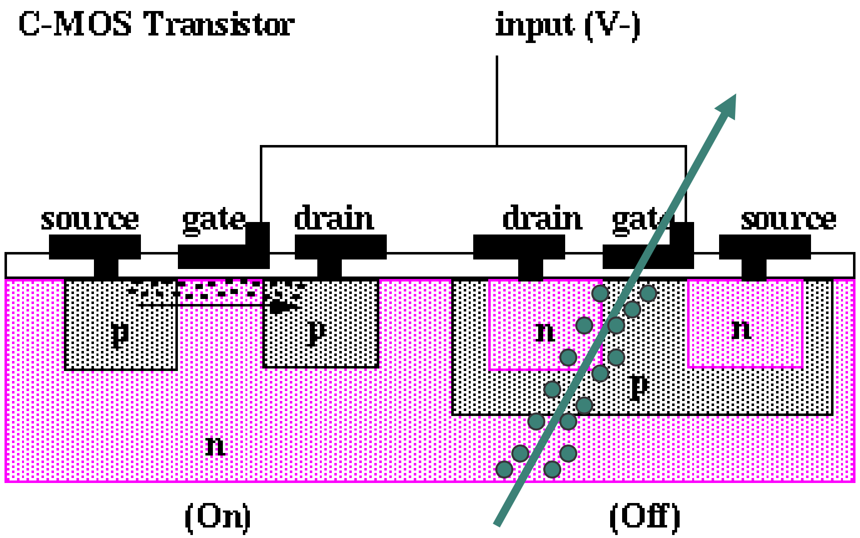
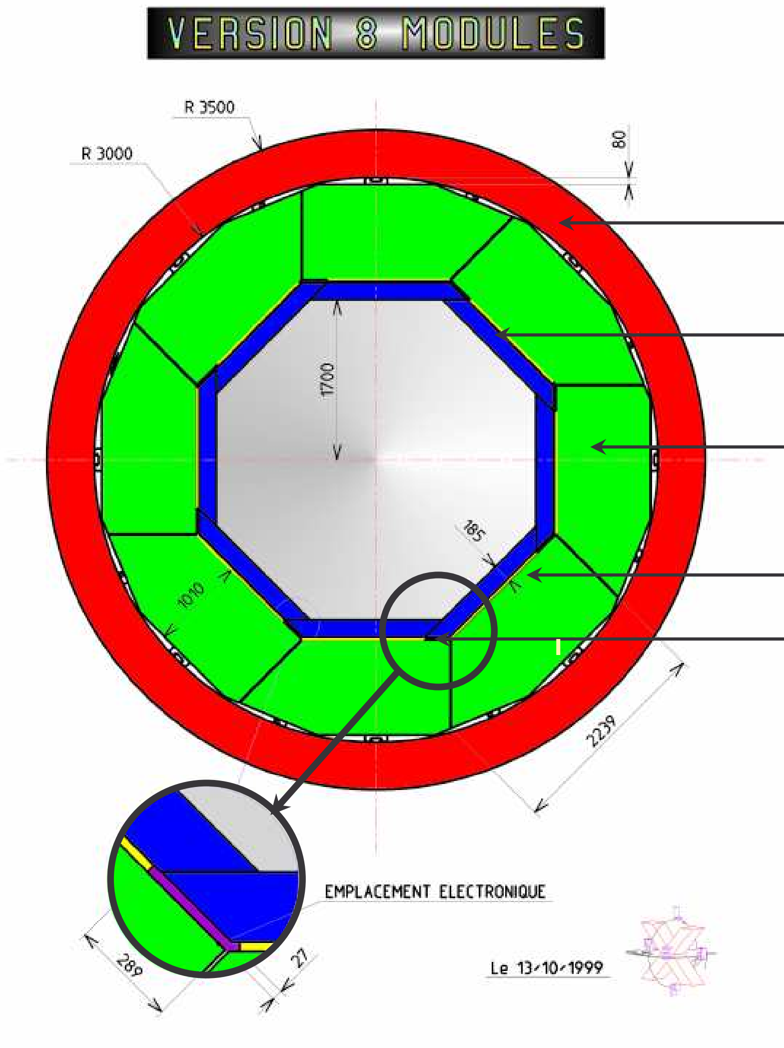
Estimation of SEUs in the FPGAs



