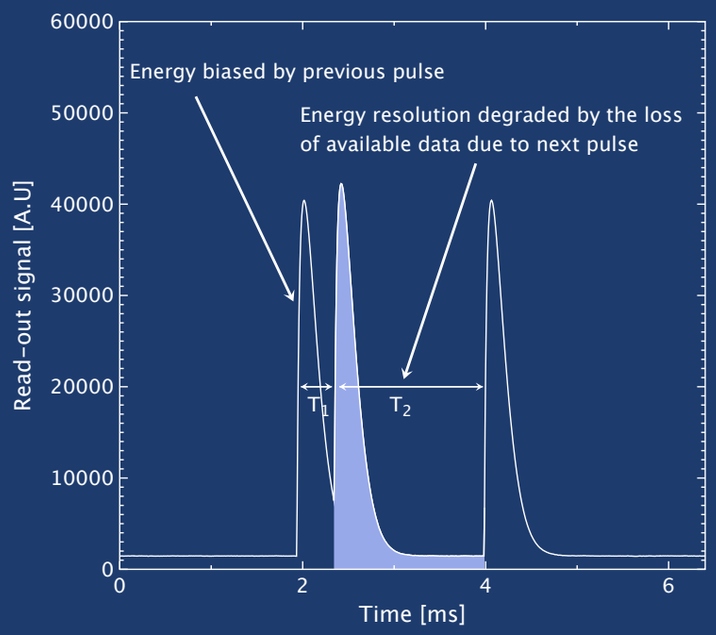
CHARACTERIZING THE X-IFU PIXELS COUNT RATE CAPABILITY

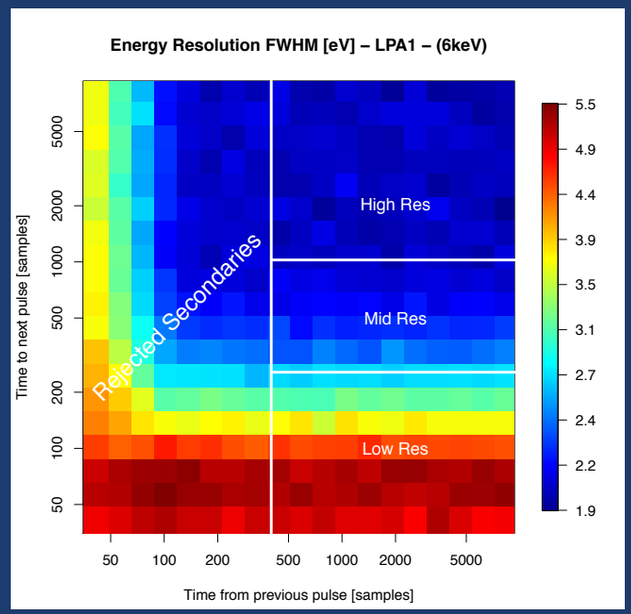


- TESSIM allows the generation of representative data streams from the future X-IFU pixels

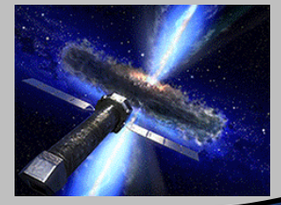
- The degradation of energy resolution as a function of count rate can be assessed by SIRENA
  - Generation of pulses separated by variable time intervals
  - Energy reconstruction using the optimal filtering technique (Szymkowiak et al., 1993)

$$min\left(\sum \frac{|D(f) - E \times T(f)|^2}{|N(f)|^2}\right) \Rightarrow E \propto \sum \frac{D(f) \times S^*(f)}{|N(f)|^2}$$

