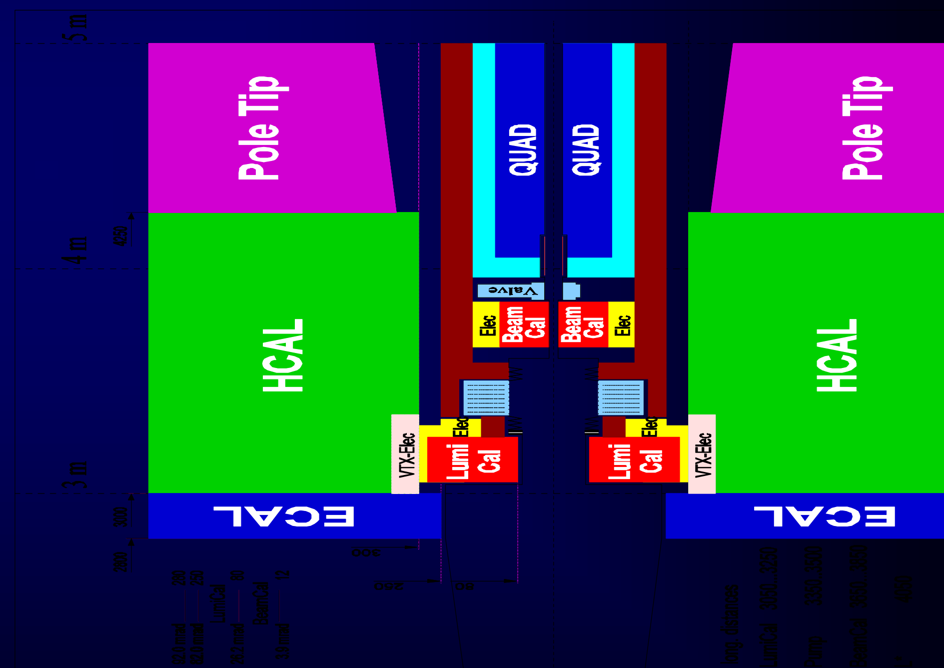
Beam Monitoring from Beam Strahlung

Fast Luminosity Signal

→ Feed-Back

→ Distinguish diff. detunings

Work for TESLA



work by summer students

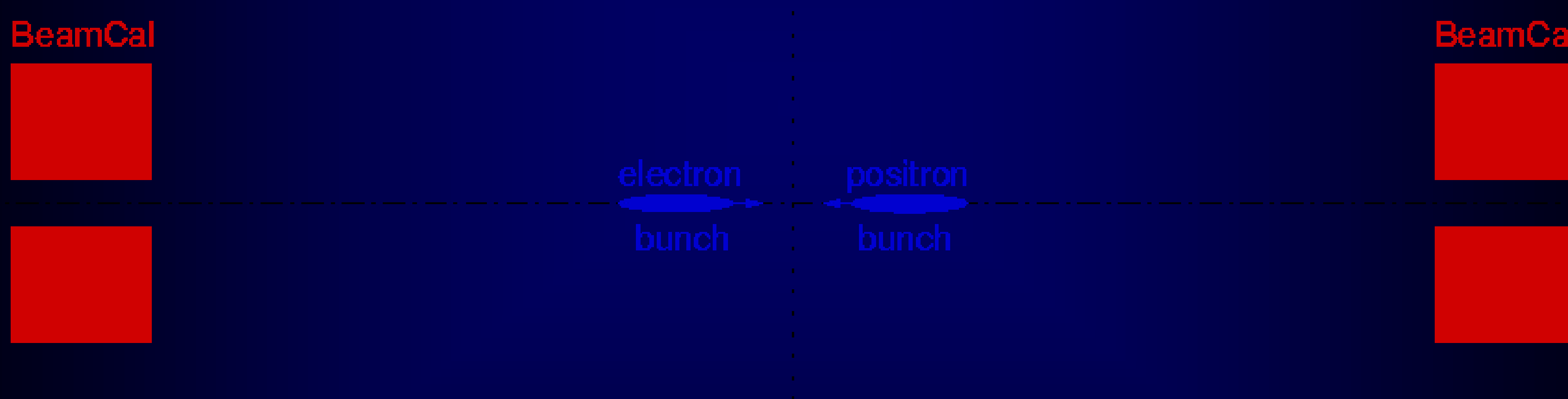
- Gunnar Klämke (U Jena, 01)
- Marko Ternick (TU Cottbus, 02)
- Magdalena Luz (HU Berlin, 03)
- Regina Kwee (HU Berlin, 03)
- New student, summer 04

Achim Stahl DESY Zeuthen 16.Apr.2004

Beam Strahlung

TESLA: small bunches (5nm x 550nm x 300µm)

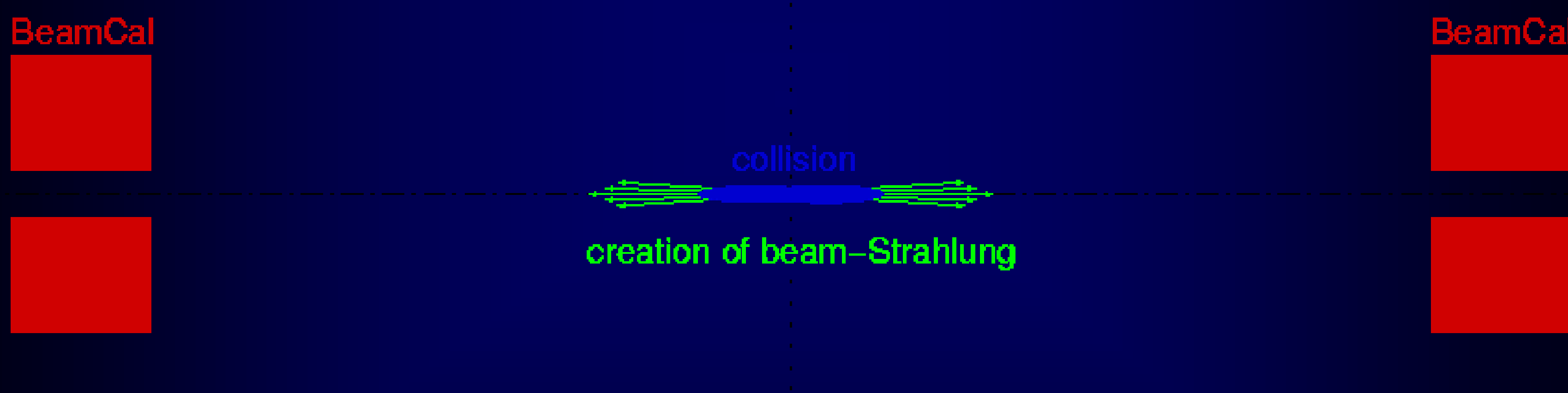
huge electric/magnetic fields



Beam Strahlung

Particles accelerated by electric field

→ creation of photon radiation (beamstrahlung)

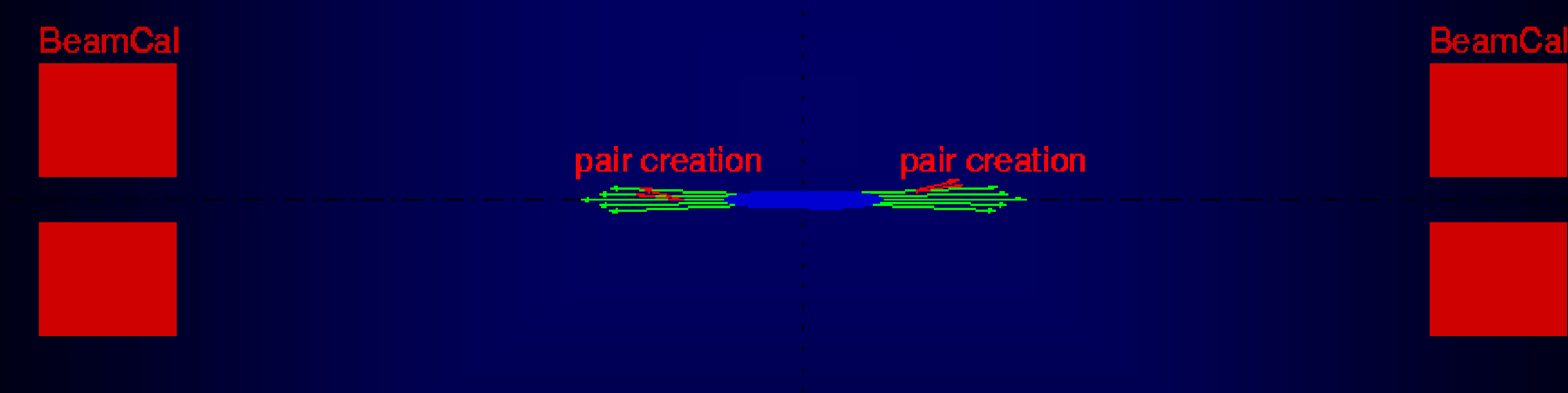


Simulation of collisions
by guinea-pig

Beam Strahlung

Creation of e^+e^- pairs by photon-photon interactions

(2nd order effect, $e^+e^- \ll \gamma s$)

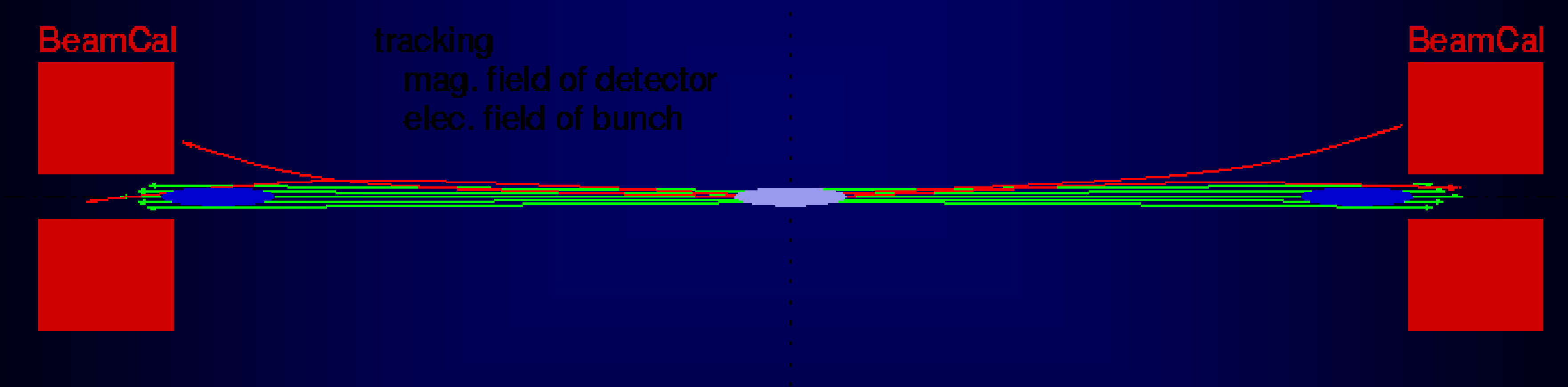


Simulation of collisions
by guinea-pig

Beam Strahlung

Tracking of particles into the forward region

(e^+e^- confined by magnetic field of detector)



