May 11th, 2012
SuperB-SVT meeting

update on Strasbourg activities on CMOS pixel developments & effect of high occupancy on SVT performances

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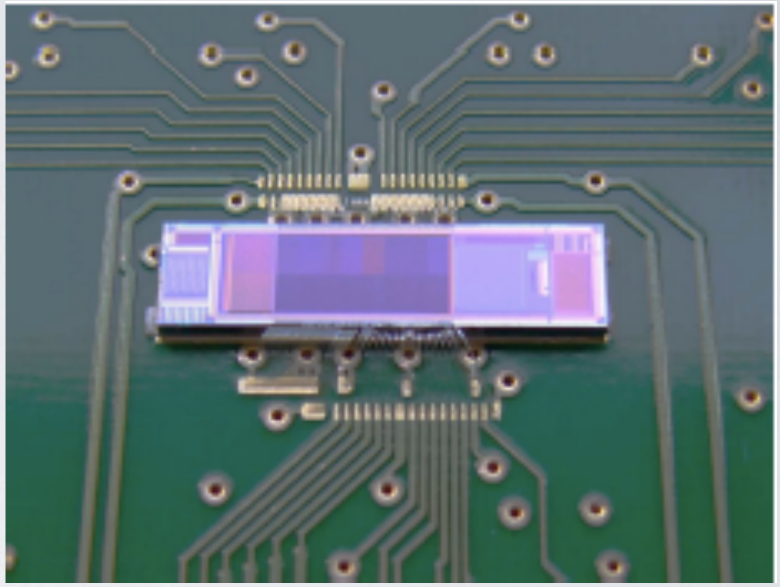
I.

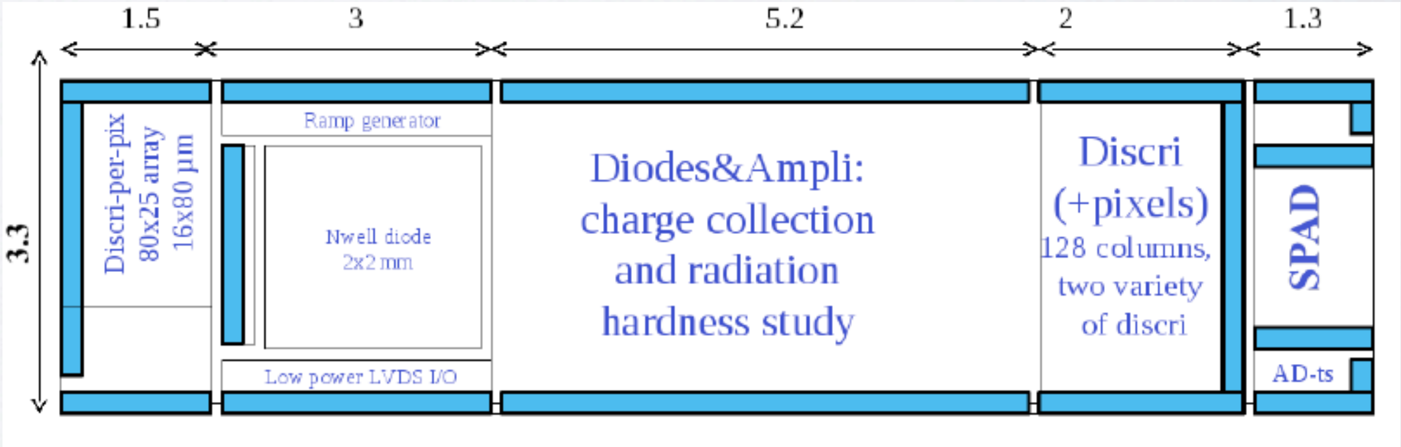
Update on Strasbourg activities on CMOS pixel sensor developments for the SuperB SVT

MIMOSA-32: 0.18 μm technology exploration



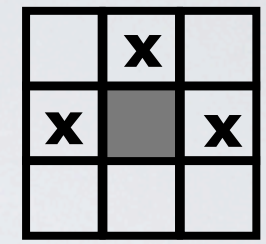
- Submitted in Oct. 2011, delivered in January 2012.
  ➛ lab. tests since April 2012.
- Technology:
  - epitaxial layer: 18 μm thick, High-Resistivity 1-5 kΩ.cm,
  - quadruple well: deep P-type skin embedding N-well hosting P-MOS transistors,
  - 4 Metal Layers (6 ML at next submission in 2012).
- Prototype sub-divided in several blocks:
  - Explore pixel sizes: 20x20, 20x40 and 20x80 μm^2.
  - Explore charge amplification / collection systems: diode sizes ~9-15 μm^2, N-MOS and P-MOS transistor based amplifiers.
  - Explore discrimination: 1 sub-array of 128 columns with 1 discriminator at each column end, and one sub-array with in-pixel discrimination (16x80 μm^2 pixels).

  ➛ total surface ~ 43 mm^2.

