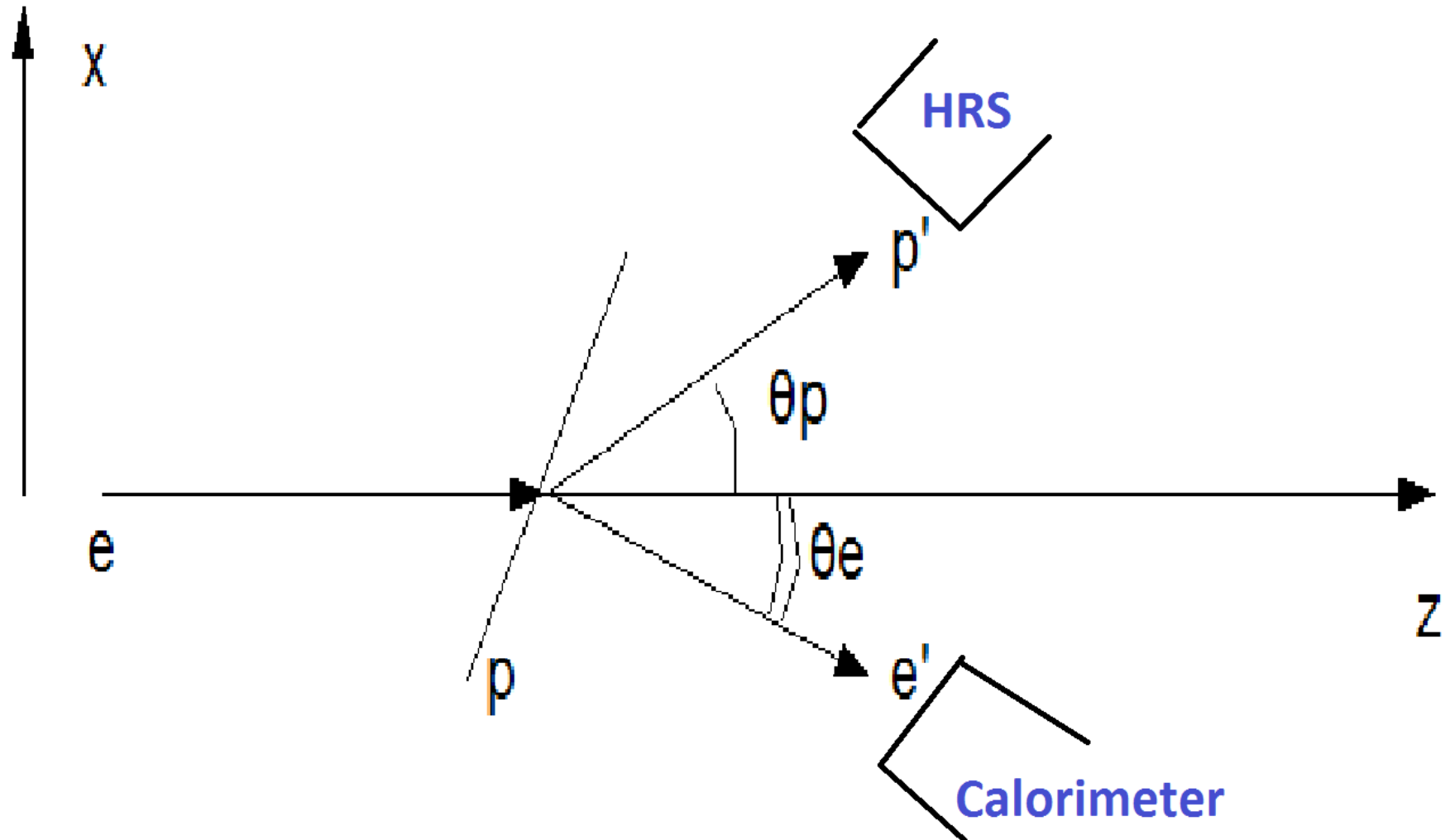


Elastic calibration

- Calibration procedure
- Simulation geant4
- Results
- Conclusions

Calibration procedure

- Elastic scattering : $ep \rightarrow e'p'$



Energy conservation : $E_j = E_b + m - E_j^p$

E_j = energy of the scattered electron

E_b = beam energy

m = proton mass

E_j^p = recoil proton energy

Use of χ^2

$$\chi^2 = \sum_{j=1}^N (E_j - \sum_i C_i A_j^i)^2$$