Tracking by simple stand-alone program

Beam Strahlung

Diagnostics of bunches at IP

3 potential sources of information

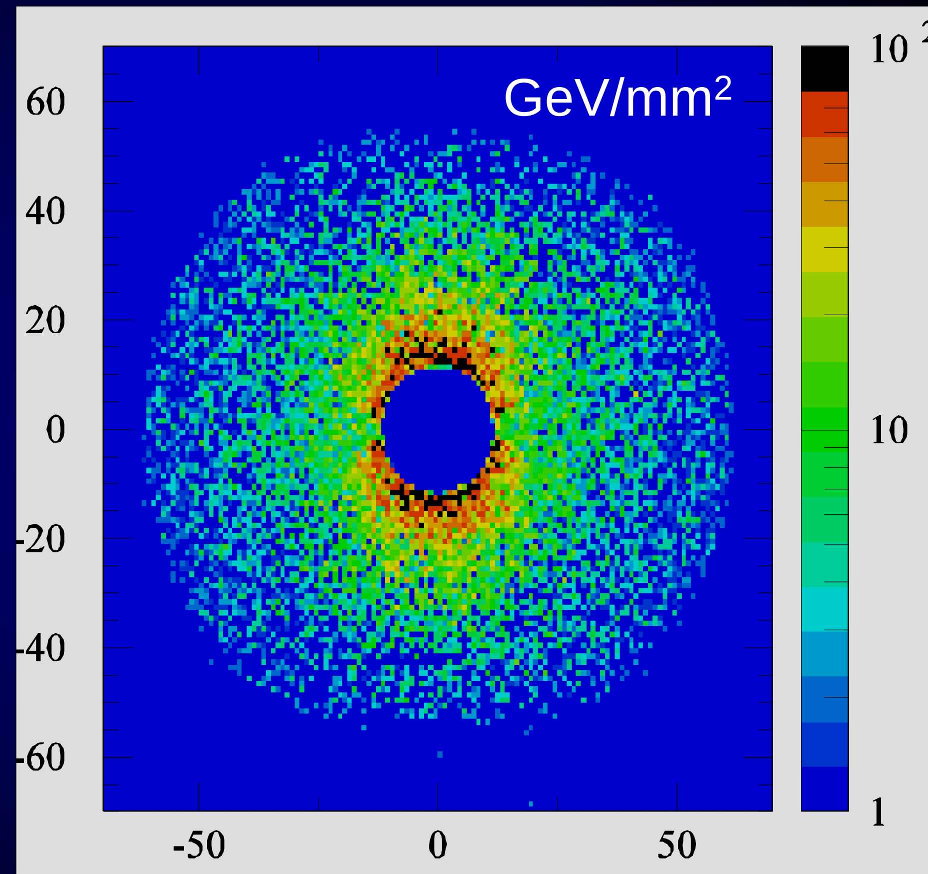
- energy-distribution of pairs
- number-distribution of pairs
- distribution of photons

Over-simplified detector simulation

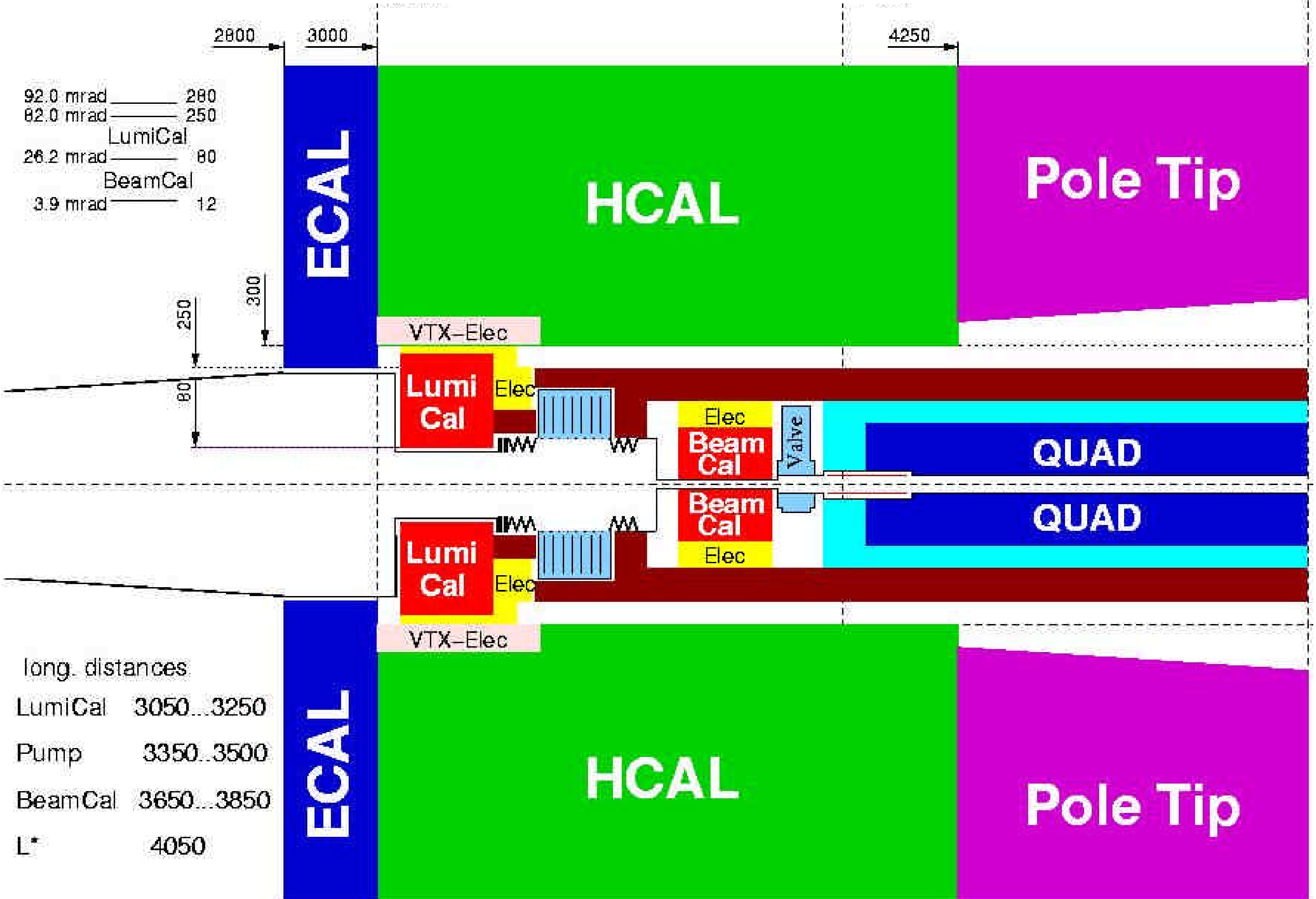
- detectors subdivided into cells
- sum energy impact on cells

main source of uncertainty

→ stat. fluctuations of beam str.



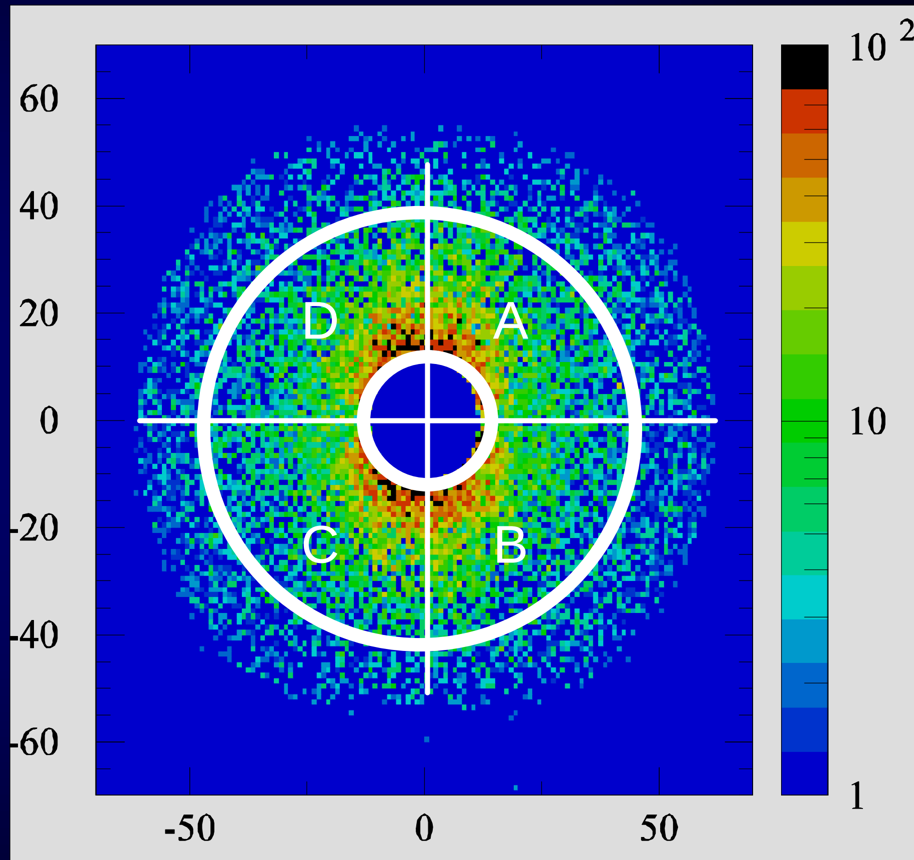
Re-design of TESLA Forward Region for L* > 4.1 m