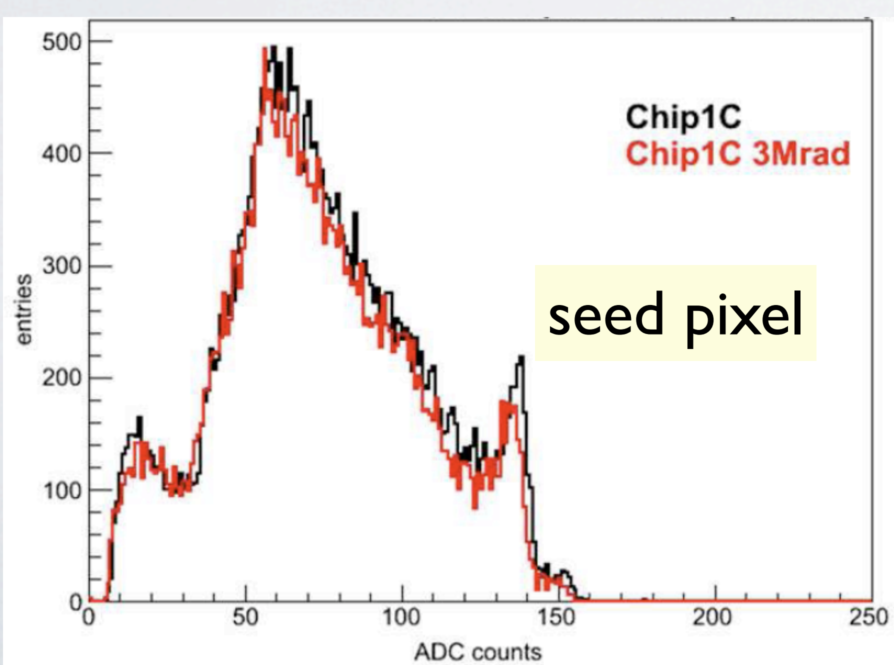


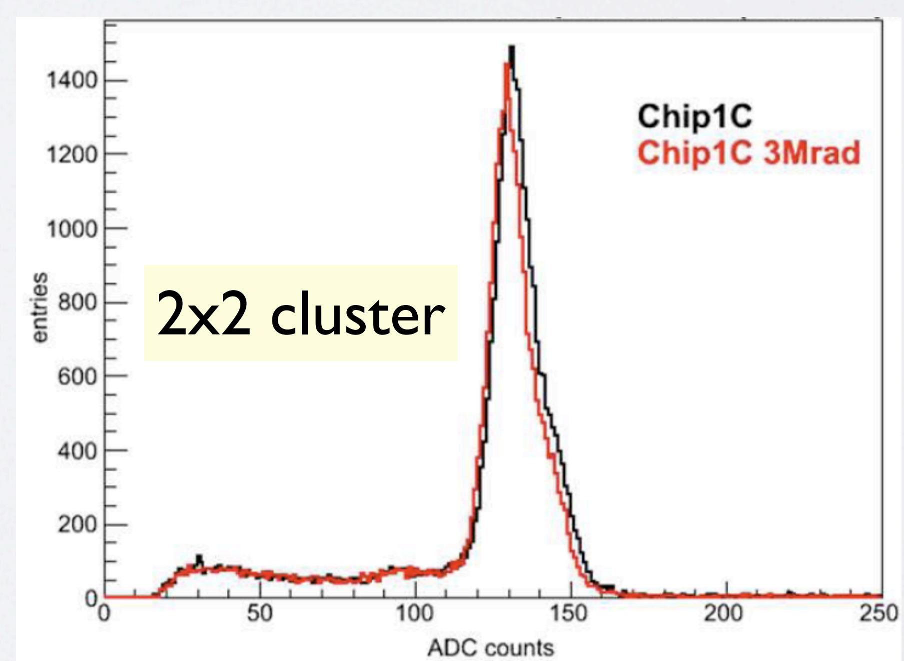
preliminary 0.18 µm process tests results

- Charge collection efficiency with 20x20 µm^2 pixels: lab tests with ^{55}Fe source.
  - · seed pixel: 40-50 % of total charge
    ➛ corresponds to S/N ~ 30.
  - · 2x2 pixels cluster (1st crown): nearly 100 % of total charge.
  - ➛ confirms HR (limited thermal diffusion),
    and no parasitic charge collection with deep P-well.
  - · with 20x40 µm^2 pixels: seed ~ 30 % and 1st crown ~ 75 %.



- Noise: ~15-20 e$^-$ at room T°.
- Irradiation: 3 MRad ➛ no impact at room T° (tests on going after 6 and 8 MRad).
  Non ionising radiations: 6 chips have been irradiated at $3x10^{12}$ - 10^{13} - $3x10^{13}$ n_{eq}/cm^2
  ➛ results next week.