C. Targett-Adams
V. Bartsch,
M. Wing
M. Warren,
M. Postranecky

FPGAs



magnet

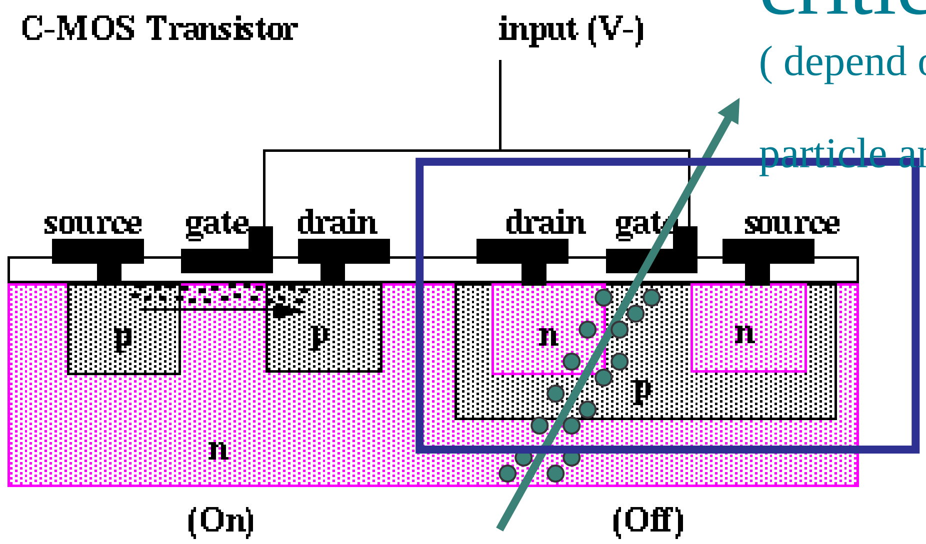
ECAL, 30 slabs stacked on top each other,
in z direction 25 slabs next to each other
extends to |eta|=1.1

HCAL

very frontend electronics (VFE) based on ASICs

frontend electronics (FE) based on FPGAs,
1 FPGA/slab

SEU dependence



critical energy

(depend on angle and entry point of the incident particle and its energy at each point of the volume)