Observables

- total energy
- first radial moment
- first moment in 1/r
- thrust value
- angular spread
- E(ring = 4) / E_{tot}
- (A + D) – (B + C)
- (A + B) – (C + D)
- E / N

forward / backward calorimeter



Current Analysis Concept

Beam Parameters

- determine collision
- creation of beamstr.
- creation of e^+e^- pairs

guinea-pig

1st order Taylor-Exp. →

Observables

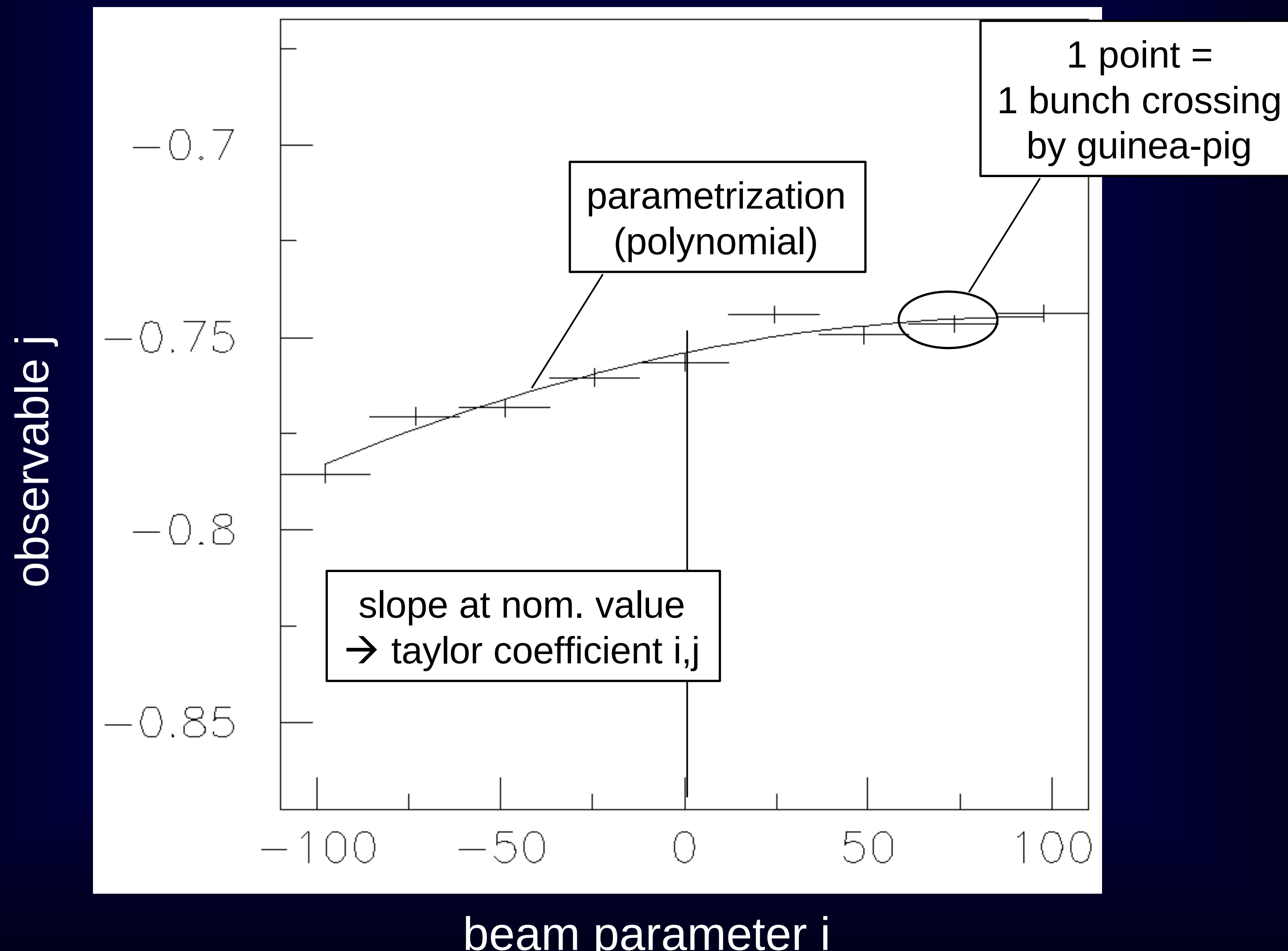
- characterize energy distributions in detectors

analysis program

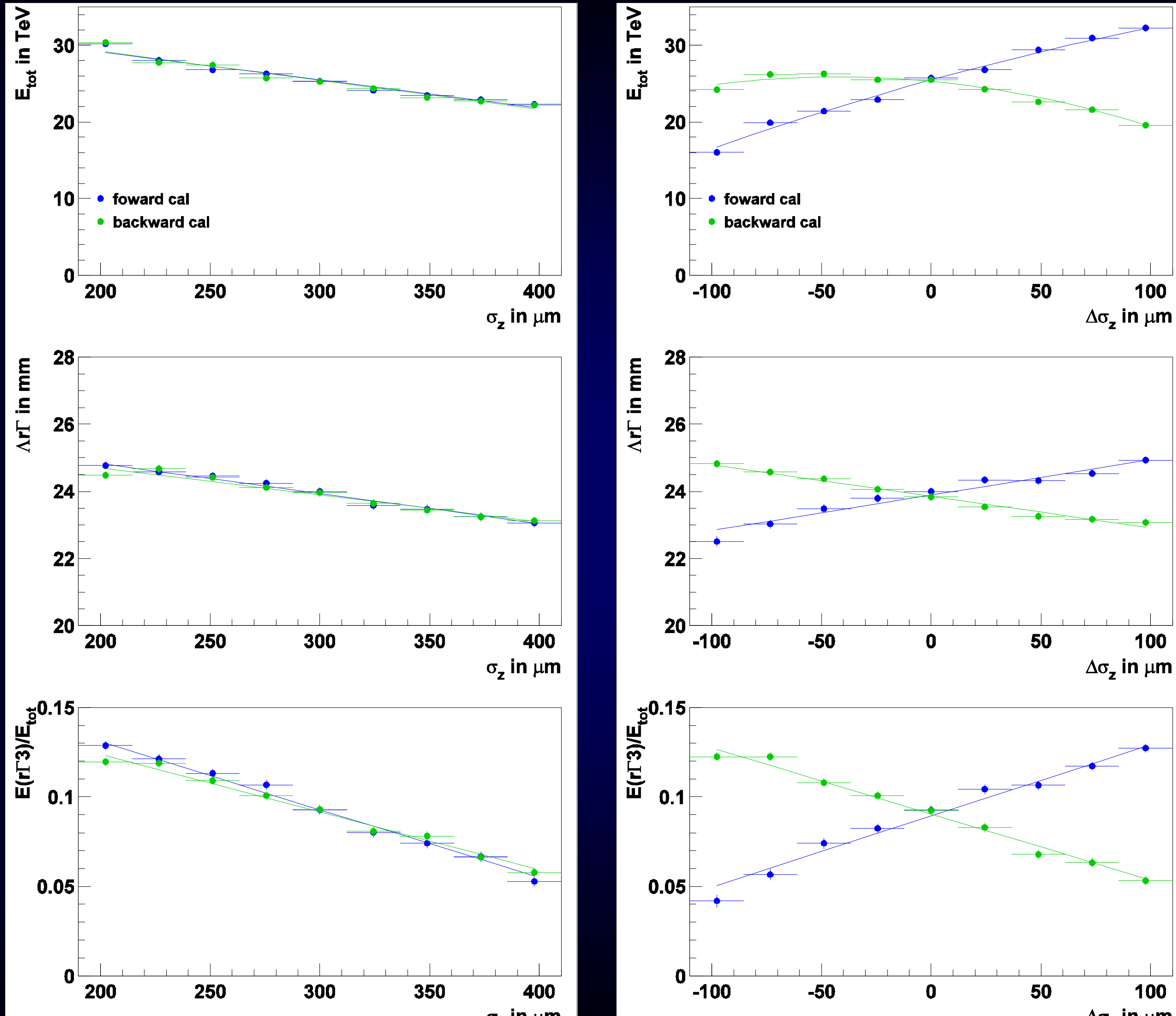
$$\left(\text{Observables}\right) = \left(\text{Observables}\right)_{\text{nom}} + \left(\begin{array}{c}\text{Taylor}\\ \text{Matrix}\end{array}\right) * \left(\text{? BeamPar}\right)$$

Solve by matrix inversion
(Moore-Penrose Inverse)

Slopes

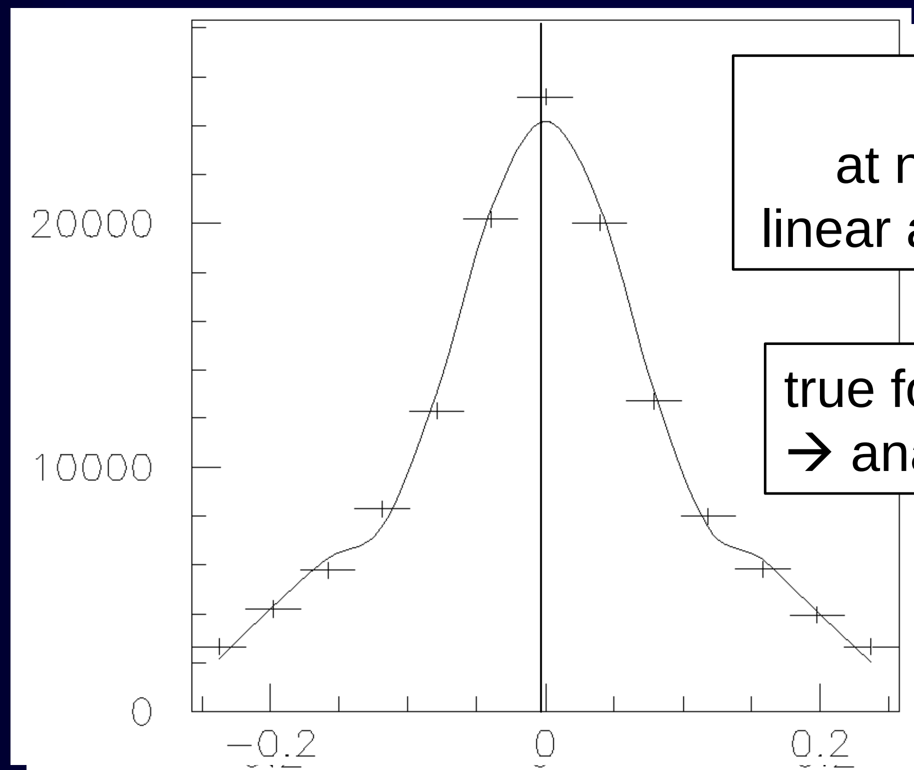

1 point =
1 bunch crossing
by guinea-pig
parametrization
(polynomial)
slope at nom. value
→ taylor coefficient i,j
observable j
−0.7
−0.75
−0.8
−0.85
−100
−50
0
50
100
beam parameter i