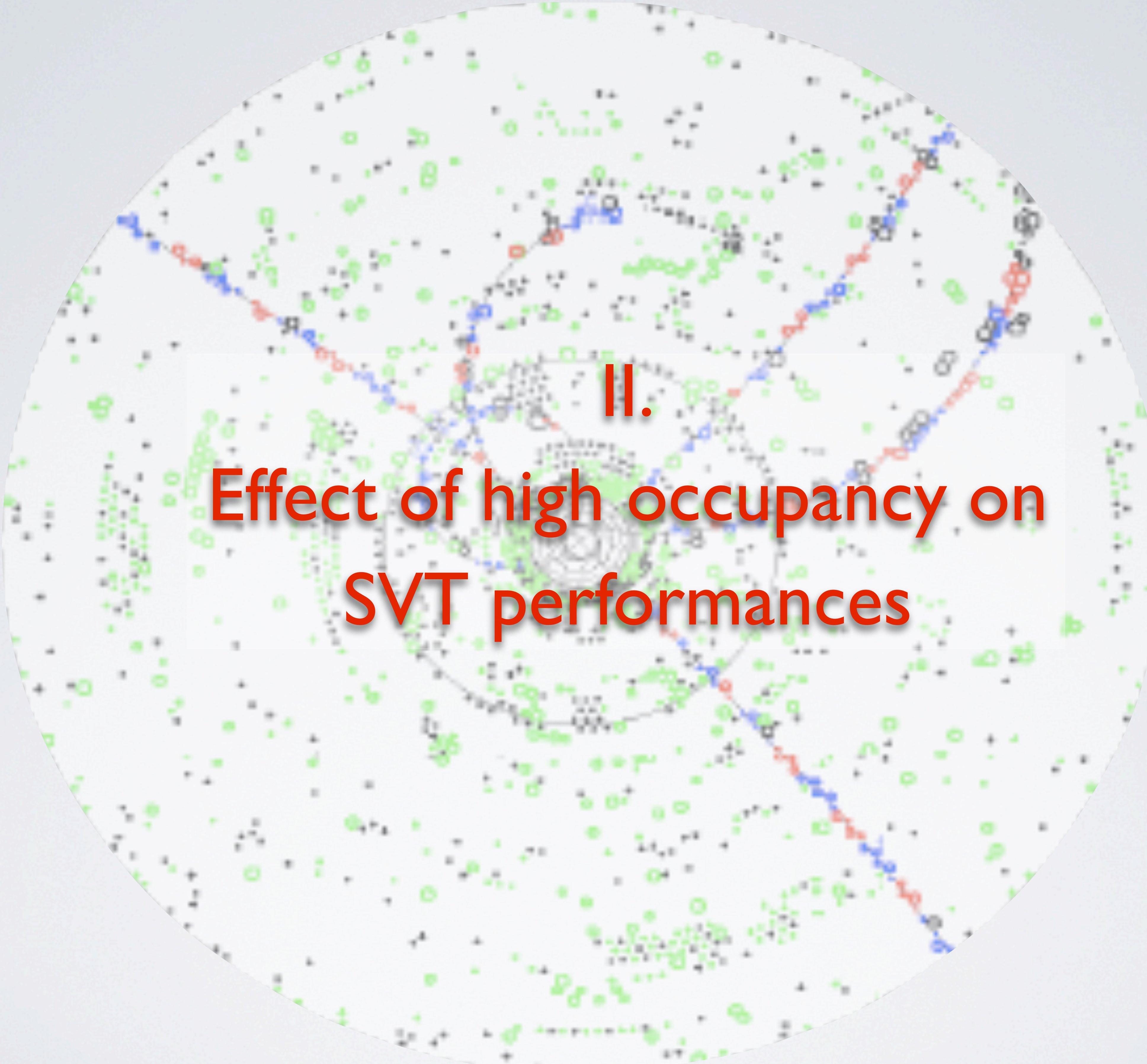


➛ **more results to come.**

next steps

"towards a read-out time ~ 1.5 µs"

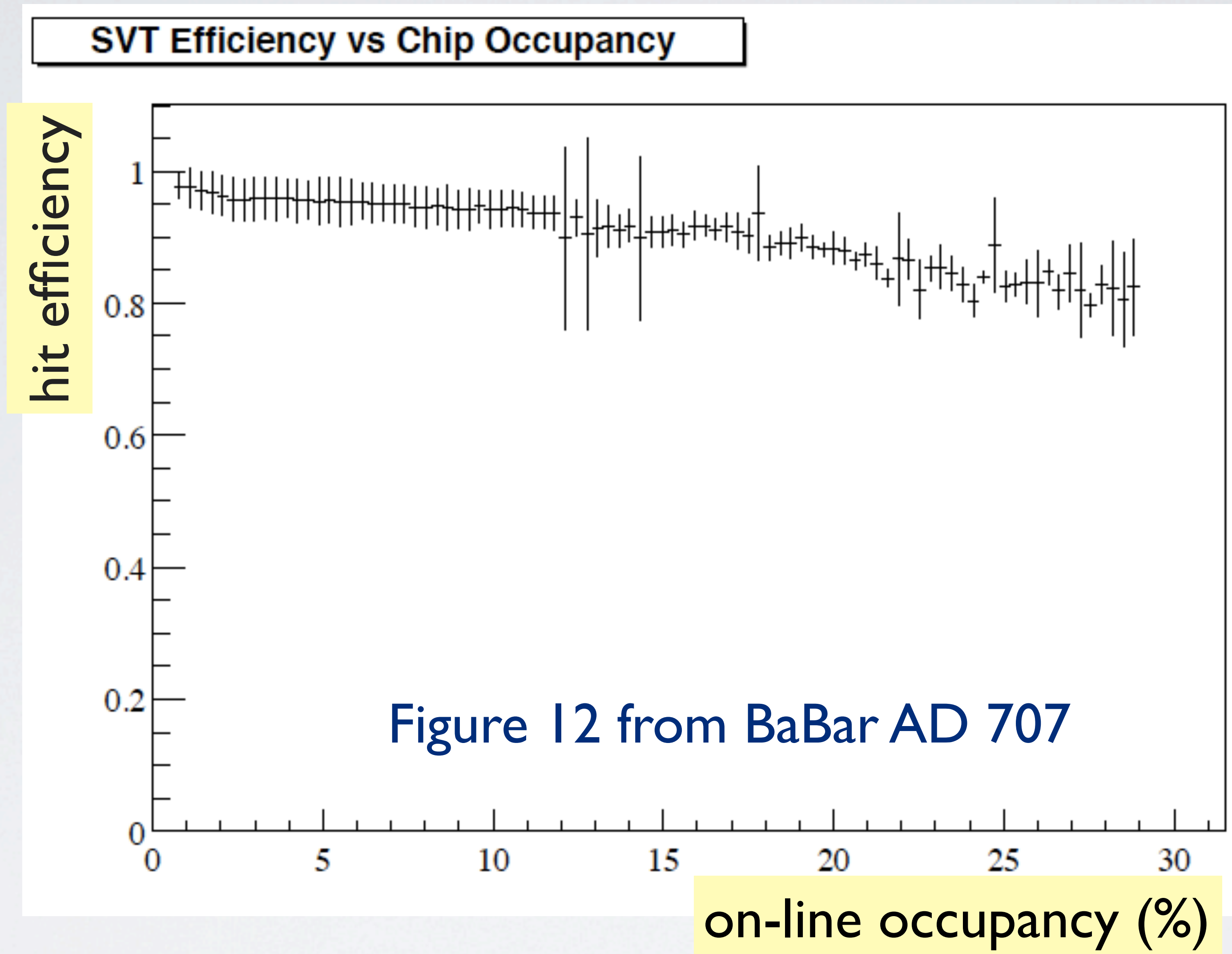
- MIMOSA-32: validation of the 0.18 µm technology.
  - Beam tests in June-August 2012:
    analog output, digital output, non-ionising radiation tolerance.
  - Next submissions:
    - MIMOSA-32bis (Spring 2012): standard epitaxial layer ➛ lab. tests in Summer 2012.
    - MIMOSA-32ter (July 2012): alternative in-pixel amplification schemes.
- MIMOSA-22THR: validation of the optimised rolling shutter architecture.
  - Submission Autumn 2012.
  - 2 different chips:
    - translation of MIMOSA-22AHR (0.35 µm techno.) with end-of-column discrimination.
    - simultaneous 2-row encoding with 2 discriminators/column ➛ twice faster.
- AROM-1 (Accelerated Read-Out Mimosa): validation of the in-pixel discrimination.
  - Submission Autumn 2012.
  - Simultaneous 4-row encoding with in-pixel discrimination ➛ 8 times faster.
- SUZE-02: validation of the sparsification.
  - Submission Autumn 2012.
  - Sparsification for 2 and 4 // rows ➛ data flow and power reduction.