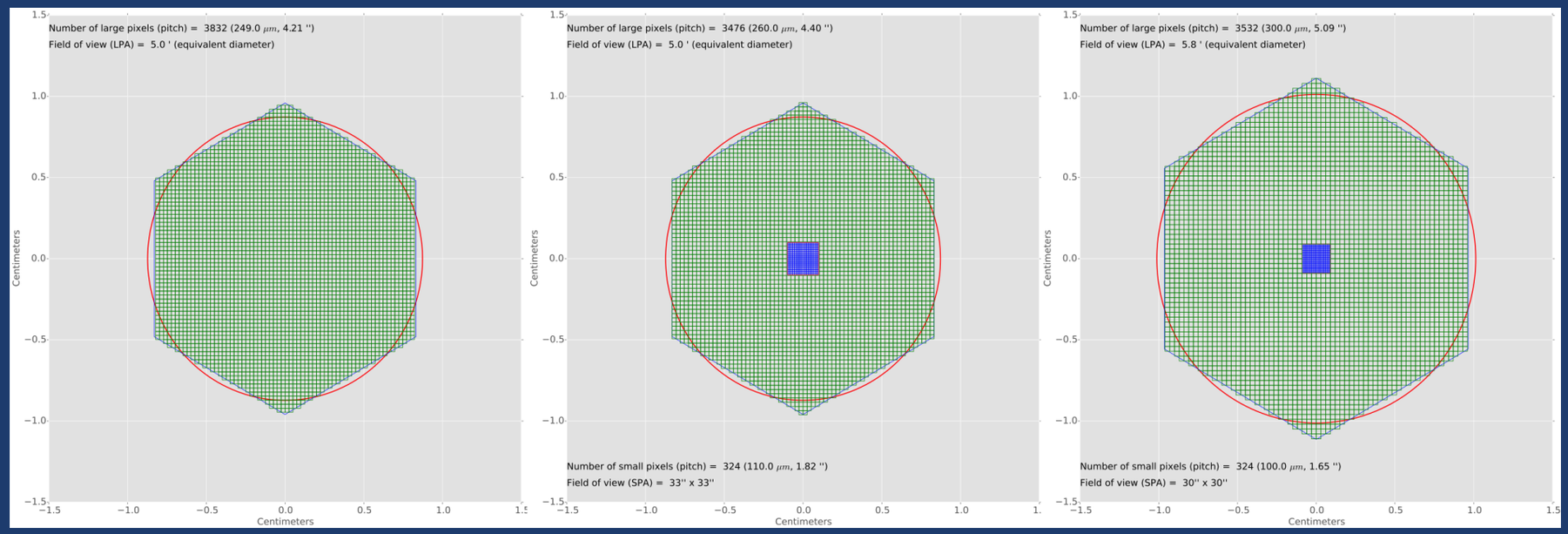




EVENT GRADING AND TES ARRAY OPTIMIZATION



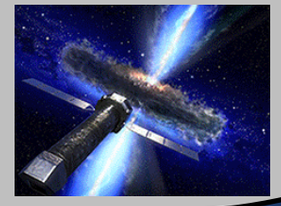
- Different TES array configuration studied during a TES array optimization exercise
  - Corresponding TES parameters provided by the GSFC team



- Event grades determined using the observed energy resolution degradation

Parameter	LPA (a)	LPA (b)	LPA (c)	SPA (b-c)
Valid event criterium	$T_1 \geq 2.6$ ms	$T_1 \geq 5.1$ ms	$T_1 \geq 9$ ms	$T_1 \geq 820$ µs
High res event criterium / ΔE	$T_2 \geq 6.6$ ms / 2.5 eV	$T_2 \geq 105$ ms / 2.5 eV	$T_2 \geq 105$ ms / 2.5 eV	$T_2 \geq 3.3$ ms / 2.5 eV
Medium res event criterium / ΔE	$T_2 \geq 1.6$ ms / 3.0 eV	$T_2 \geq 3.3$ ms / 3.0 eV	$T_2 \geq 6.6$ ms / 3.0 eV	$T_2 \geq 820$ µs / 3.0 eV
Low res event criterium / ΔE	N/A / 15 eV	N/A / 30 eV	N/A / 90 eV	N/A / 15 eV

TRANSLATING TO OVERALL X-IFU COUNT RATE CAPABILITY



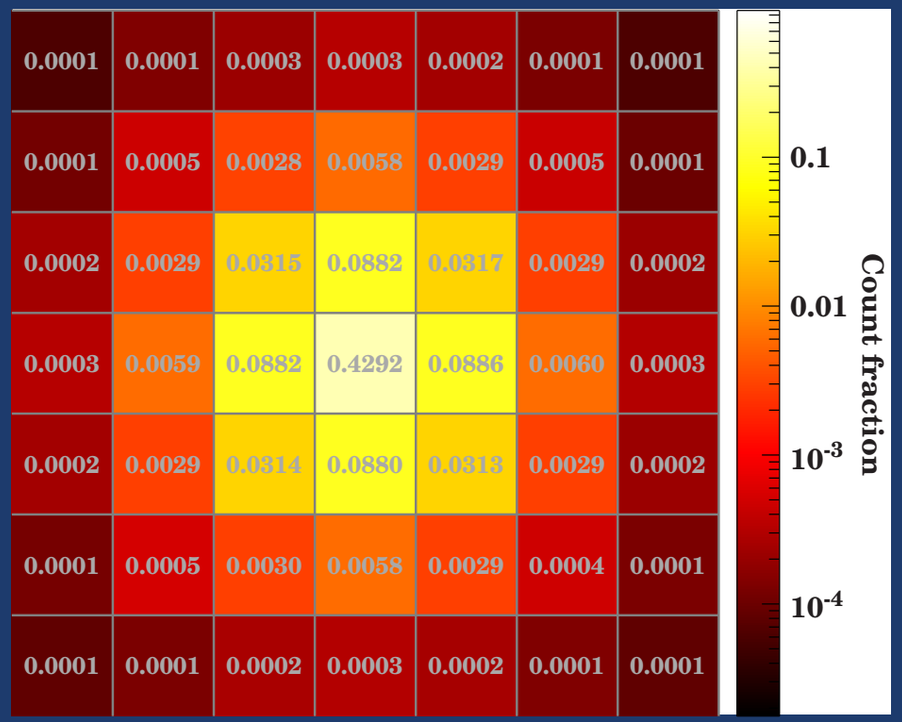
- Crab spectrum defined by an absorbed powerlaw

tbabs*powerlaw

Parameter	nH	Γ	norm
Value	0.4 10^{22} cm^{-2}	2.1	9.5 ph/keV/cm^2/s

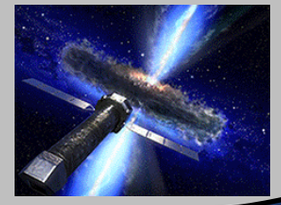
  - 1 mCrab corresponds to ~ 92 cts/s taking gaps into account