Example: Slopes



Analysis Problem

((A+C) – (B+D))/ total energy



bunch rotation in mrad

slope = 0
at nom. Parameter
linear approximation fails

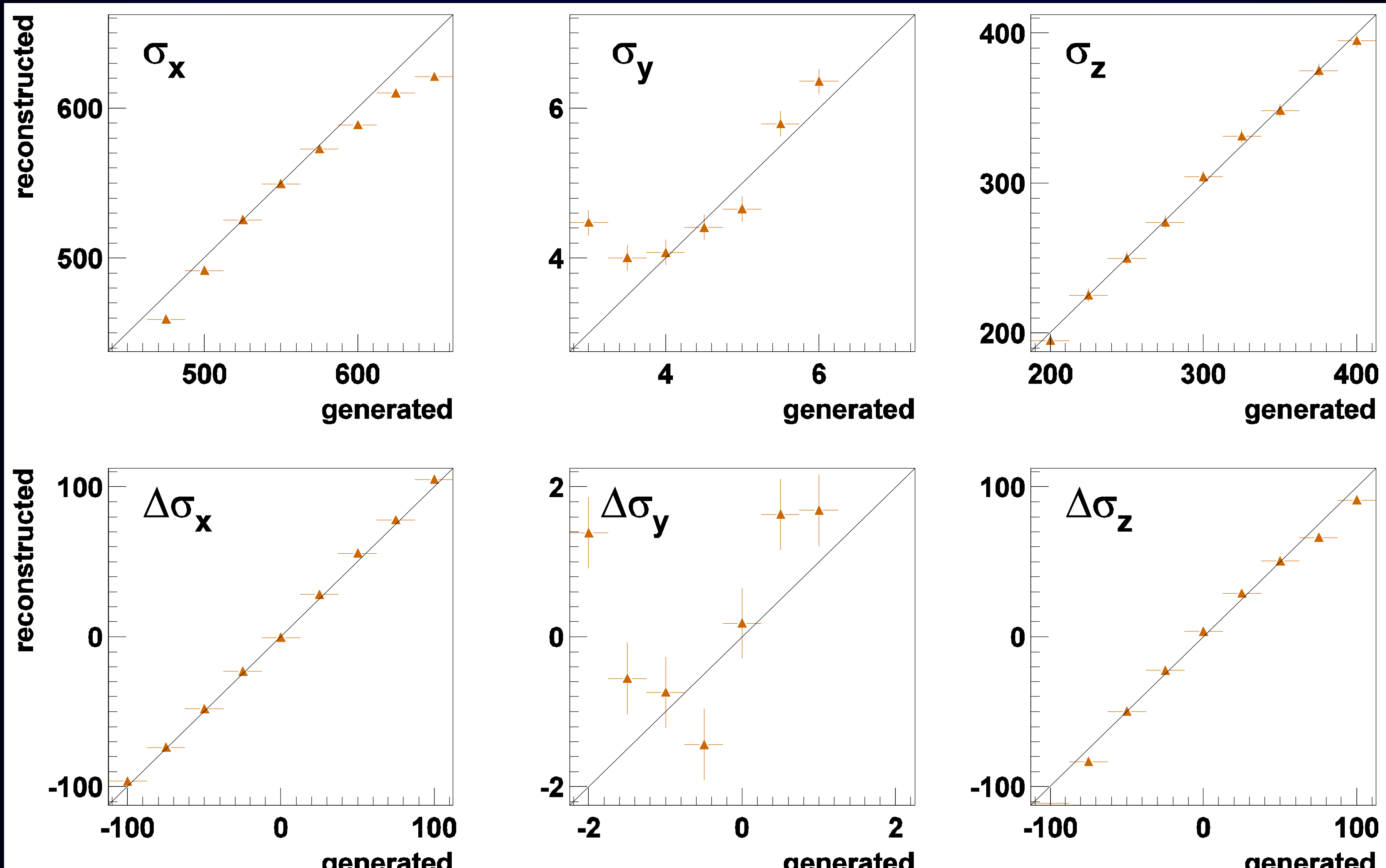
true for all observables
→ analysis fails

Single Parameter Analysis

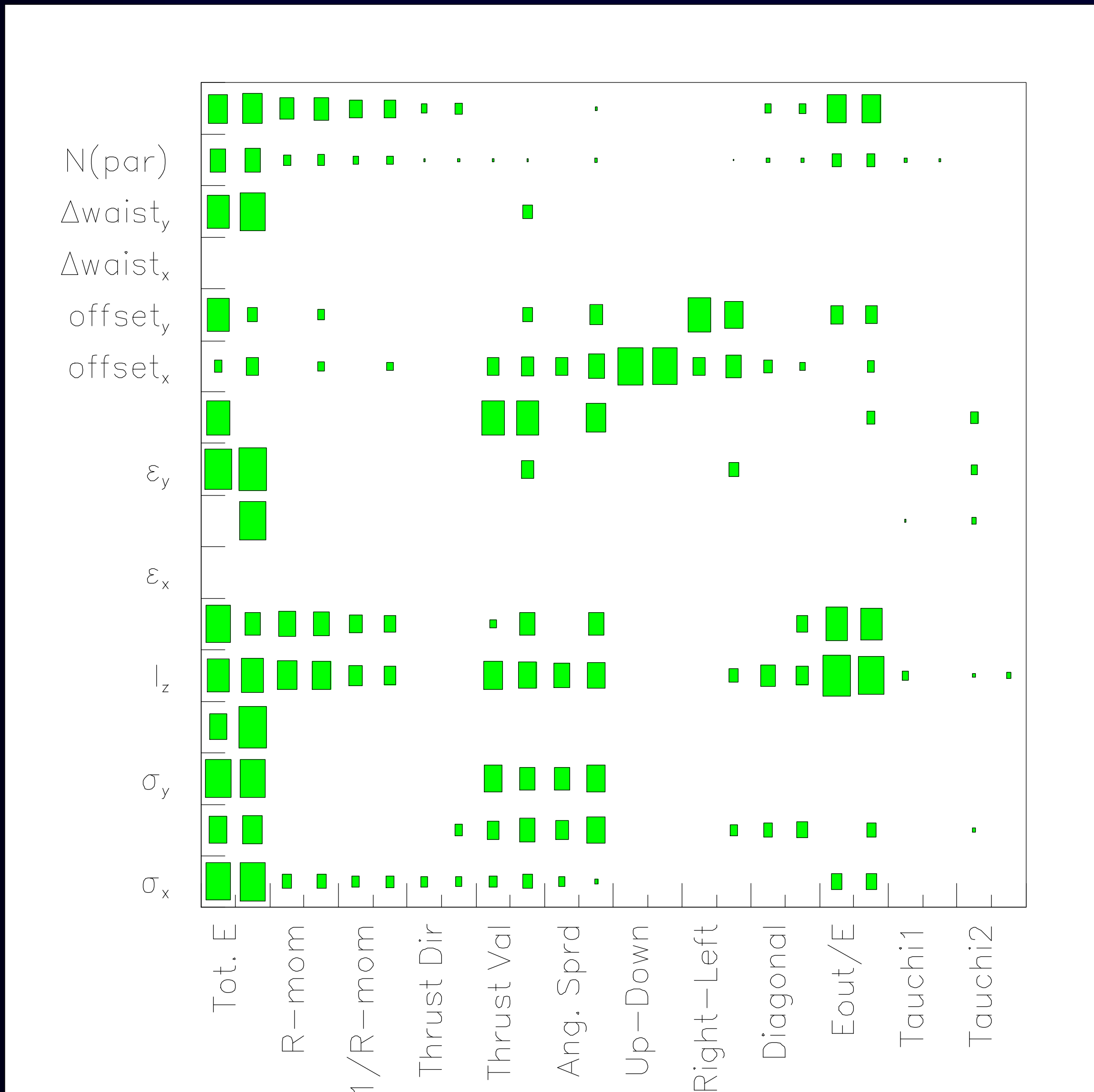
	nominal	1-Par.-Anal	Beam Diag.
Bunch width x Ave.	553 nm	1.5 nm	~ 10 %
Diff.		2.1 nm	~ 10 %
Bunch width y Ave.	5.0 nm	0.2 nm	Shintake
Diff.		0.5 nm	Monitor
Bunch length z Ave.	300 µm	4.3 µm	~ 10 %
Diff.		2.7 µm	~ 10 %
Emittance in x Ave.	10.0 mm mrad	---	?
Diff.		0.7 mm mrad	?
Emittance in y Ave.	0.03 mm mrad	0.001 mm mrad	?
Diff.		0.002 mm mrad	?
Beam offset in x	0	6 nm	5 nm
Beam offset in y	0	0.4 nm	0.1 nm
Horizontal waist shift	0 µm	---	None
Vertical waist shift	360 µm	24 µm	None