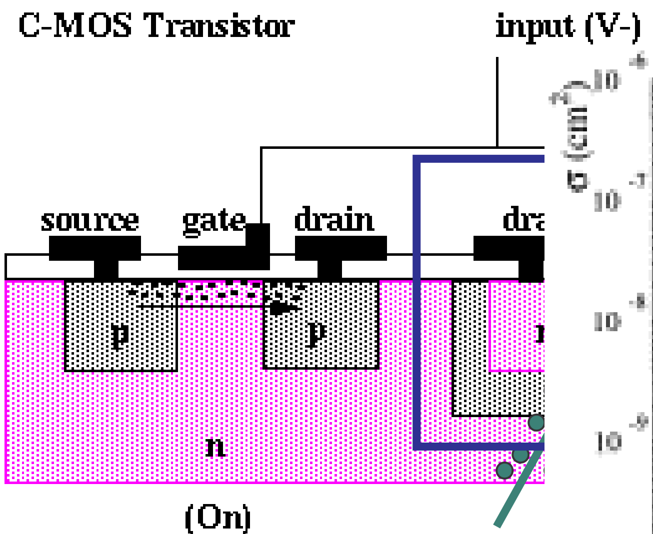
sensitive volume

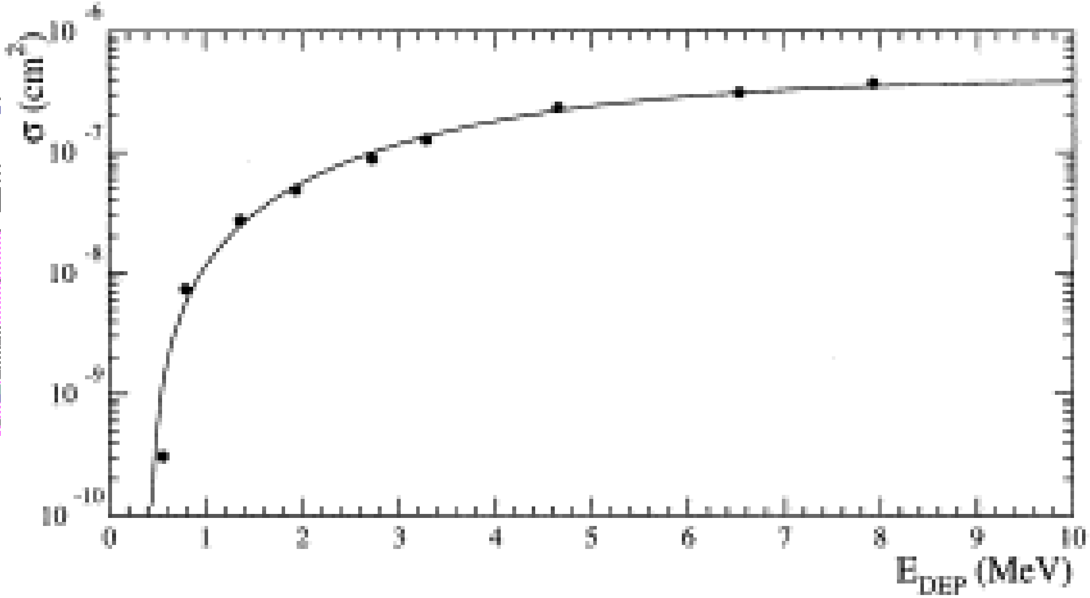
(can be guessed by irradiating with different ions with a different linear energy transfer, plus guessing the dephts of the device => Weibull fit which gives the cross sectional area of the sensitive region per node)

look for particles which deposit much charge in small area

SEU dependence

critical energy





look for particles
charge in small a

Weibull fit

described in E. Normand, Extensions of the Burst Generation Rate Method for Wider Application to p/n induced SEEs

interesting physics processes

- ttbar:
  – 50-70 events/hour depending on CMS energy
- WW
  – 800-900 events/hour
- QCD events
  – 0.02-0.1 ev/BX => 7-9Mio events/hour
  – Photon/photon 0.1-0.02 per bunchx