II.

Effect of high occupancy on SVT performances

study of tracking performances with BaBar data



BaBar AD 707: Final Report of the SVT Long Term Task Force (2004):
Study with BaBar dimuon data taken between Jan. and June 2003 (instantaneous luminosity increasing), of hit efficiency as a function of chip on-line occupancy.

➢ how to translate this BaBar study to SuperB?

on-line occupancy (1)

- On-line occupancy: number of hits during the on-line time window
  = on-line strip occupancy.

In SuperB: we know the off-line strip occupancy
(see Giuliana's presentation "background inputs for performance studies and electronics design", SVT 13 April 2012):

➛ $$\text{on-line occupancy} = \text{off-line occupancy} \times \frac{\text{on-line time window}}{\text{off-line time window}}$$

see calculations on next slide.

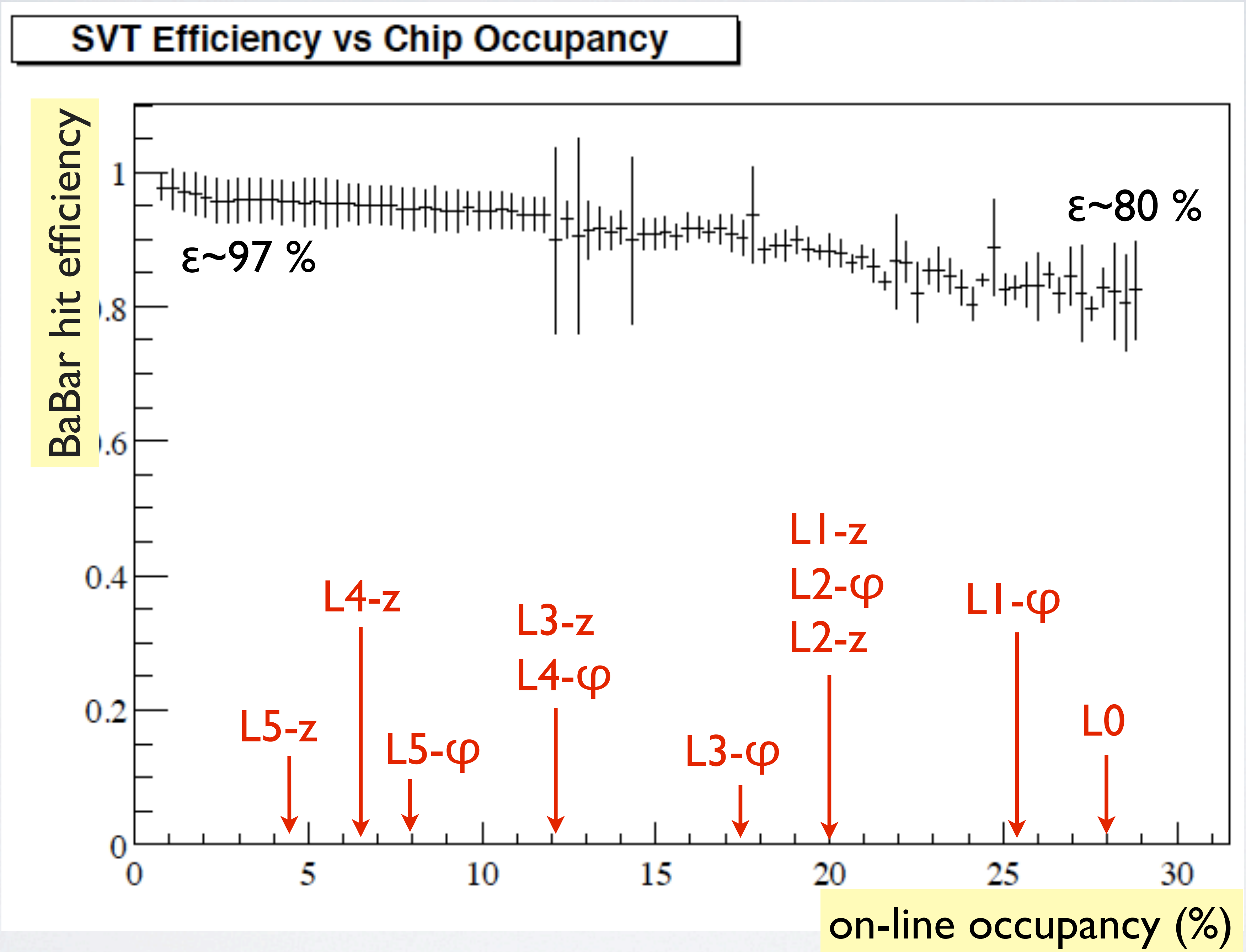
on-line occupancy (2)