- ATHENA PSF used to translate into individual count rates

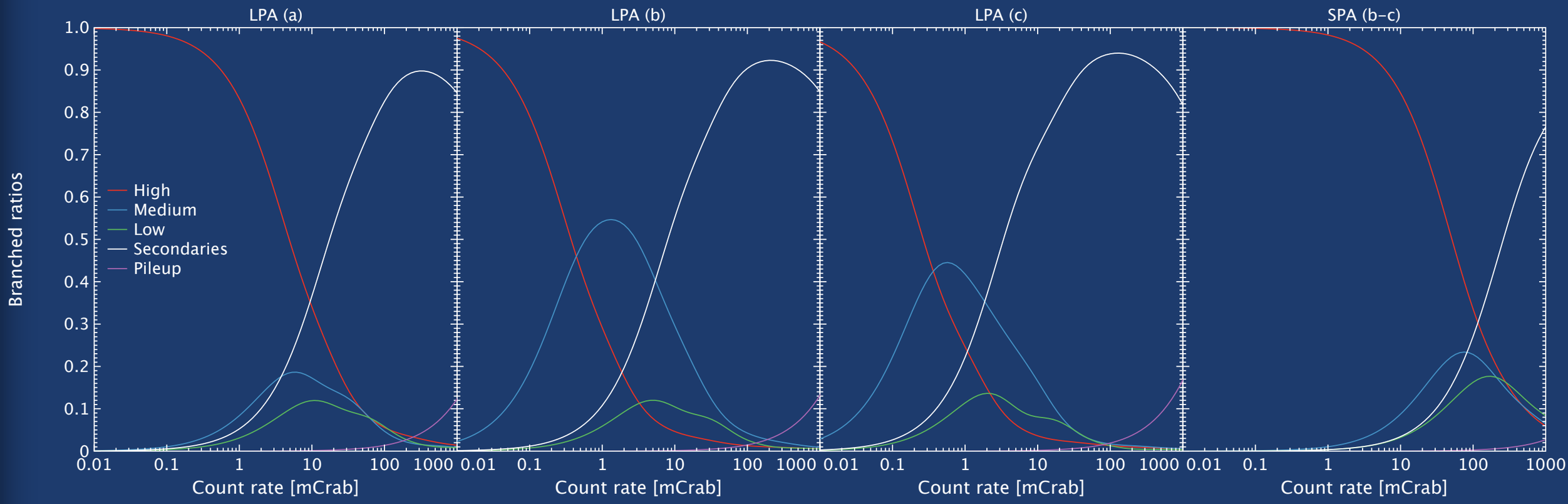


PSF spread on the baseline X-IFU pixels

TRANSLATING TO OVERALL X-IFU COUNT RATE CAPABILITY

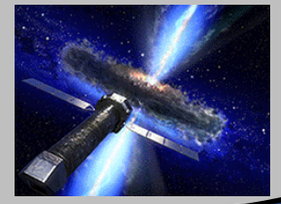


- The event grades scheme allows to estimate the X-IFU count rate capability for different configurations