N = number of events

A_j^i = signal amplitude of a the calorimeter block i

C_i = the block calibration coefficient

The coefficients C_i are those which minimize this

$$\chi^2 \longrightarrow \frac{\partial \chi^2}{\partial C_k} = 0$$

We get this linear set of equations :

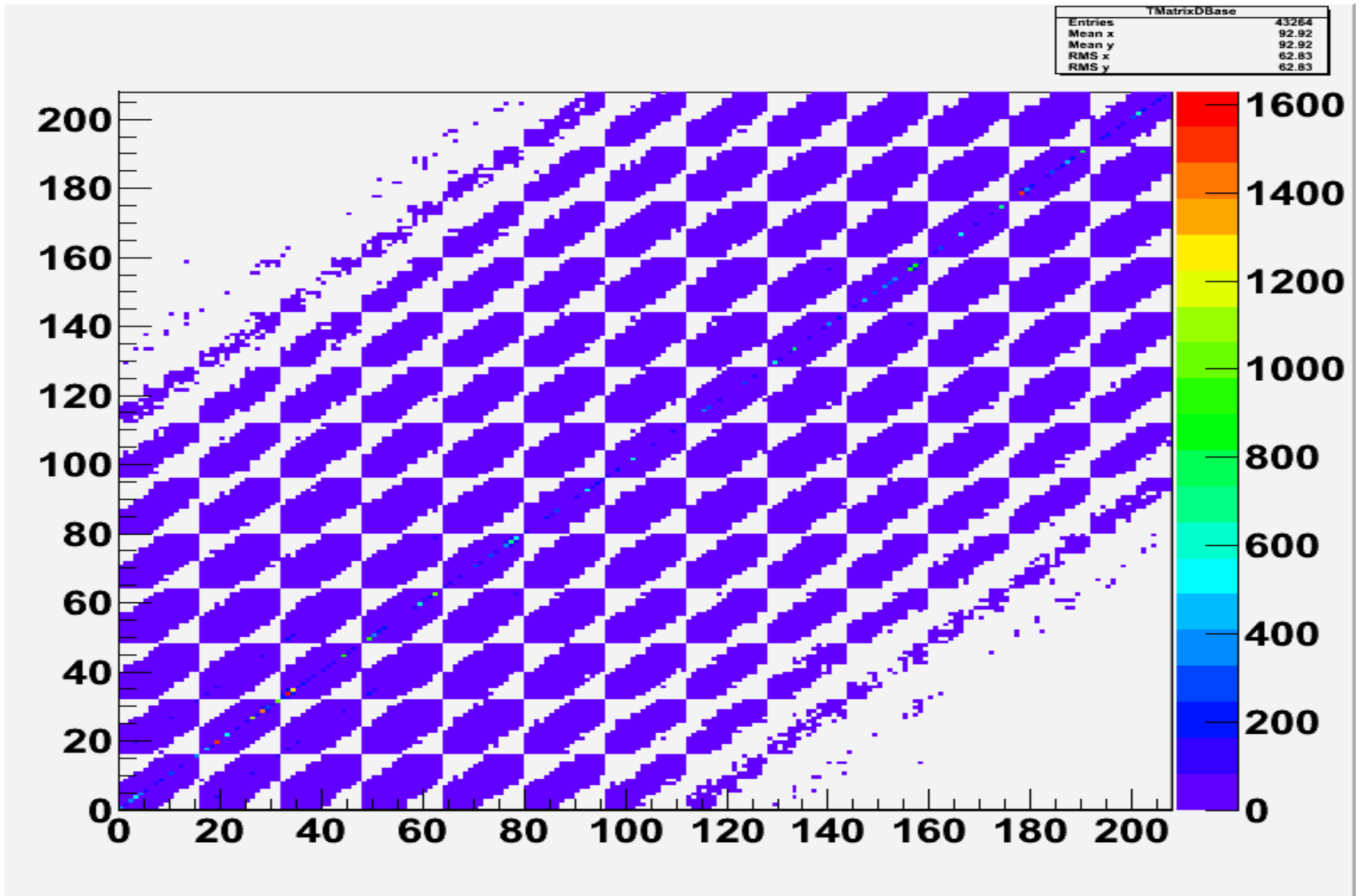
$$\sum_i \left[\sum_{j=1}^N A_j^k A_j^i \right] C_i = \sum_{j=1}^N E_j A_j^k$$