Layer	on-line time window (ns)	off-line time window (5xσt_0)(ns)	strip rate (kHz) (x5 included)	off-line strip occupancy (x5 included)	on-line occupancy (x5 included)
0 φ	300	100	932.0	0.093	0.280
0 z	300	100	932.0	0.093	0.280
1 φ	300	150	847.9	0.127	0.254
1 z	300	150	670.0	0.101	0.201
2 φ	300	150	664.9	0.100	0.199
2 z	300	150	665.2	0.100	0.200
3 φ	300	250	577.0	0.144	0.173
3 z	300	250	394.2	0.099	0.118
4 φ	1000	460	124.1	0.057	0.124
4 z	1000	460	66.43	0.031	0.066
5 φ	1000	800	80.34	0.064	0.080
5 z	1000	800	43.61	0.035	0.044
	A	B	C	D = B x C	E = D x A / B = A x C

new numbers w.r.t. my previous presentation (11 May 2012) → B

from Giuliana's presentation → C

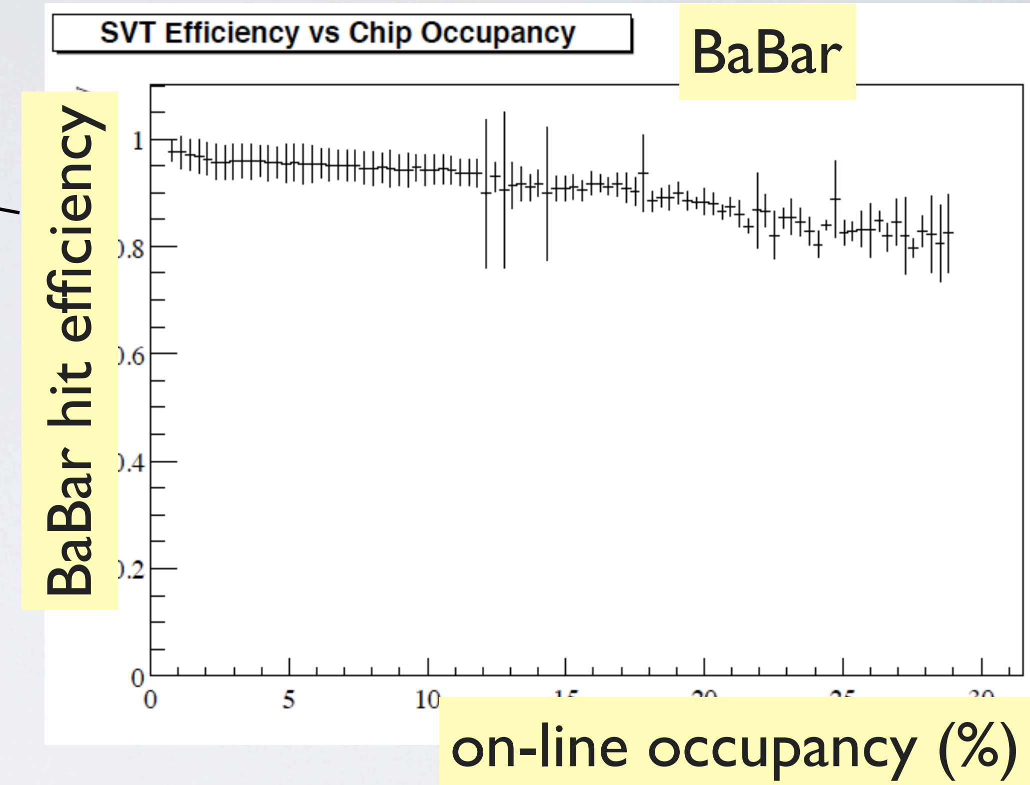
on-line occupancy (3)



➛ **on-line occupancy in SuperB is 2 to 10x higher than in BaBar.**

hit efficiency (I)

BaBar measured
hit efficiency
=
BaBar hit
detection efficiency
x
BaBar hit-to-track
matching efficiency



For the BaBar-to-SuperB translation I first assume that hit-to-track matching efficiency is the same in SuperB and in BaBar, for a given occupancy rate.