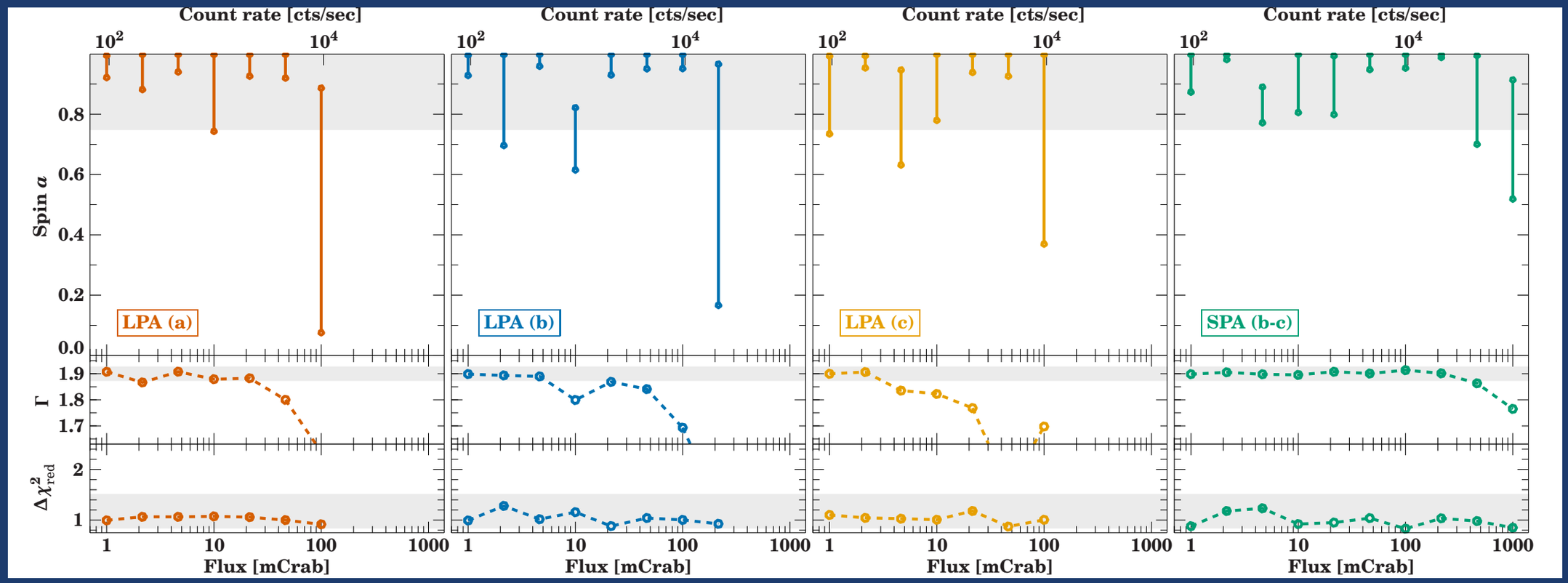


Introducing an SPA improves the CR capability by an order of magnitude

X-IFU SPECTRAL STABILITY



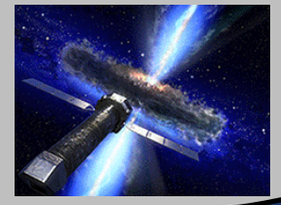
- Verification of the End-to-End count rate capability of the X-IFU through SIXTE simulations
  - Study of spinning black hole spectra with different intensities



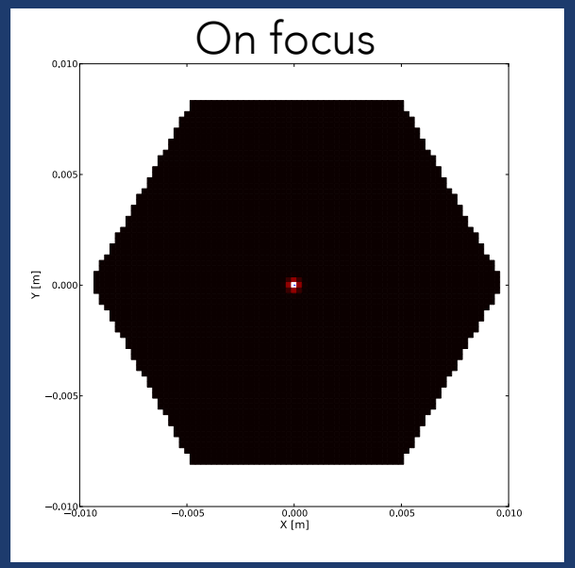
Introducing an SPA improves the spectral stability by an order of magnitude