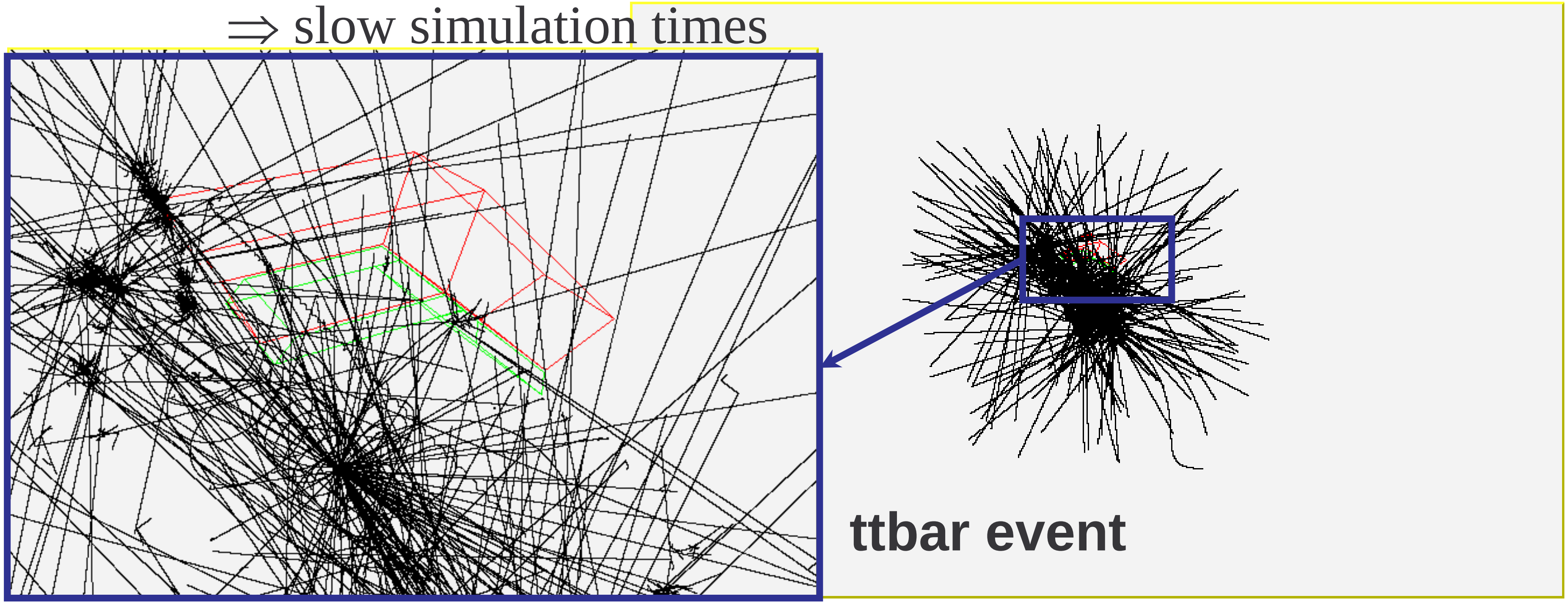
from the TESLA TDR

simulation

turns out that one can not make too many spatial cuts

$\Rightarrow$ need to simulate whole events

$\Rightarrow$ slow simulation times



Cut: |eta|<2

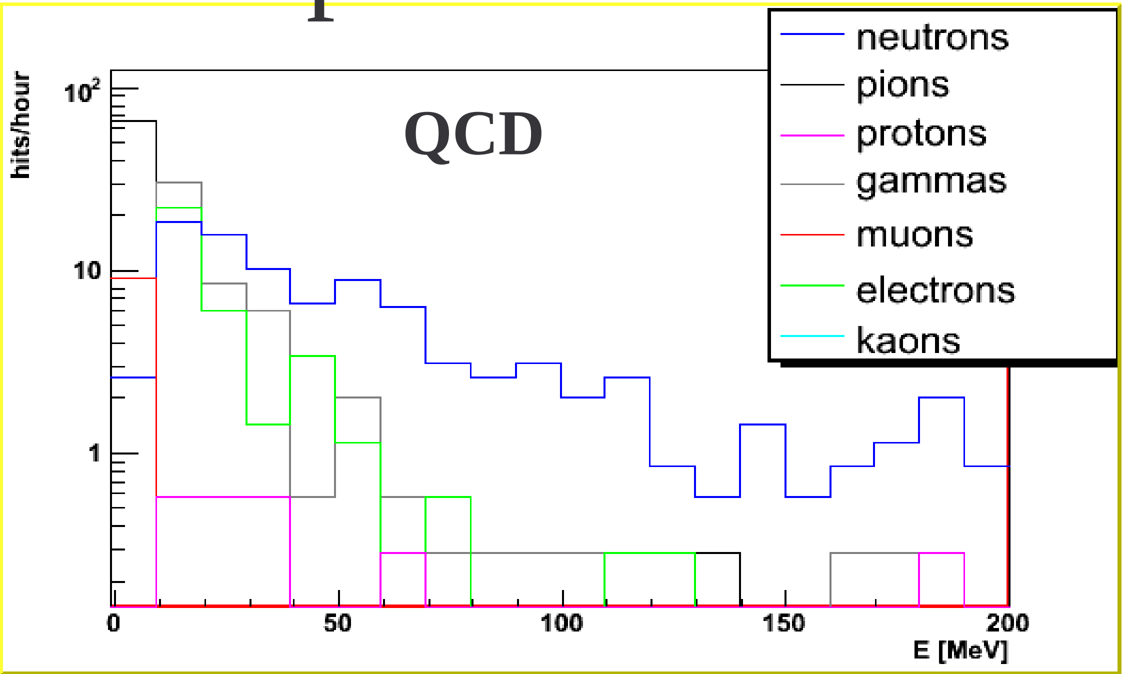
Selection:

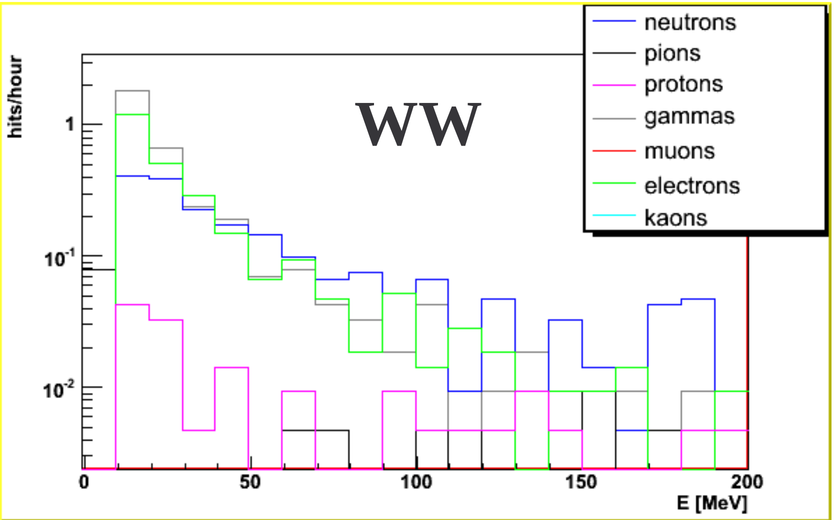
ttbar: 246/500 events

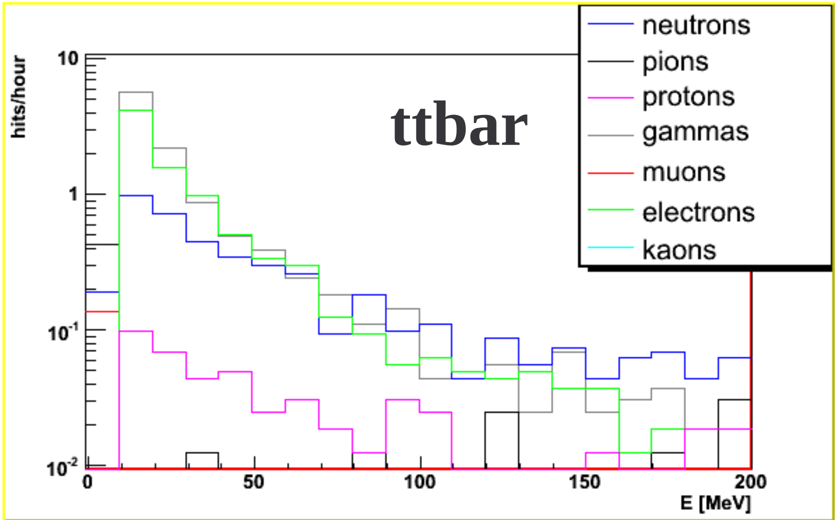
WW: 230/5000 events

QCD: 239/50000 events

energy spectrum of particles in the FPGAs







SEU - Weibull Fit

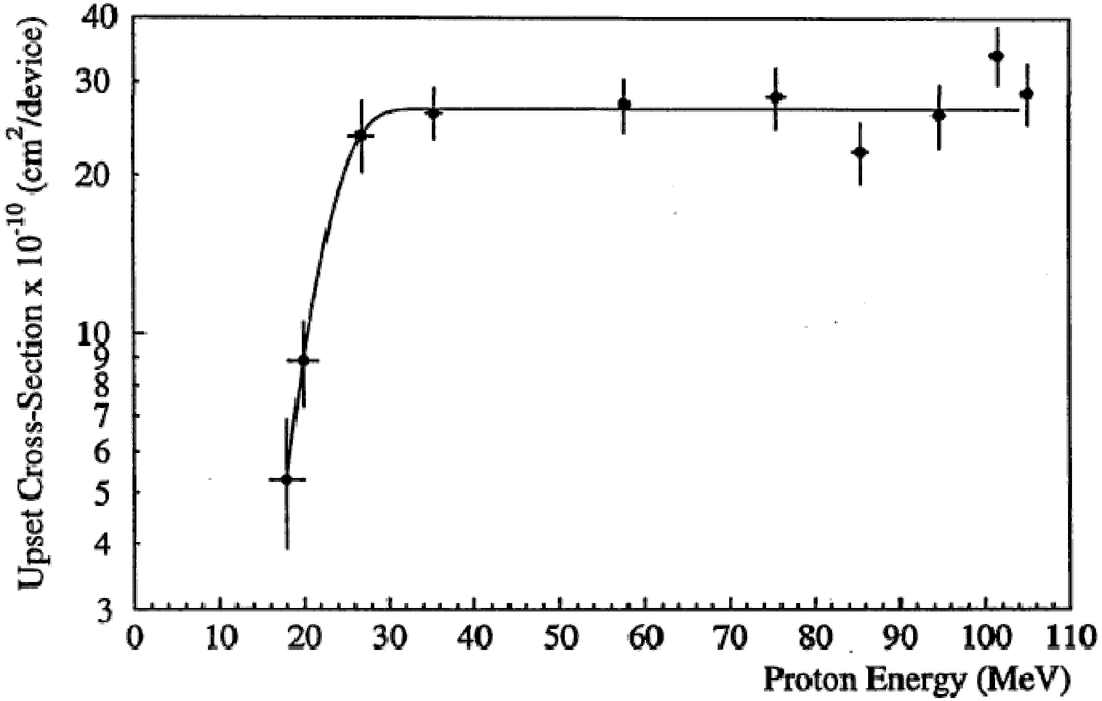


Fig. 4. Proton-induced SEU cross section for the switches and circuit in the Xilinx XC4036XLA FPGA. The curve is a fit to the data using a Weibull cumulative density function.

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⇒ above 20MeV neutrons start doing upsets

SEU σ

.	p,n,pi hits/hour above 20MeV	probability of SEU/h
ttbar	5	
WW	2	
QCD	**70**	**0.0010**

⇒one SEU/device every 40 days

Other FPGAs

FPGA	year	threshold [MeV]	SEU σ [cm^2/device]
Virtex II X-2V100 & Virtex II X-2V6000	2004	5MeV	$8*10^{-9}$
Altera Stratix	2004	10MeV	10^{-7}
Xilinx XC4036XLA	**2003**	**20MeV**	**$3*10^{-9}$**
Virtex XQVR300	2003	10MeV	$2*10^{-8}$
9804RP	1998	20MeV	10^{-8}

all data from literature, references not given in talk

It has been assumed that each device consists of 10^6 bits in order to make the numbers comparable