Single Parameter Analysis

Test of Linearity Range



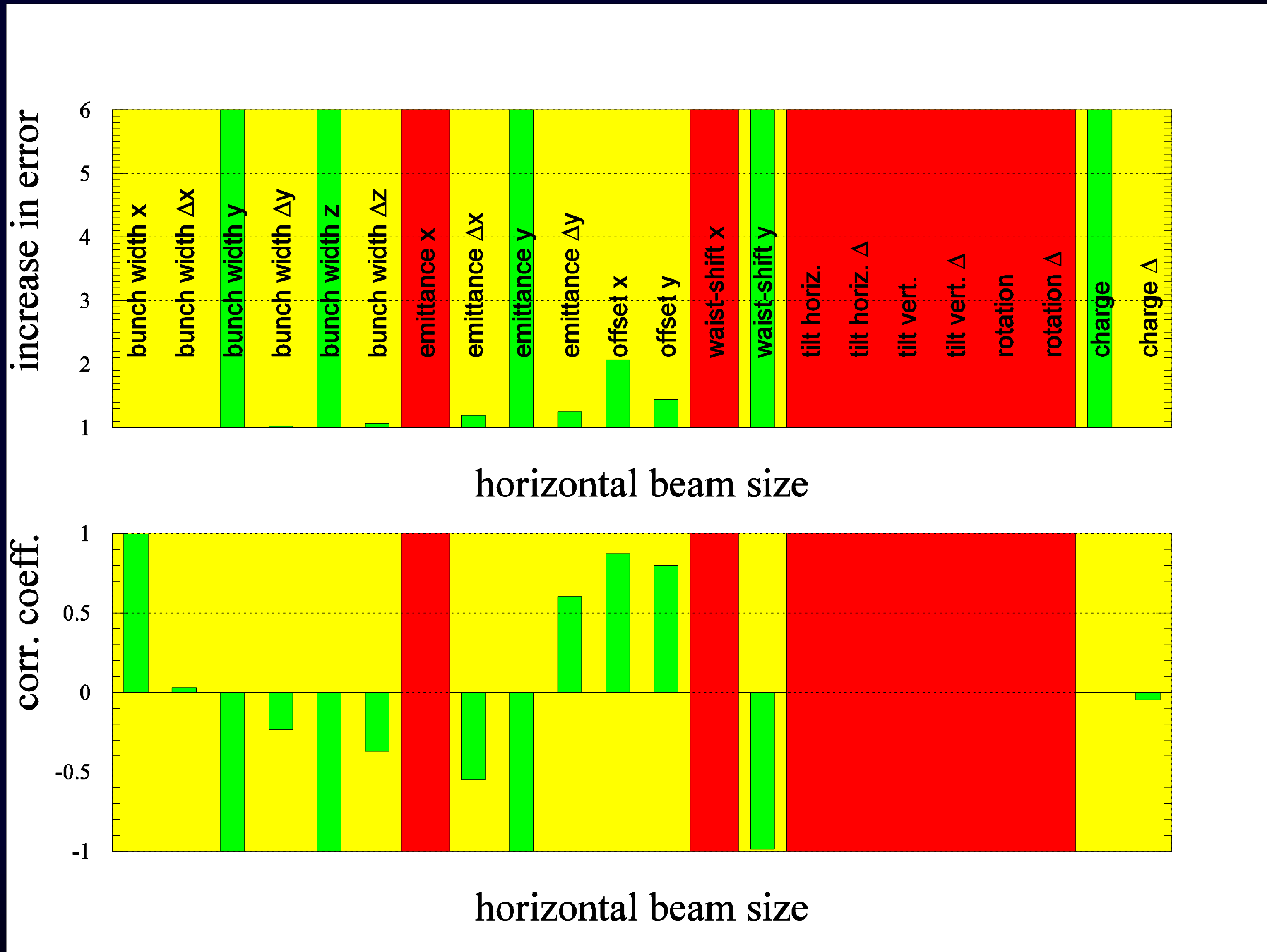
Single Parameter Analysis



weight of individual observables

Two Parameter Analysis

Example: horizontal beam size
Sngl Param Reso: 1.5 nm



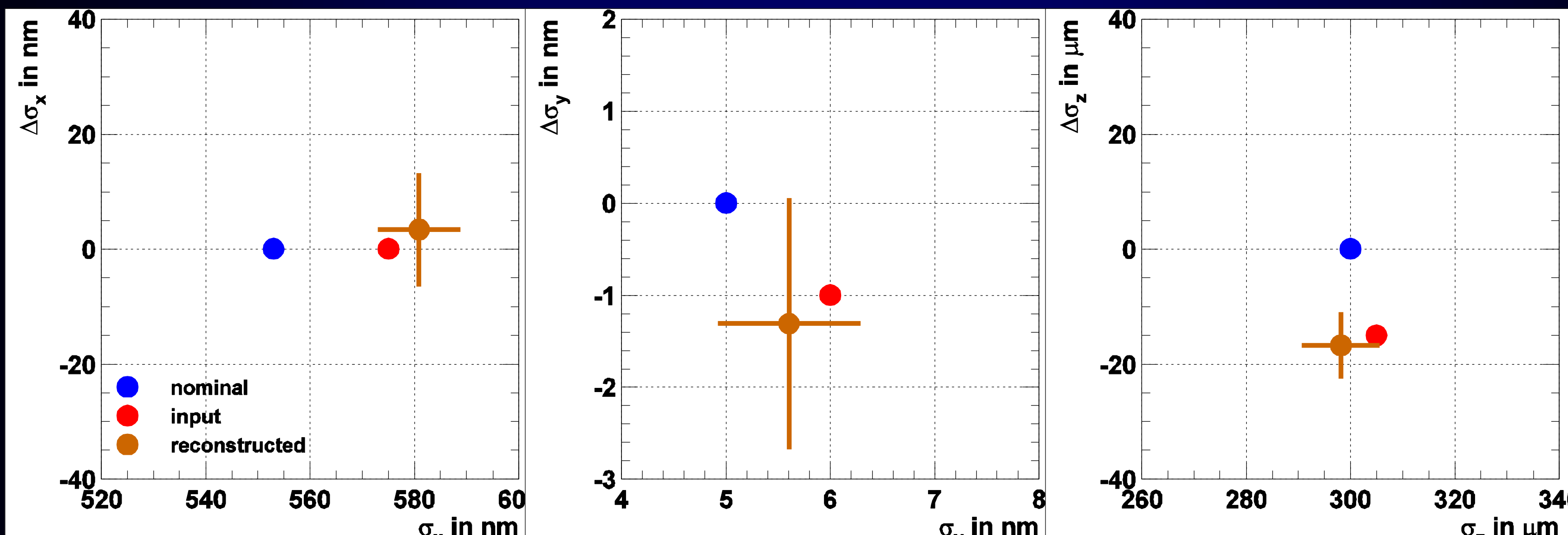
Multi Parameter Analysis

s_x	$?s_x$	s_y	$?s_y$	s_z	$?s_z$
0.3 %	0.4 %	3.4 %	9.5 %	1.4 %	0.8 %
0.3 %	0.4 %	3.5 %	11 %	1.5 %	0.9 %
0.9 %	1.0 %	11 %	24 %		
		5.7 %	24 %	1.6 %	1.9 %
1.8 %	1.1 %	16 %	27 %	3.2 %	2.1 %

Multi Parameter Analysis

Test with non-nominal bunches:

	e^-	e^+	nom.
bunch size x:	575nm	575nm	553nm
bunch size y:	5nm	7nm	5nm
bunch size z:	290µm	320µm	300µm



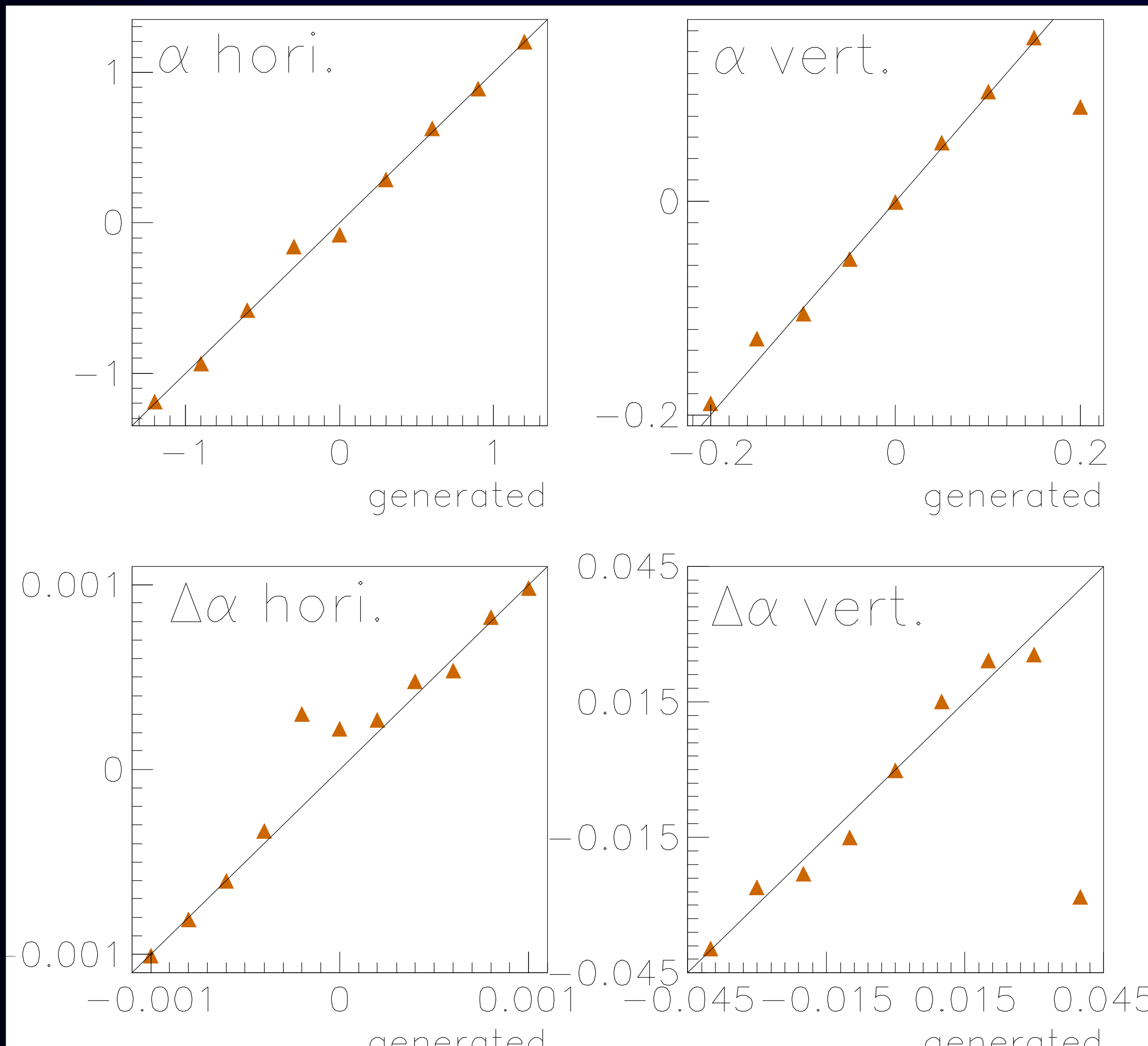
Full Analysis

	nominal	1-Par.	constraint	Result	Beam Diag.
Bunch width x Ave.	553 nm	1.5	---	25	~ 10 %
Diff.		2.1	---	12	~ 10 %
Bunch width y Ave.	5.0 nm	0.2	---	1.3	Shintake
Diff.		0.5	---	2.2	Monitor
Bunch length z Ave.	300 µm	4.3	---	20	~ 10 %
Diff.		2.7	---	24	~ 10 %
Beam offset in x	0 nm	6	5	6.4	5 nm
Beam offset in y	0 nm	0.4	0.5	0.8	0.1 nm
Vertical waist shift	360 µm	24	---	300	None
Bunch charge Ave.	$2\ 10^{10}$	0.002	0.1	0.08	None
Diff.	$2\ 10^{10}$	0.007	0.1	0.07	None

Fits with non-linear Terms

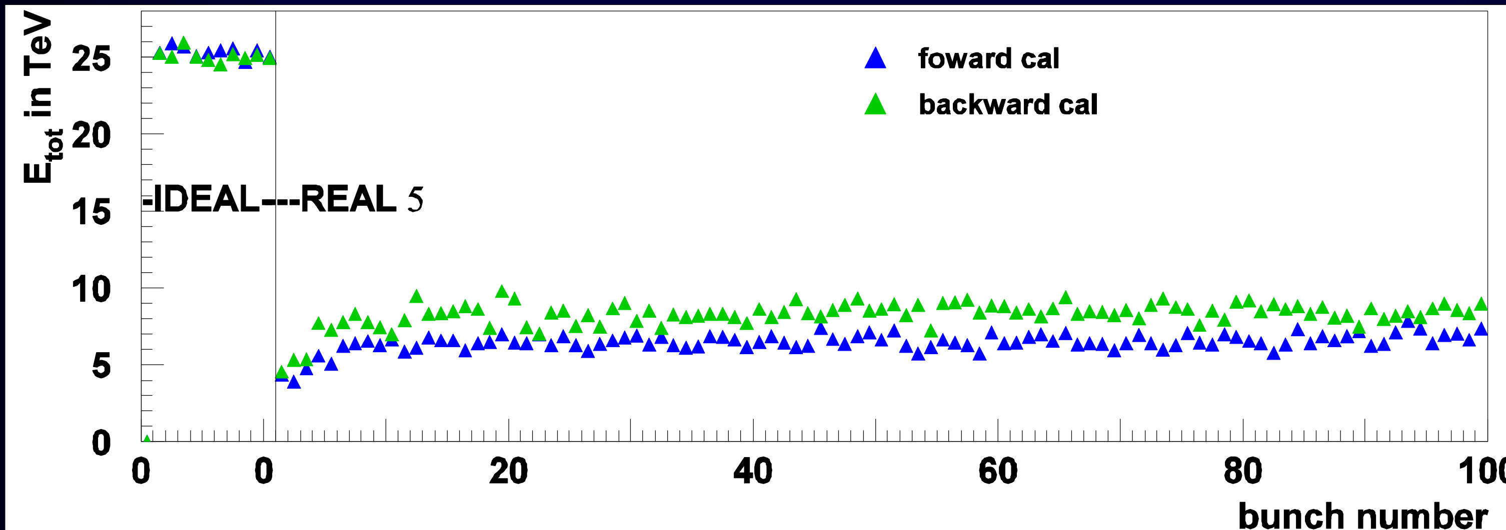
	nominal	linear appr.	fit	Beam Diag.
Bunch width x Ave.	553 nm	1.5	1.5	~ 10 %
Diff.		2.1	2.2	~ 10 %
Bunch width y Ave.	5.0 nm	0.2	0.2	Shintake
Diff.		0.5	0.3	Monitor
Bunch length z Ave.	300 µm	4.3	4.6	~ 10 %
Diff.		2.7	2.7	~ 10 %
Emittance in x Ave.	10.0 mm mrad	---	---	?
Diff.		0.7	1.0	?
Emittance in y Ave.	0.03 mm mrad	0.001	0.001	?
Diff.		0.002	0.003	?
Beam offset in x	0 nm	6	7	5 nm
Beam offset in y	0 nm	0.4	0.03	0.1 nm
Horizontal waist shift	0 µm	---	---	None
Vertical waist shift	360 µm	24	73	None
bunch rot. horizontal	0 mrad	---	49	?
	0 mrad	---	0.06	?
bunch rot. vertical	0 mrad	---	0.9	?
	0 mrad	---	0.07	?