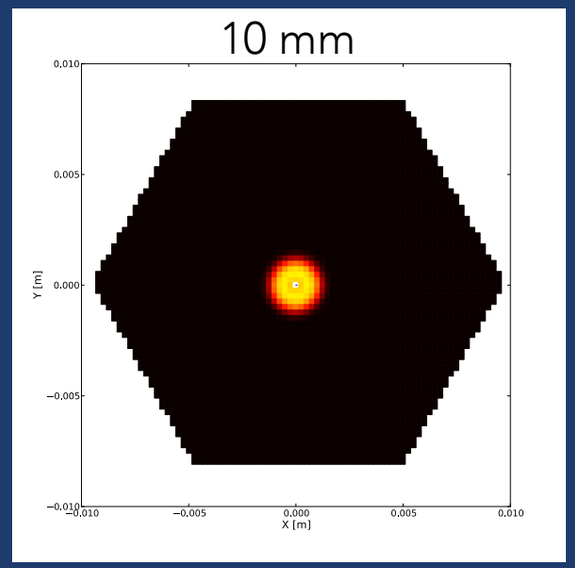
Philippe Peille

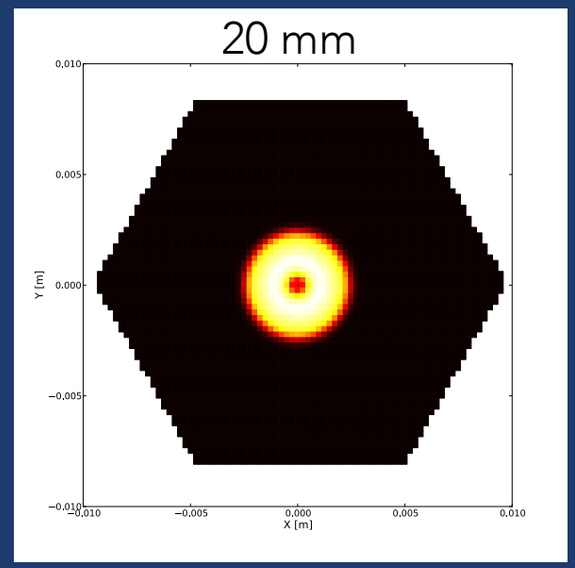
DEFOCUSING

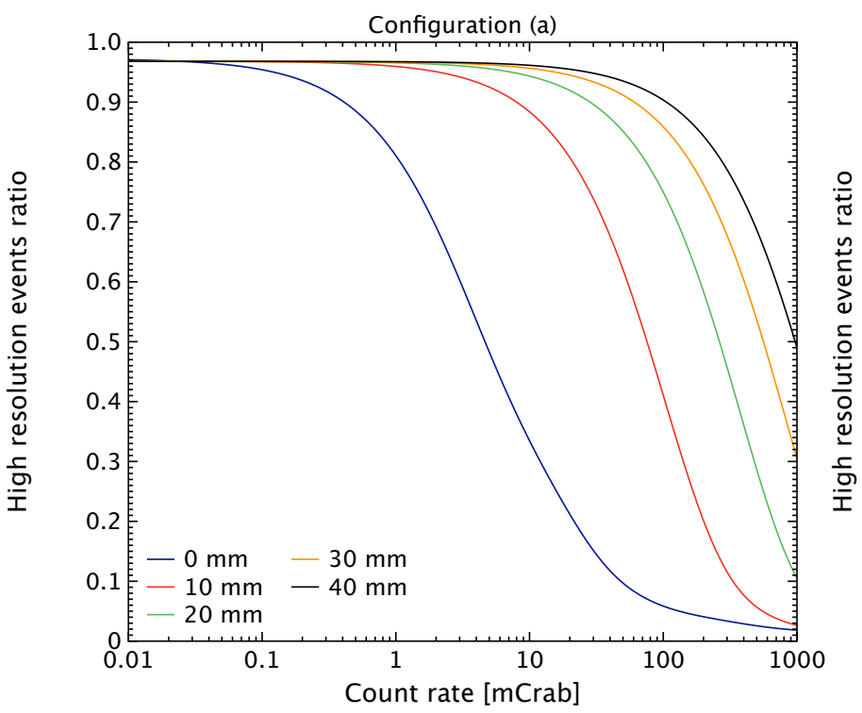


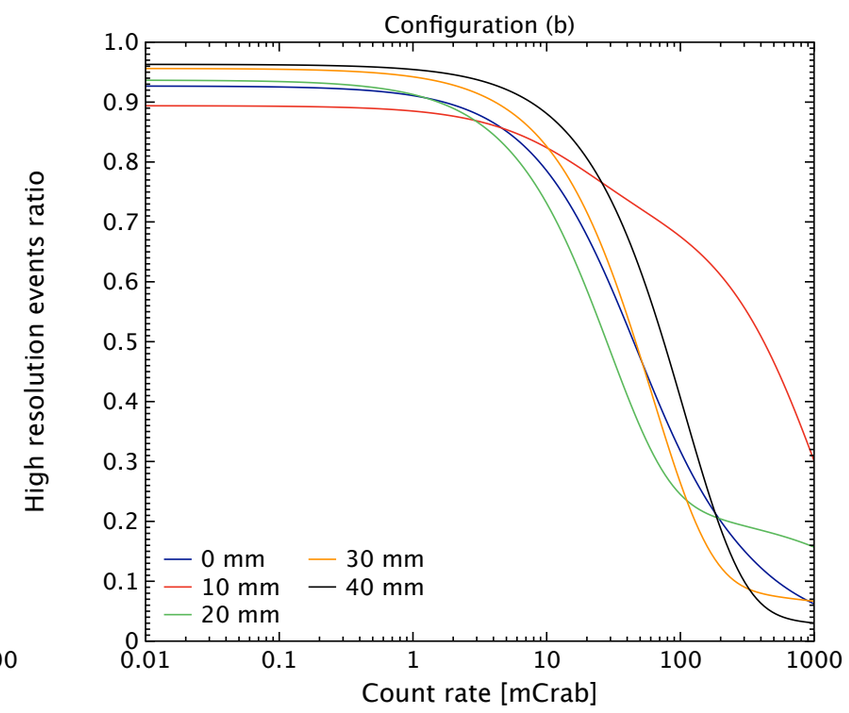
- PSFs sent to the E2E team by Dick Willingale for different defocussing offsets
  - Count rate capability study redone with defocused PSFs