Other FPGAs

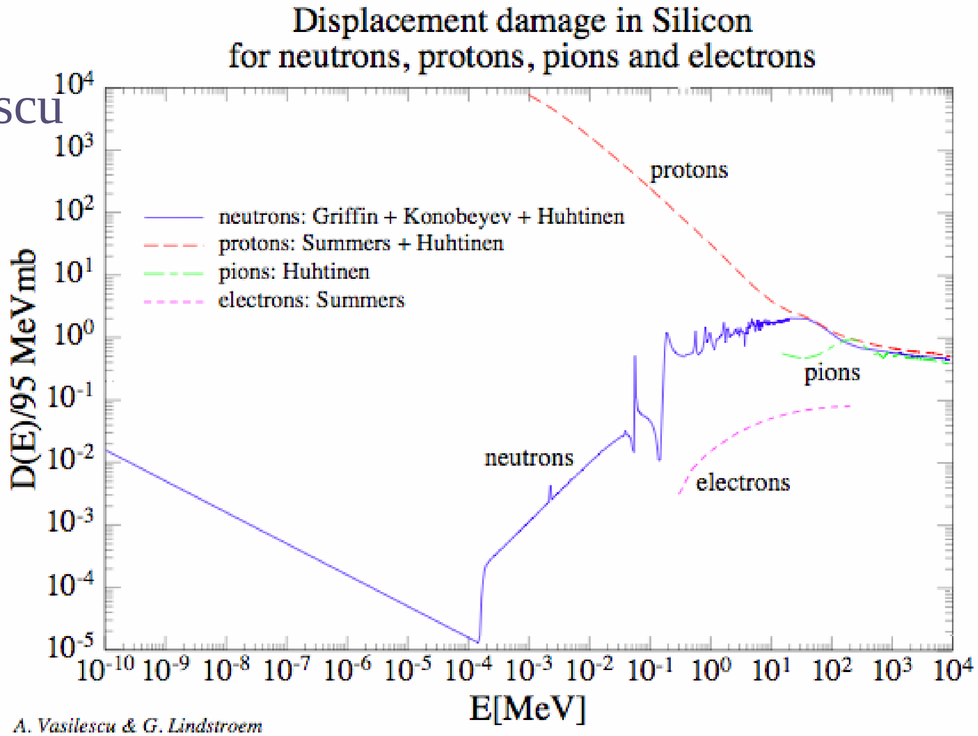
Virtex II X-2V100 Virtex II X-2V6000	0.005 SEUs/h
Altera Stratix	0.062 SEUs/h
Xilinx XC4036XLA	**0.001 SEUs/h**
Virtex XQVR300	0.012 SEUs/h
9804RP	0.005 SEUs/h

other radiation effects

- neutron spallation:
  - non-ionizing effects like nuclear spallation reaction, which make neutrons stop completely => leads to destruction of electronics
  - depending on 1MeV neutron equivalent fluence, no comparison to measurements up to now
- deep level traps:
  - cause higher currents
  - depending on radiation dose (energy deposition in the electronics), not yet done

NIEL hypothesis

according to Vasilescu and Lindstroem, on-line compilation



annual 1MeV neutron equivalent fluence assuming 10^7s: 10^4 /cm^2

(factor 10^{10} smaller than inner detector@LHC)

Radiation dosis

- strategy1: take worst case scenario
  - look at innermost layer which has most hits
  - take the whole energy loss => also non electromagnetic energy loss

=> 0.003 rad/year

- strategy2: estimate from the flux calculated for the SEUs
  - take average energy from spectrum for each particle

=> 0.003 rad/year

Radiation dosis

- strategy1: take worst case scenario

Energy deposited: (1952MeV / 6986 events) *

(9Mio events/hour / 3600sec) * 10^7 sec/year

= $7*10^9$MeV ==0.001J

with 1eV=$1.6*10^{-19}$J

Volume/mass: V = (24Mio cells/40layers) * $1cm^2$ * 300µm

=$0.018m^3$

m = $0.018m^3$ * 2330 kg/m^3 = 42 kg

Radiation dosis: 0.001J/42kg = $2.8*10^{-5}$ J/kg (Gy)

== $2.8*10^{-3}$ rad

Breakdown of FPGAs

	Radiation dosis before error occured
Xilinx Virtex XQVR300TID	100kRad
XC4036XL	60kRad
XC4036XLA	42kRad