SuperB estimated
hit efficiency
=
SuperB hit
detection efficiency
x
hit-to-track matching
efficiency

➛ **this assumes that DCH tracking in SuperB is as good as in BaBar and also each layer intrinsic resolution** (because hit-to-track matching depends on the track extrapolation resolution):

$$P_{match} = \frac{1}{1 + 2\pi\, \sigma_{\phi,\, eff}\ \sigma_{Z,\, eff}\ \rho}$$

$\sigma_{\phi,\, eff}$, $\sigma_{Z,\, eff}$ → intrinsic resolution ⊕ track extrapolation

ρ → hit density ~ integration time

hit efficiency (2)

SuperB hit efficiency
=
SuperB hit detection efficiency
x
SuperB hit-to-track matching efficiency

depends on the electronics (shadowing)
➛ L. Ratti and L. Bombelli's simulations.

Layer	Peaking time (ns)	Bkg x5 (%) (r-ϕ/z)
L0	25	96/96
L1	100	88/89
L2	100	89/89
L3	200	77/86
L4	500	89/93
L5	1000	86/91

depends on the tracking resolution and the detector occupancy
➛ same as in BaBar for the same occupancy:

$$\text{BaBar hit-to-track matching efficiency} = \frac{\text{BaBar hit efficiency}}{\text{BaBar hit detection efficiency}}$$

known from fig. 12 of BaBar AD 7070

➛ $$\text{SuperB hit efficiency} = \text{SuperB hit detection efficiency} \times \frac{\text{BaBar hit efficiency}}{\text{BaBar hit detection efficiency}}$$

need to evaluate the shadowing in BaBar

estimation of BaBar hit detection efficiency (1)

Evaluation of the shadowing in BaBar:

- How many hits are lost during dead time due to analog shaping time?

$$R_{lost} = \text{on-line occupancy} \times \frac{\text{analog shaping time}}{\text{on-line time window}}$$

R_{lost} is the rate of shadowed hits

with:

· on-line time window = 1 μs

· analog shaping time = 2.4 x $\tau_{shaping}$ = 2.4 x 200 ns = 0.48 μs (for BaBar Layer-1).

➛ hit detection efficiency = 1 - R_{lost}

$$\simeq \frac{1}{1 + R_{lost}} = \frac{1}{1 + 0.48 \times \text{on-line occupancy}} \quad \text{if } R_{lost} << 1$$

formula used by Giuliana

➛ see plot on next slide.

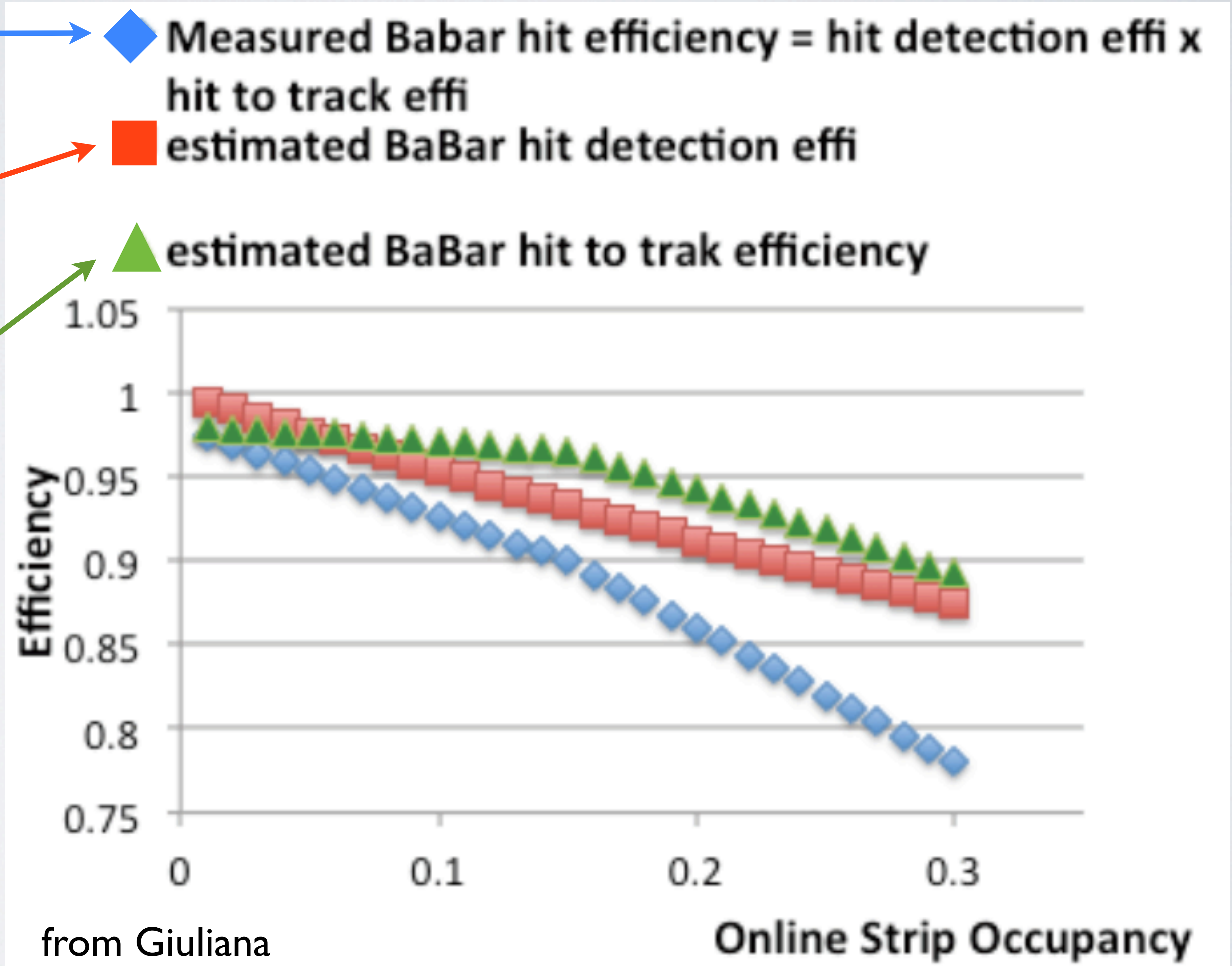
estimation of BaBar hit detection efficiency (2)