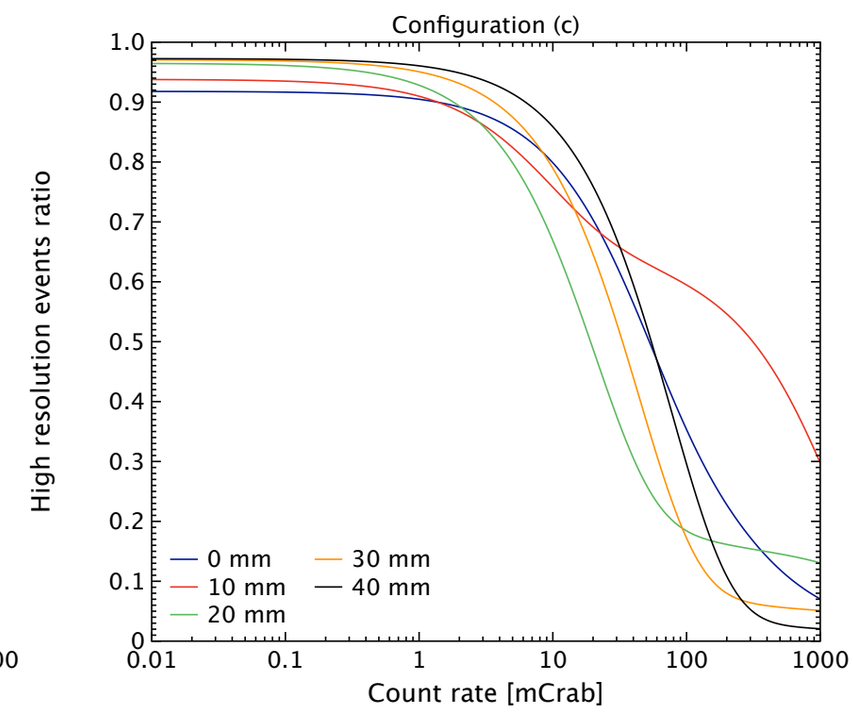




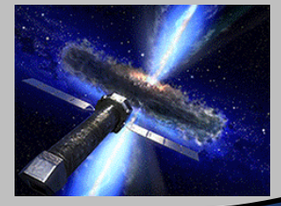






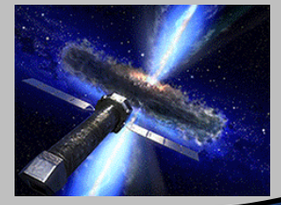


Next step: Crosstalk



- At high count rates, a significant fraction of events will be influenced by crosstalk events from neighbor pixels
  - Thermal crosstalk through TES array substrate
  - Electrical crosstalk through FDM multiplexing and non-linearity of the readout chain
- Crosstalk may be a limiting factor for bright source observations requiring the nominal energy resolution
  - WHIM absorption lines detection through gamma-ray afterglows
- First implementation in SIXTE using 1- and N-dimensional coupling matrices
  - Parametrization already implemented in SIXTE

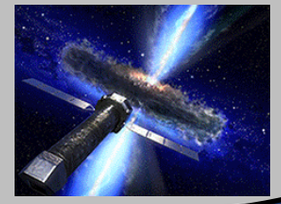
NEXT STEP: CROSSTALK



- Crosstalk implementation in the advanced detector XML

```
<?xml version="1.0"?>

<pixdetector type="x-ifu" npix="324" xoff="0" yoff="0">
    <readout_freq value="156.25e3">

    <grading num="1" name="high" pre="128" post="512" rmf="athena_xifu_rmf_highres_v20150609.rmf"/>
    <grading num="2" name="mid" pre="128" post="128" rmf="athena_xifu_rmf_midres_v20150609.rmf"/>
    <grading num="3" name="low" pre="128" post="0" rmf="athena_xifu_rmf_lowres_v20150609.rmf"/>

    <threshold_event_lo_keV value="5.e-2"/>
    <channel_freq_list filename="roland_chan.dat"/>

    <crosstalk>
        <thermalcrosstalk distance="4.01e-6" weight="1e-3" />
        <thermalcrosstalk distance="5.66e-6" weight="4e-4" />
        <electricalcrosstalk R0="1.1e-3" Lfprim="120e-9" Lcommon="2.5e-9" Lfsec="2e-6"/>
        <timedependence filename="SPA_timedep_crossweights_6keV.dat" pixeltype="SPA"/>
        <intermodulation filename="nlxtlk-lut-v5.fits"/>
    </crosstalk>

    <loop start="0" end="17" increment="1" variable="$l" offset="-8.5">
        <loop start="0" end="17" increment="1" variable="$c" offset="-8.5">
            <pixel>
                <shape posx="$c" delx="110e-6" posy="$l" dely="110e-6" width="106e-6" height="106e-6"/>
            </pixel>
        </loop>
    </loop>

</pixdetector>
```