We get the calibration coefficients by inverting the

208x208 matrix $M_{ik} = \sum_{j=1}^N A_j^k A_j^i$

$$\Rightarrow C_i = M_{ik}^{-1} \cdot \sum_{j=1}^N E_j A_j^k$$

Matrix 208x208 to invert



Simulation in geant4

Generation of a proton in the HRS

→ we get the answer of the scattered electron in the calorimeter

- 3 settings (of Eric) :
 - $\theta_{\text{HRS}} = 37^\circ$
 - $\theta_{\text{HRS}} = 34.76^\circ$
 - $\theta_{\text{HRS}} = 33.29^\circ$
- $E_b = 5.562 \text{ GeV}$ (5 passes)
- $\Theta_{\text{calo}} = 22.6^\circ$
- Extended target of 15cm

- From a Monte Carlo simulation, we decalibrate the energies of the blocks of a Gaussian (decalibration coefficients D_j)

- We try to find the same values of the calibration coefficients

$$\rightarrow C_j^{\text{decalibrated}} = \frac{C_j^{\text{initial}}}{D_j}$$

Results

- for a precision of 1% (except for the blocks of the crown)
- Luminosity of $1e37\text{cm}^{-2}/\text{s}$

3 x 30,000 generated events

- Total time \approx 1h47
- $37^\circ \rightarrow$ time = 0h23 (6200 accepted events)
- $34.76^\circ \rightarrow$ time = 0h37 (19400 accepted events)
- $33.29^\circ \rightarrow$ time = 0h47 (12400 accepted events)

Result of the calibration : 30,000 x 3 events For a Gaussian (1,0.1)

Calorimeter 208 blocks

15	31	47	63	79	95	111	127	143	159	175	191	207
14	30	46	62	78	94	110	126	142	158	174	190	206
13	29	45	61	77	93	109	125	141	157	173	189	205
12	28	44	60	76	92	108	124	140	156	172	188	204
11	27	43	59	75	91	107	123	139	155	171	187	203
10	26	42	58	74	90	106	122	138	154	170	186	202
9	25	41	57	73	89	105	121	137	153	169	185	201
8	24	40	56	72	88	104	120	136	152	168	184	200
7	23	39	55	71	87	103	119	135	151	167	183	199
6	22	38	54	70	86	102	118	134	150	166	182	198
5	21	37	53	69	85	101	117	133	149	165	181	197
4	20	36	52	68	84	100	116	132	148	164	180	196
3	19	35	51	67	83	99	115	131	147	163	179	195
2	18	34	50	66	82	98	114	130	146	162	178	194
1	17	33	49	65	81	97	113	129	145	161	177	193
0	16	32	48	64	80	96	112	128	144	160	176	192

decalibration

>18%
>5%
>3%
>2%
>1%

For a Gaussian (1, 0.7)