measured y-axis of figure 12 from BAD 707

estimation of shadowing $1 / (1+ R_{lost})$

obtained through:

▲ = ◆ / ■



from Giuliana

hit-to-track matching efficiency as a function of off-line cluster occupancy (I)

Finally, the track is matched to a cluster, what really matters is the off-line cluster occupancy.

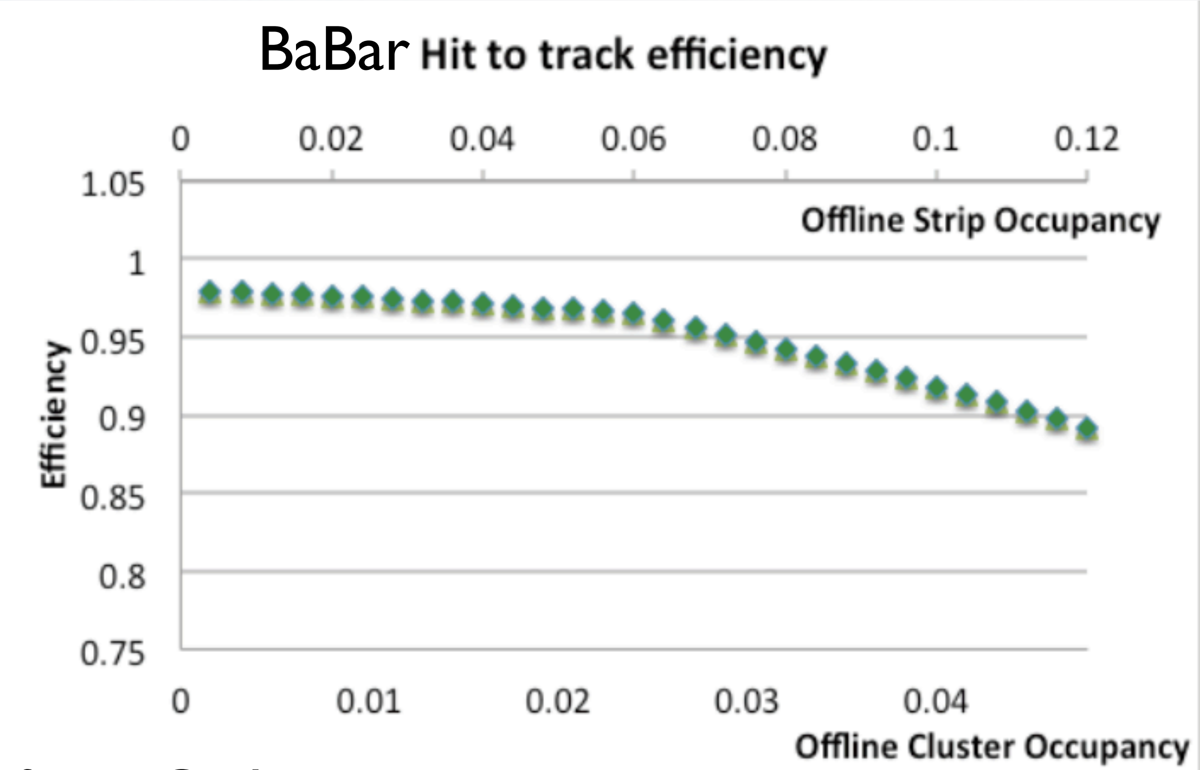
With: off-line strip occupancy = off-line cluster occupancy x nbr of strips/cluster

and: BaBar: ~2.5 strips/cluster.

Then translate the curve "BaBar hit-to-track matching efficiency =f(on-line strip occupancy)" to: "BaBar hit-to-track matching efficiency =f(off-line cluster occupancy)" using:

$$\text{off-line strip occupancy} = \text{on-line strip occupancy} \times \frac{\text{off-line time window}}{\text{on-line time window}}$$