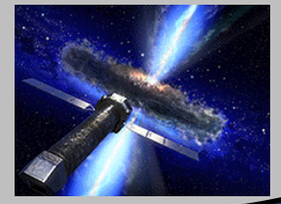
Next step: Crosstalk



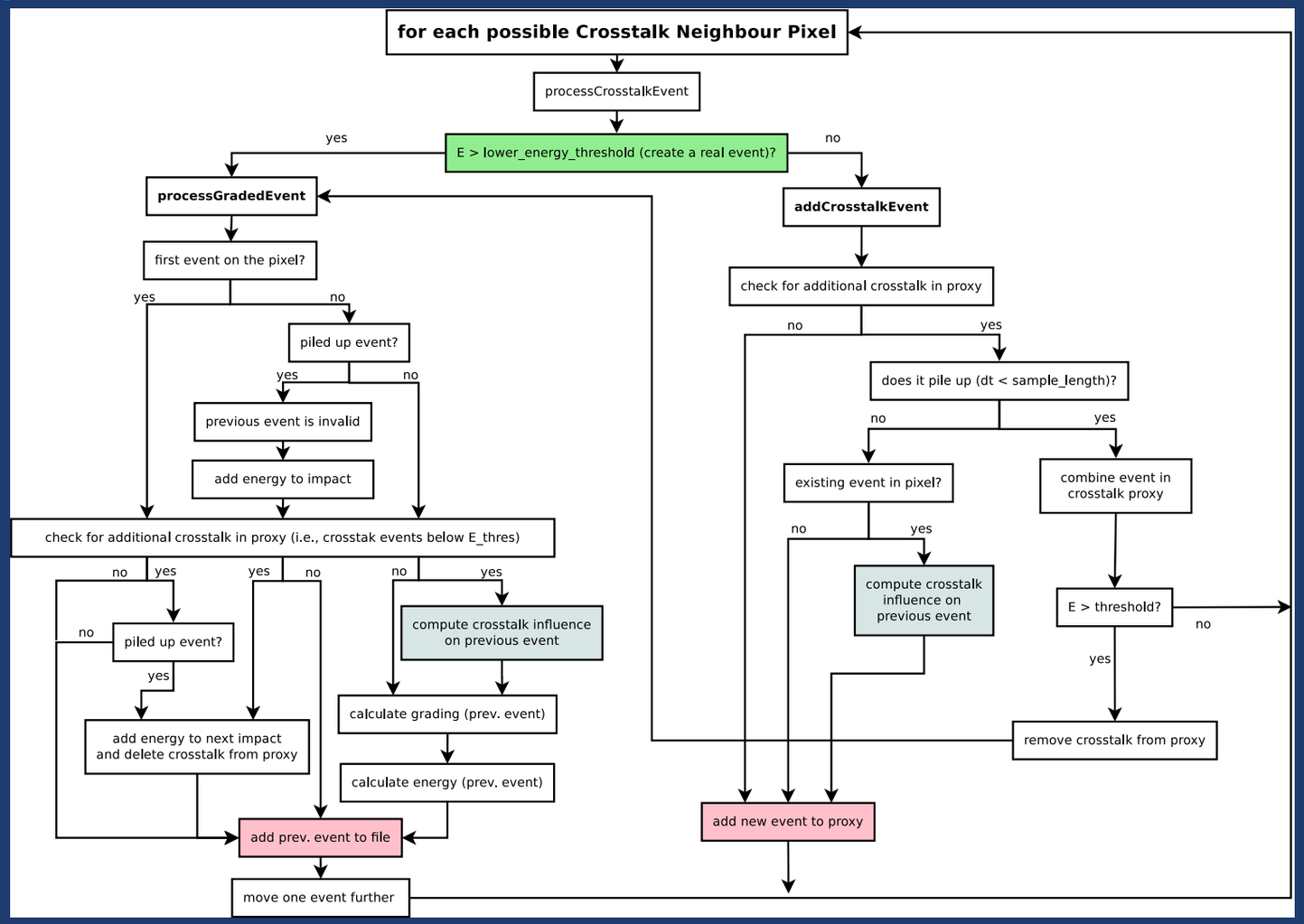
- Read-out channels on a small pixel array