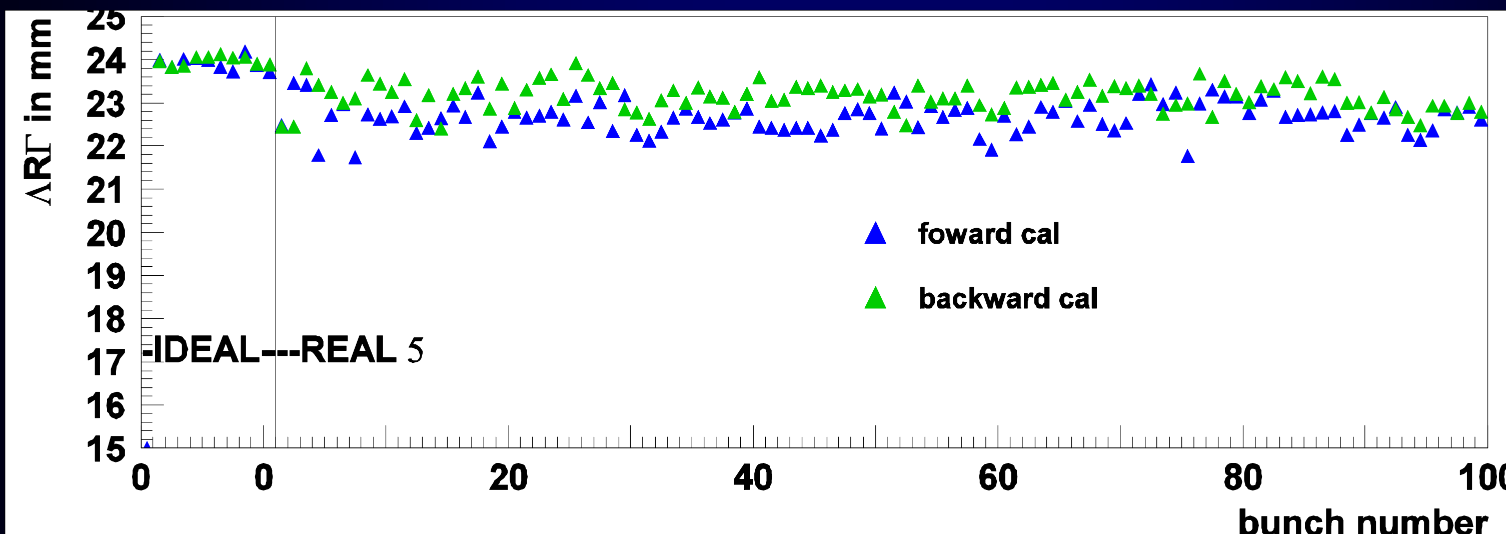
Fit with non-linear Terms



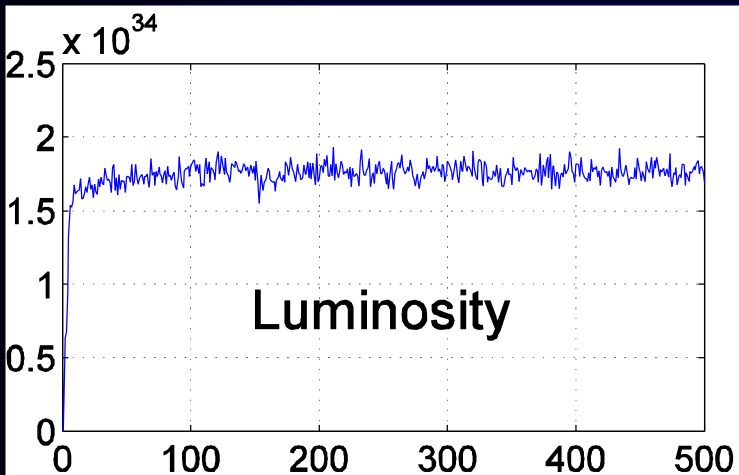
Real Beams: first look

Example of 2 observables:

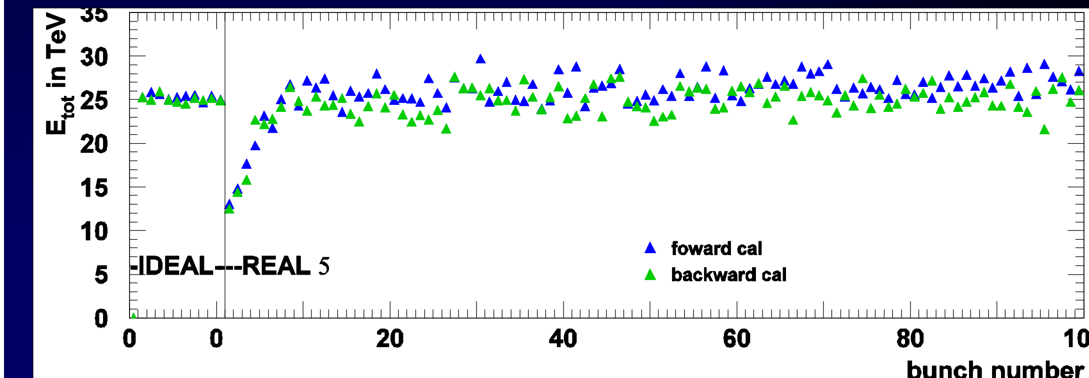


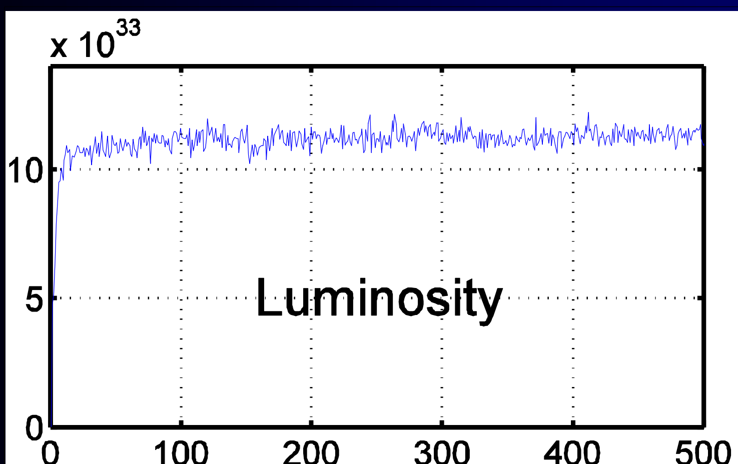


Real Beams: first look

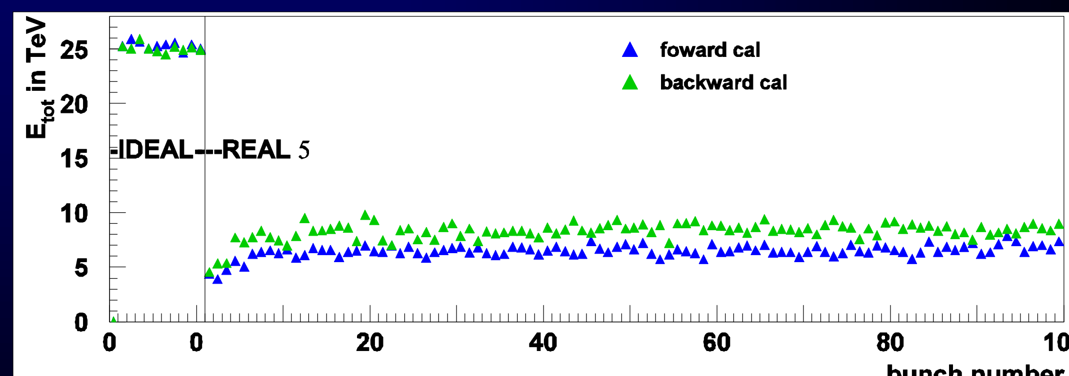


Run 2



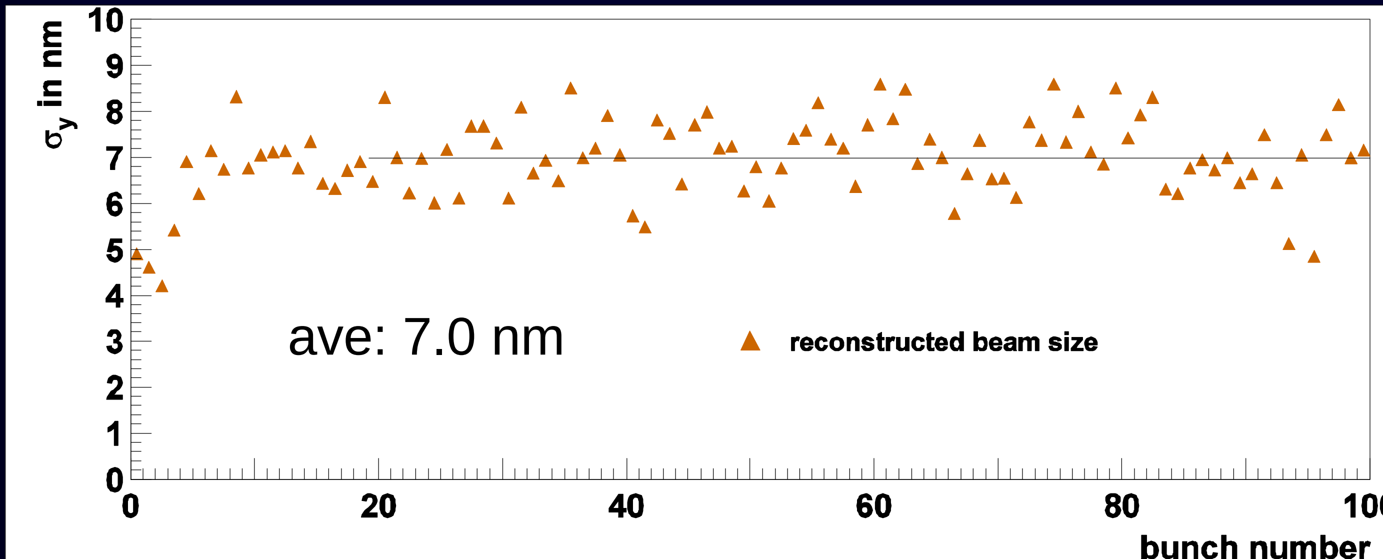


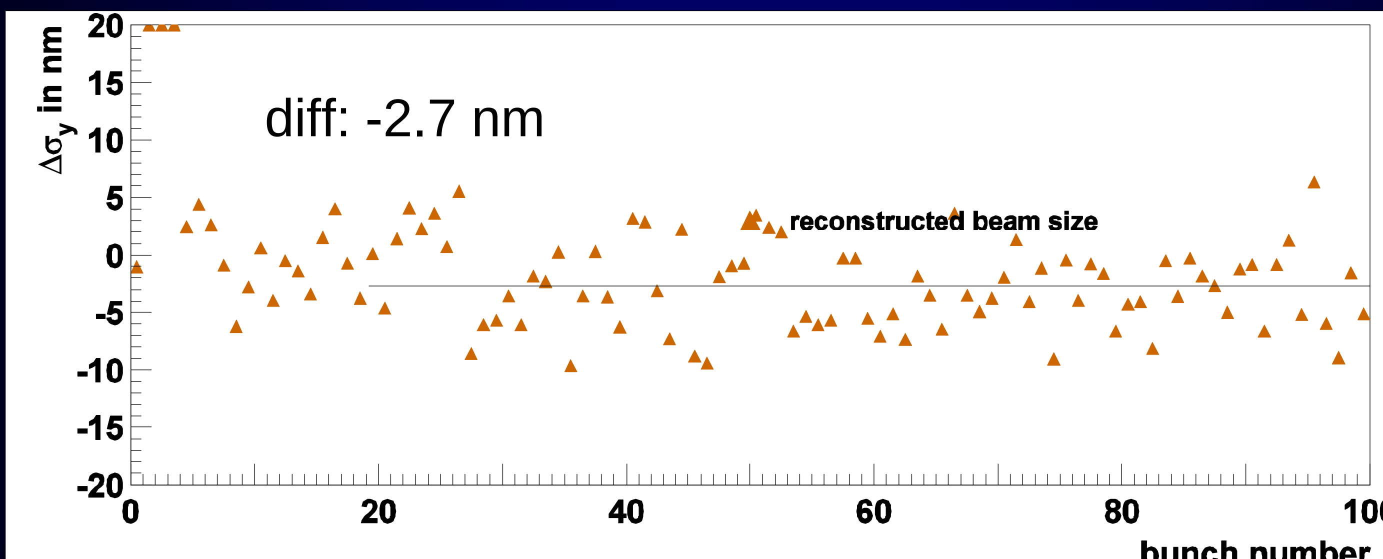
Run 4



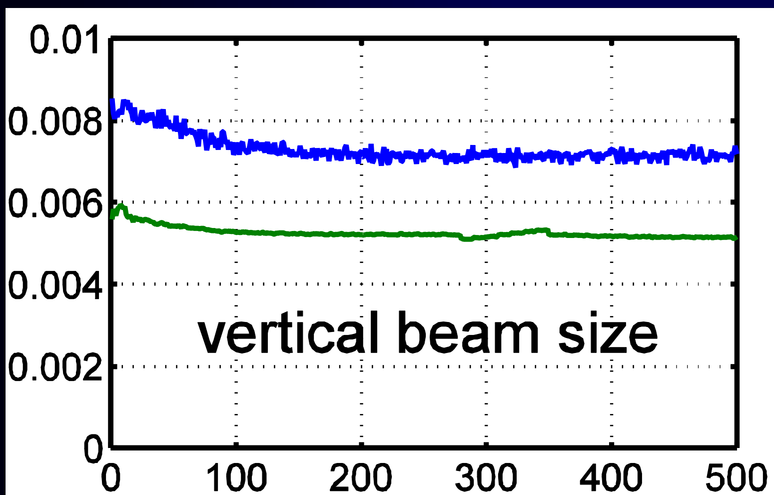
E_{tot} not strictly proportional to luminosity

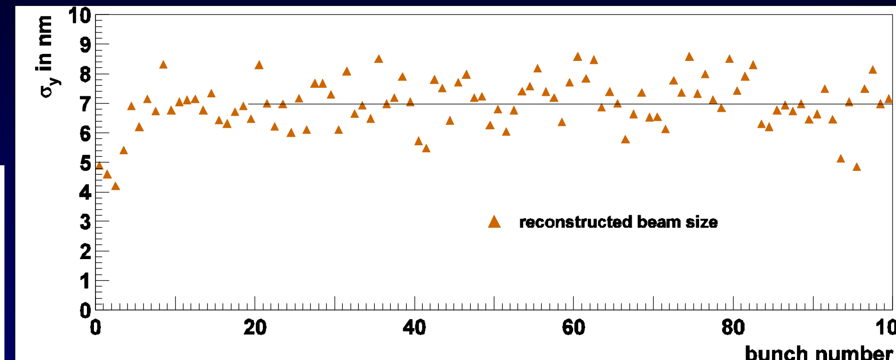
Real Beams: first look

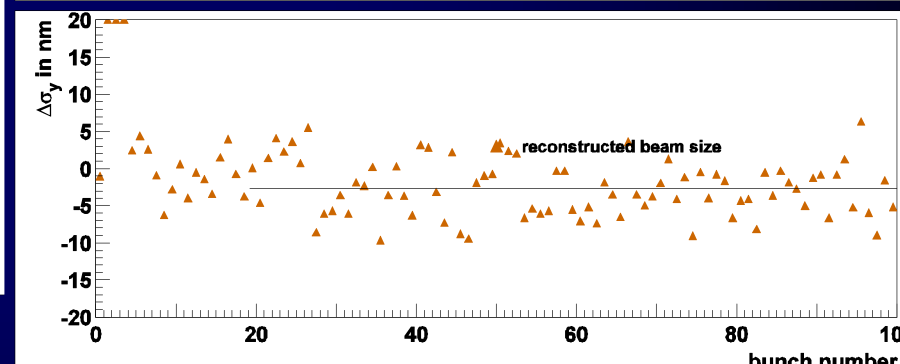




Real Beams: first look







input:

$s_y(e^-)$ ˜ 7.7 nm

$s_y(e^+)$ ˜ 5.5 nm

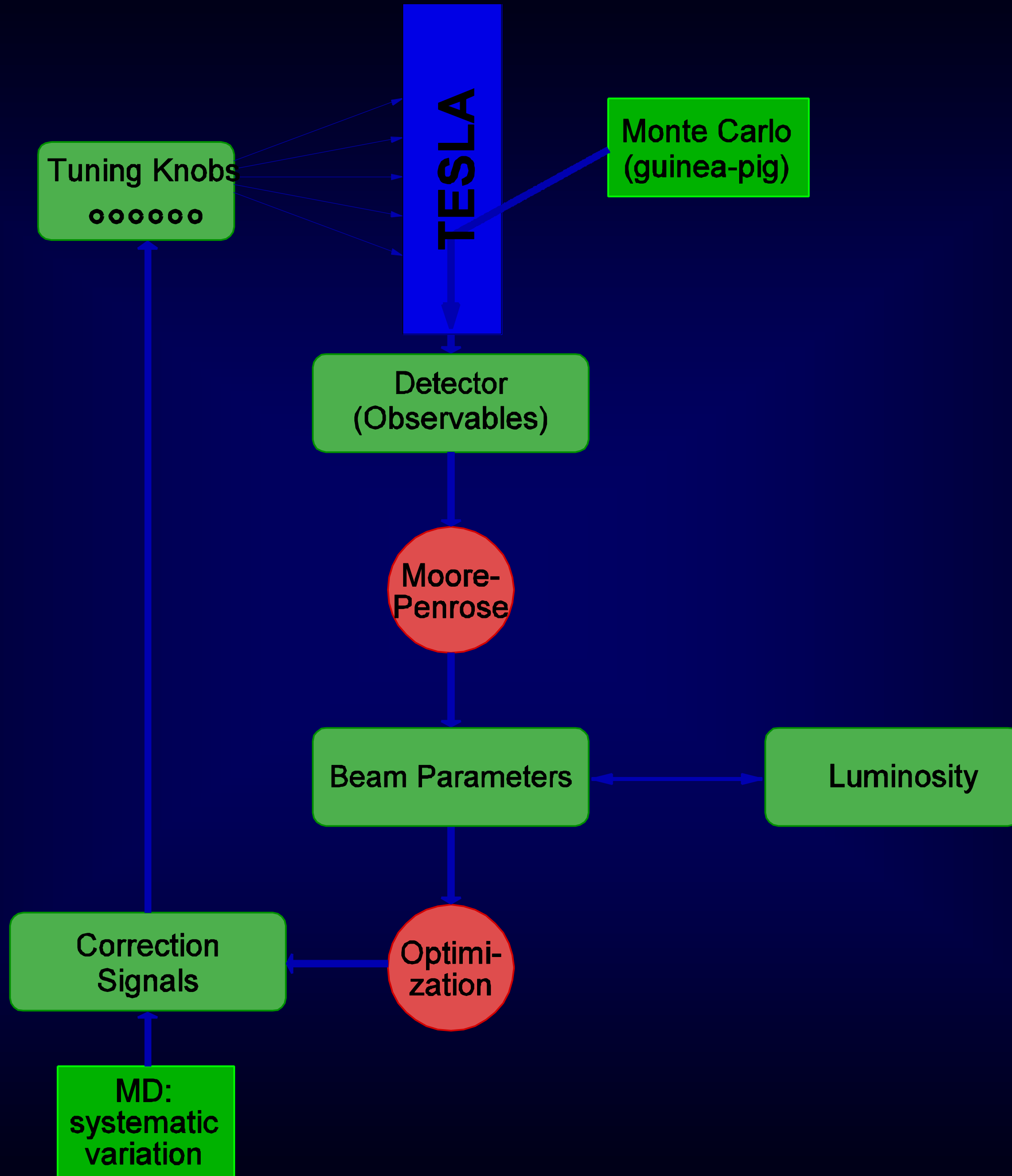
reco:

s_y ave. ˜ 7.0 nm

s_y diff. ˜ -2.7 nm

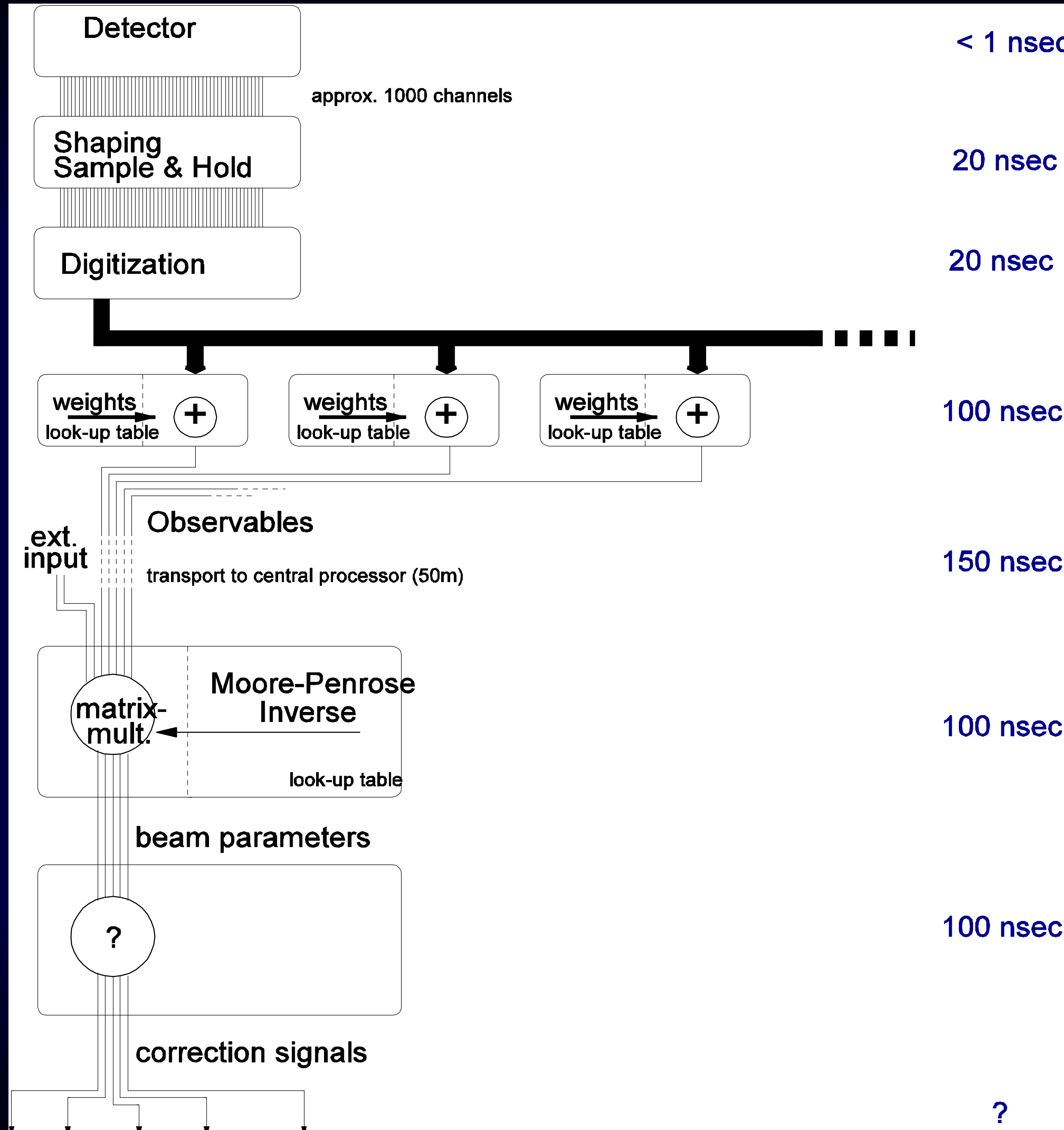
Feed-Back System

1st Idea



Time-Flow

wild guess



3 Sources of Information

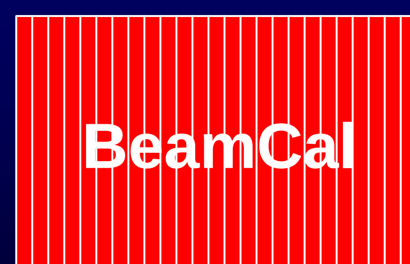
- energy-distribution of pairs
- number-distribution of pairs
- distribution of photons

up to now: only energy distribution of pairs used

test: number-distribution of pairs

new observable

➢ N_{pairs} / E_{tot}



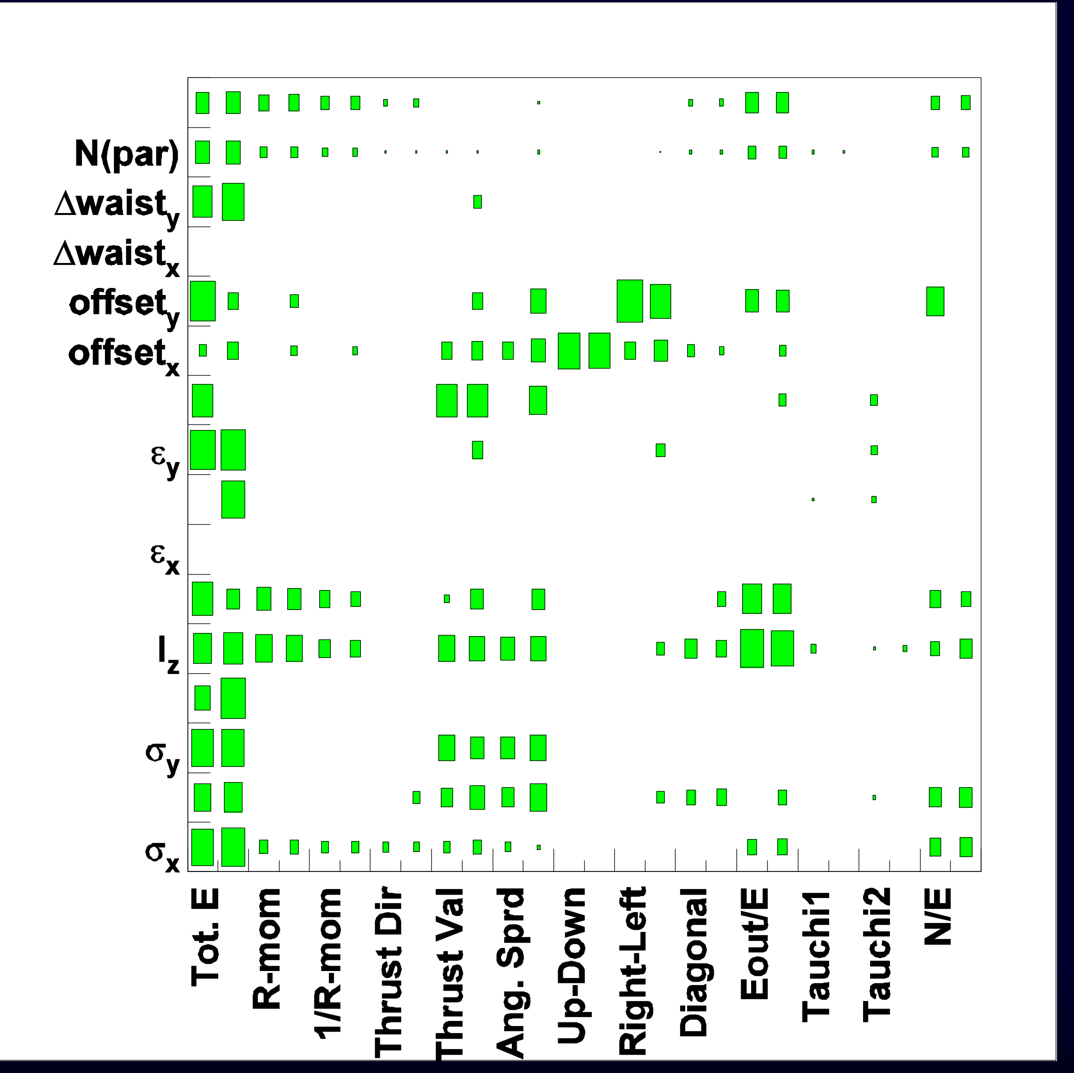
1^{st} layer: measures N

all layers: measure E

➔ **approx. 10% improved resolution**

Number Distribution

weight of new variable



Number Distribution

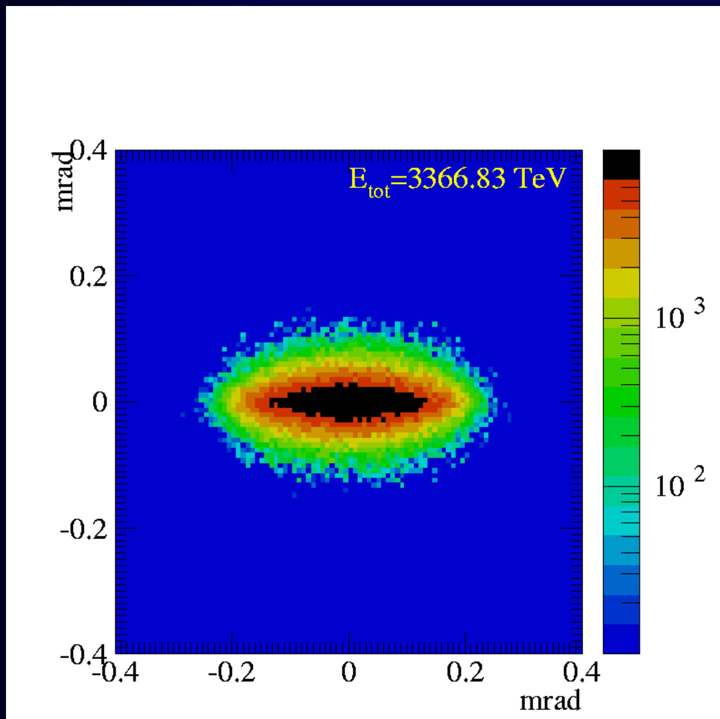
Example: 6-Par. Analysis

		nominal	1-Par.	6-Par. without N	6.-Par with N
Bunch width x	Ave.	553 nm	1.5	9.9	8.3
	Diff.		2.1	6.2	6.0
Bunch width y	Ave.	5.0 nm	0.2	0.8	0.6
	Diff.		0.5	1.3	0.9
Bunch length z	Ave.	300 µm	4.3	9.5	9.4
	Diff.		2.7	6.2	6.1

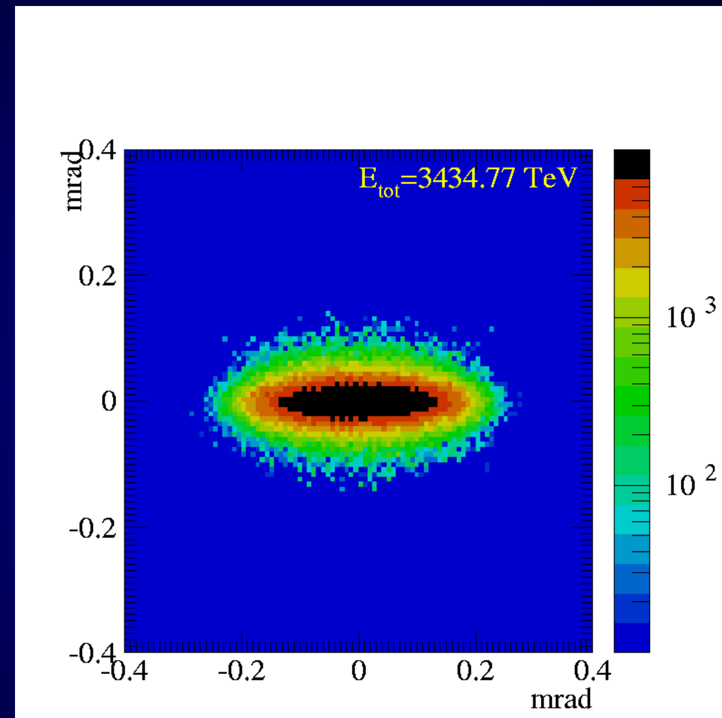
➔ roughly 10% improvement

First Look at Photons

First Look at Photons



nominal setting
(550 nm x 5 nm)



s_x = 650 nm
s_y = 3 nm

Conclusions:

- Interesting resolutions achieved from single bunches
- Multi-parameter analysis possible
- Electron – Positron bunch can be separated
- Not all parameters measurable

Next Steps:

- understand realistic beam simulation
- include photons

? impact on calorimeter design ?