BaBar: 0.4 μs / 1 μs

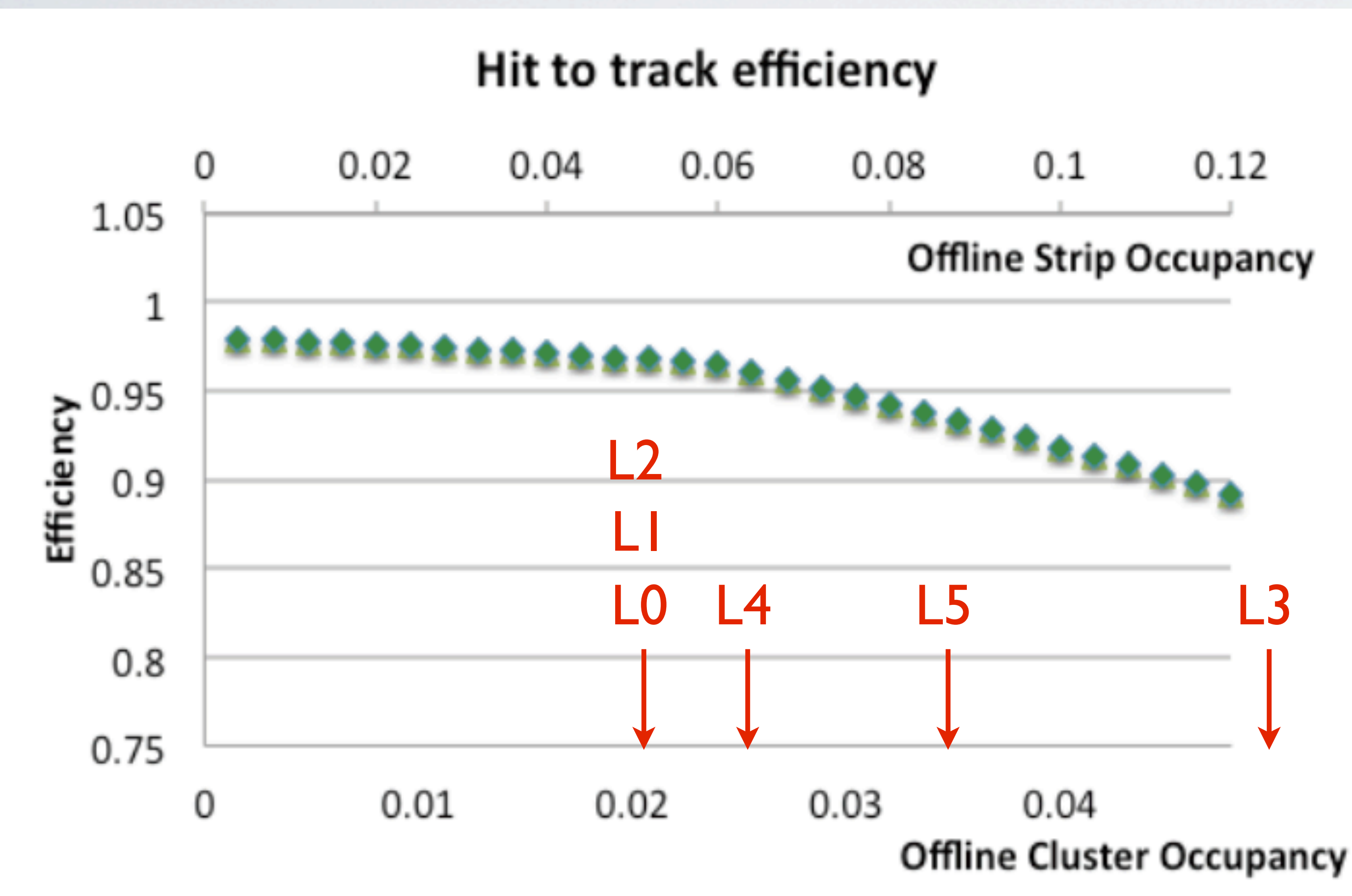


from Giuliana

Finally in BaBar:
off-line cluster occupancy = on-line strip occupancy x 0.16

hit-to-track matching efficiency as a function of off-line cluster occupancy (2)

And then see where SuperB Layers are on this curve:



Layer	View	Strip rate with renormalized area KHz estimates	time window used by neri) ns	offline cluster occupancy (x5 included)
0	1	9.32E+02	100	0.023
0	2	9.32E+02	100	
1	phi	8.479E+02	150	0.022
1	z	6.700E+02	150	
2	phi	6.649E+02	150	0.019
2	z	6.652E+02	150	
3	phi	5.770E+02	250	0.050
3	z	3.942E+02	250	
4	phi	1.241E+02	460	0.025
4	z	6.643E+01	460	
5	phi	8.034E+01	800	0.034
5	z	4.361E+01	800	

estimation of SuperB hit efficiency

Layer	on-line strip occupancy (x5 included)	off-line cluster occupancy (x5 included)	hit detection efficiency (simulation) (x5 included)	hit-to-track matching efficiency (estimation from off-line cluster occ.)	total hit efficiency
0 φ	0.28	0.023	0.96	0.96	0.92
0 z	0.28		0.96		0.92
1 φ	0.25	0.022	0.88	0.96	0.84
1 z	0.20		0.89		0.85
2 φ	0.20	0.019	0.89	0.97	0.86
2 z	0.20		0.89		0.86
3 φ	0.20	0.050	0.77	0.88	0.68
3 z	0.17		0.86		0.76
4 φ	0.12	0.025	0.89	0.96	0.85
4 z	0.07		0.93		0.89
5 φ	0.08	0.034	0.86	0.93	0.80
5 z	0.04		0.91		0.85

next steps

- List all assumptions I have made to obtain this BaBar to SuperB translation, to decide whether the result is a best- or a worst-case.
- Examples of comparisons with FastSim results:
  - probability that a track is successfully associated with all its correctly measured hits ➛ $\prod$ hit-to-track matching probability for each layer.
  - rate of tracks to which the measured hit in Layer-0 has not been associated.
- What about the SVT stand-alone tracking? Important for low momentum particles and detector alignment.
- Decide what conclusion can be done and write the corresponding part in the TDR.