306 1300.0	307 3625.0	308 4675.0	309 1720.0	310 5348.1	311 4058.1	312 4541.9	313 5025.6	314 2445.6	315 5025.6	316 1881.2	317 5348.1	318 3090.6	319 1397.5	320 4703.1	321 3775.0	322 1000.0	323 1300.0
288 1000.0	289 2425.0	290 4375.0	291 3475.0	292 3251.9	293 3735.6	294 1881.2	295 1397.5	296 3090.6	297 3735.6	298 3251.9	299 2445.6	300 3574.4	301 2606.9	302 2125.0	303 2725.0	304 2425.0	305 3625.0
270 3775.0	271 2725.0	272 4825.0	273 4075.0	274 1450.0	275 2929.4	276 2284.4	277 3574.4	278 4380.6	279 2768.1	280 1720.0	281 2042.5	282 5186.9	283 3925.0	284 1600.0	285 4825.0	286 4375.0	287 4675.0
252 4703.1	253 2125.0	254 1600.0	255 3175.0	256 2575.0	257 2042.5	258 1558.8	259 2768.1	260 1236.2	261 4380.6	262 3413.1	263 3896.9	264 1236.2	265 4525.0	266 3175.0	267 4075.0	268 3475.0	269 1720.0
234 1397.5	235 2606.9	236 3925.0	237 4525.0	238 2875.0	239 1750.0	240 4703.1	241 3413.1	242 4864.4	243 4058.1	244 1558.8	245 2929.4	246 2275.0	247 2875.0	248 2575.0	249 1450.0	250 3251.9	251 5348.1
216 3090.6	217 3574.4	218 5186.9	219 1236.2	220 2275.0	221 3325.0	222 4225.0	223 5186.9	224 4219.4	225 1075.0	226 2284.4	227 1900.0	228 3325.0	229 1750.0	230 2042.5	231 2929.4	232 3735.6	233 4058.1
198 5348.1	199 2445.6	200 2042.5	201 3896.9	202 2929.4	203 1900.0	204 1150.0	205 2606.9	206 1075.0	207 4541.9	208 4864.4	209 1150.0	210 4225.0	211 4703.1	212 1558.8	213 2284.4	214 1881.2	215 4541.9
180 1881.2	181 3251.9	182 1720.0	183 3413.1	184 1558.8	185 2284.4	186 4864.4	187 3025.0	188 3896.9	189 4219.4	190 3025.0	191 2606.9	192 5186.9	193 3413.1	194 2768.1	195 3574.4	196 1397.5	197 5025.6
162 5025.6	163 3735.6	164 2768.1	165 4380.6	166 4058.1	167 1075.0	168 4541.9	169 4219.4	170 4975.0	171 4975.0	172 3896.9	173 1075.0	174 4219.4	175 4864.4	176 1236.2	177 4380.6	178 3090.6	179 2445.6
144 2445.6	145 3090.6	146 4380.6	147 1236.2	148 4864.4	149 4219.4	150 1075.0	151 3896.9	152 4975.0	153 4975.0	154 4219.4	155 4541.9	156 1075.0	157 4058.1	158 4380.6	159 2768.1	160 3735.6	161 5025.6
126 5025.6	127 1397.5	128 3574.4	129 2768.1	130 3413.1	131 5186.9	132 2606.9	133 3025.0	134 4219.4	135 3896.9	136 3025.0	137 4864.4	138 2284.4	139 1558.8	140 3413.1	141 1720.0	142 3251.9	143 1881.2
108 4541.9	109 1881.2	110 2284.4	111 1558.8	112 4703.1	113 4225.0	114 1150.0	115 4864.4	116 4541.9	117 1075.0	118 2606.9	119 1150.0	120 1900.0	121 2929.4	122 3896.9	123 2042.5	124 2445.6	125 5348.1
90 4058.1	91 3735.6	92 2929.4	93 2042.5	94 1750.0	95 3325.0	96 1900.0	97 2284.4	98 1075.0	99 4219.4	100 5186.9	101 4225.0	102 3325.0	103 2275.0	104 1236.2	105 5186.9	106 3574.4	107 3090.6
72 5348.1	73 3251.9	74 1450.0	75 2575.0	76 2875.0	77 2275.0	78 2929.4	79 1558.8	80 4058.1	81 4864.4	82 3413.1	83 4703.1	84 1750.0	85 2875.0	86 4525.0	87 3925.0	88 2606.9	89 1397.5
54 1720.0	55 3475.0	56 4075.0	57 3175.0	58 4525.0	59 1236.2	60 3896.9	61 3413.1	62 4380.6	63 1236.2	64 2768.1	65 1558.8	66 2042.5	67 2575.0	68 3175.0	69 1600.0	70 2125.0	71 4703.1
36 4675.0	37 4375.0	38 4825.0	39 1600.0	40 3925.0	41 5186.9	42 2042.5	43 1720.0	44 2768.1	45 4380.6	46 3574.4	47 2284.4	48 2929.4	49 1450.0	50 4075.0	51 4825.0	52 2725.0	53 3775.0
18 3625.0	19 2425.0	20 2725.0	21 2125.0	22 2606.9	23 3574.4	24 2445.6	25 3251.9	26 3735.6	27 3090.6	28 1397.5	29 1881.2	30 3735.6	31 3251.9	32 3475.0	33 4375.0	34 2425.0	35 1000.0
0 1300.0	1 1000.0	2 3775.0	3 4703.1	4 1397.5	5 3090.6	6 5348.1	7 1881.2	8 5025.6	9 2445.6	10 5025.6	11 4541.9	12 4058.1	13 5348.1	14 1720.0	15 4675.0	16 3625.0	17 1300.0

Next step: Crosstalk



- First implementation of the crosstalk mechanism already available in SIXTE
  - Currently being tested



- First assessment of the crosstalk impact to the X-IFU bright source science will be presented at the next SPIE meeting

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