=> we should be safe using FPGAs

radiation monitors

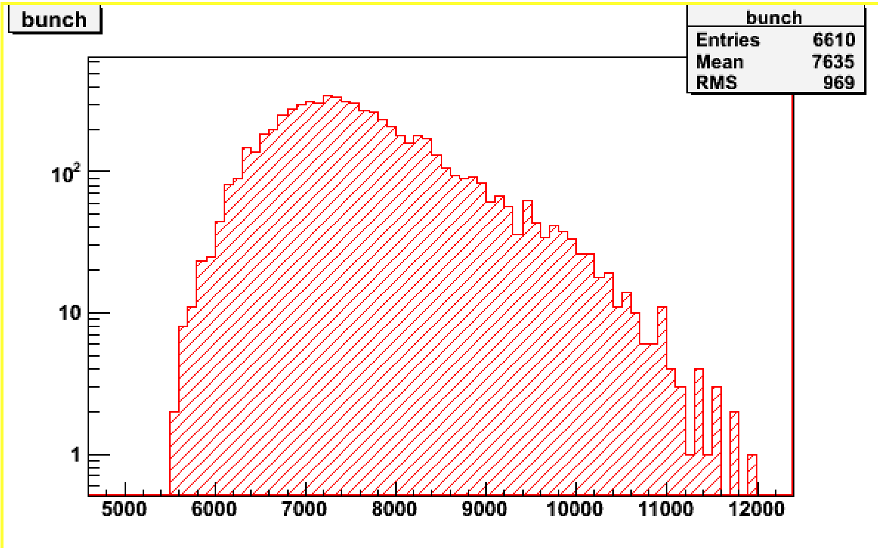
(inspired by RadMon group at LHC)

SEUs:	SRAM with high SEU probability
Dose:	Radiation Sensitive MOSFET or Gate Controlled Diodes
Fluence:	Si diodes or Gate Controlled Diodes

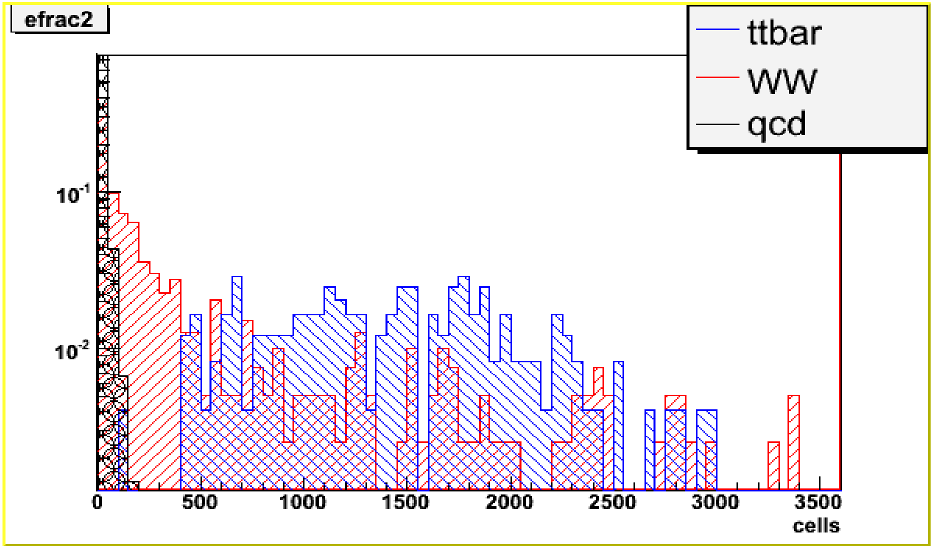
occupancy - for the barrel

Hits per bunch train
(assuming Gauss distribution of events)

hits per bx



number of cell_ids hit



number of cell_ids hit

$\Rightarrow$ Occupancy per bunch train:
12000 hits/24Mio cells = $5*10^{-4}$