Calorimeter 208 blocks

15	31	47	63	79	95	111	127	143	159	175	191	207
14	30	46	62	78	94	110	126	142	158	174	190	206
13	29	45	61	77	93	109	125	141	157	173	189	205
12	28	44	60	76	92	108	124	140	156	172	188	204
11	27	43	59	75	91	107	123	139	155	171	187	203
10	26	42	58	74	90	106	122	138	154	170	186	202
9	25	41	57	73	89	105	121	137	153	169	185	201
8	24	40	56	72	88	104	120	136	152	168	184	200
7	23	39	55	71	87	103	119	135	151	167	183	199
6	22	38	54	70	86	102	118	134	150	166	182	198
5	21	37	53	69	85	101	117	133	149	165	181	197
4	20	36	52	68	84	100	116	132	148	164	180	196
3	19	35	51	67	83	99	115	131	147	163	179	195
2	18	34	50	66	82	98	114	130	146	162	178	194
1	17	33	49	65	81	97	113	129	145	161	177	193
0	16	32	48	64	80	96	112	128	144	160	176	192

decalibration

>18%
>5%
>3%
>2%
>1%

Decalibration : Gauss(1,0.7)

30000 *3 events

Tps : 1h40

3 x 60,000 generated events

- Total time \approx 3h36
- $37^\circ \rightarrow$ time = 0h47 (28100 accepted events)
- $34.76^\circ \rightarrow$ time = 1h14 (38800 accepted events)
- $33.29^\circ \rightarrow$ time = 1h35 (24700 accepted events)

Result of the Calibration : 60,000 x3 events

Calorimeter 208 blocks

15	31	47	63	79	95	111	127	143	159	175	191	207
14	30	46	62	78	94	110	126	142	158	174	190	206
13	29	45	61	77	93	109	125	141	157	173	189	205
12	28	44	60	76	92	108	124	140	156	172	188	204
11	27	43	59	75	91	107	123	139	155	171	187	203
10	26	42	58	74	90	106	122	138	154	170	186	202
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5	21	37	53	69	85	101	117	133	149	165	181	197
4	20	36	52	68	84	100	116	132	148	164	180	196
3	19	35	51	67	83	99	115	131	147	163	179	195
2	18	34	50	66	82	98	114	130	146	162	178	194
1	17	33	49	65	81	97	113	129	145	161	177	193
0	16	32	48	64	80	96	112	128	144	160	176	192

Decalibration

>30%
>18%
>5%
>3%
>2%
>1%

3 x 90,000 generated events

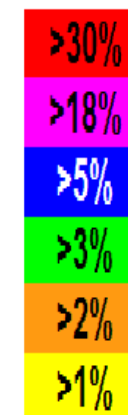
- Total time = 5h28
- $37^\circ \rightarrow$ time = 1h09 (42200 accepted events)
- $34.76^\circ \rightarrow$ time = 1h51 (58300 accepted events)
- $33.29^\circ \rightarrow$ time = 2h28 (37100 accepted events)

Result of the Calibration : 90,000 x 3 events

Calorimeter 208 blocks

15	31	47	63	79	95	111	127	143	159	175	191	207
14	30	46	62	78	94	110	126	142	158	174	190	206
13	29	45	61	77	93	109	125	141	157	173	189	205
12	28	44	60	76	92	108	124	140	156	172	188	204
11	27	43	59	75	91	107	123	139	155	171	187	203
10	26	42	58	74	90	106	122	138	154	170	186	202
9	25	41	57	73	89	105	121	137	153	169	185	201
8	24	40	56	72	88	104	120	136	152	168	184	200
7	23	39	55	71	87	103	119	135	151	167	183	199
6	22	38	54	70	86	102	118	134	150	166	182	198
5	21	37	53	69	85	101	117	133	149	165	181	197
4	20	36	52	68	84	100	116	132	148	164	180	196
3	19	35	51	67	83	99	115	131	147	163	179	195
2	18	34	50	66	82	98	114	130	146	162	178	194
1	17	33	49	65	81	97	113	129	145	161	177	193
0	16	32	48	64	80	96	112	128	144	160	176	192

Decalibration



Conclusion

- Precision remains almost the same if we decalibrate at 10%, 40% or 70% for the same number of events
- Calibration to 1% accuracy with 2-4h of beamtime (time estimates consistent with Eric's)
- Calibration script ready to use for the upcoming experiment
- Calibration will be tested this week with 4-pass Energy settings