Analysis of PCB Exposure Tests

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LAL Orsay

- Motivation

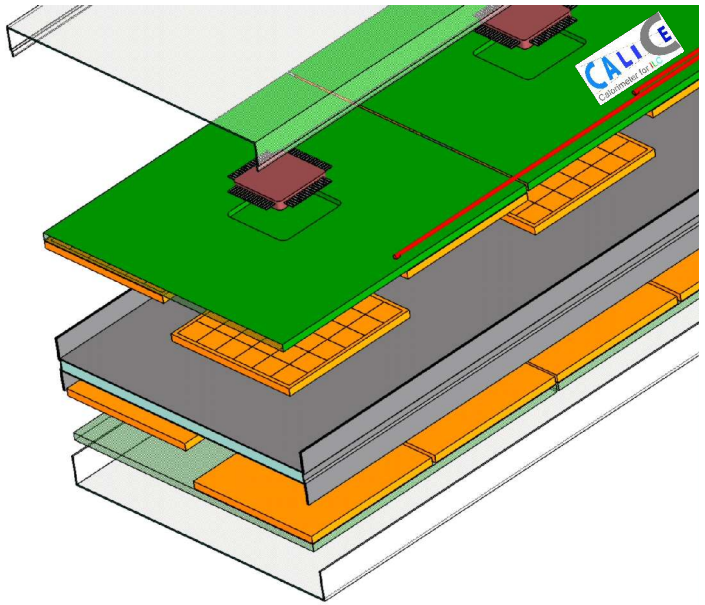
- Analysis and Results

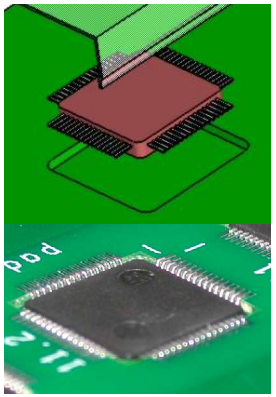
- Summary, Conclusion and Outlook

Calice Analysis Meeting 3/5/2010

Introduction

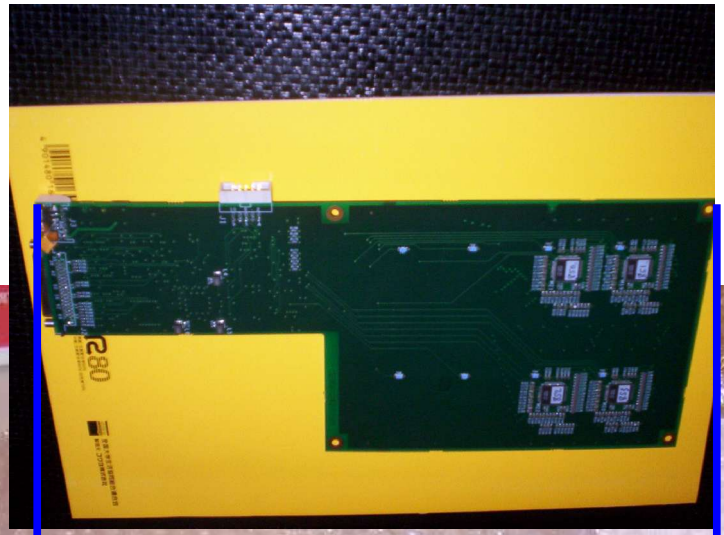
Calorimeter Electronics to be interleaved with layer structure





Do high energetic showers create signals directly in electronics ?
If yes, Rate of faked signals ?

Special PCB in Ecal Prototype during CERN 07 testbeam – Experimental Setup I



Test PCB
- equipped with
  PHY3 Chip Set

Prepared Slab
- W dummy
- capton and paper
  for electrical shielding

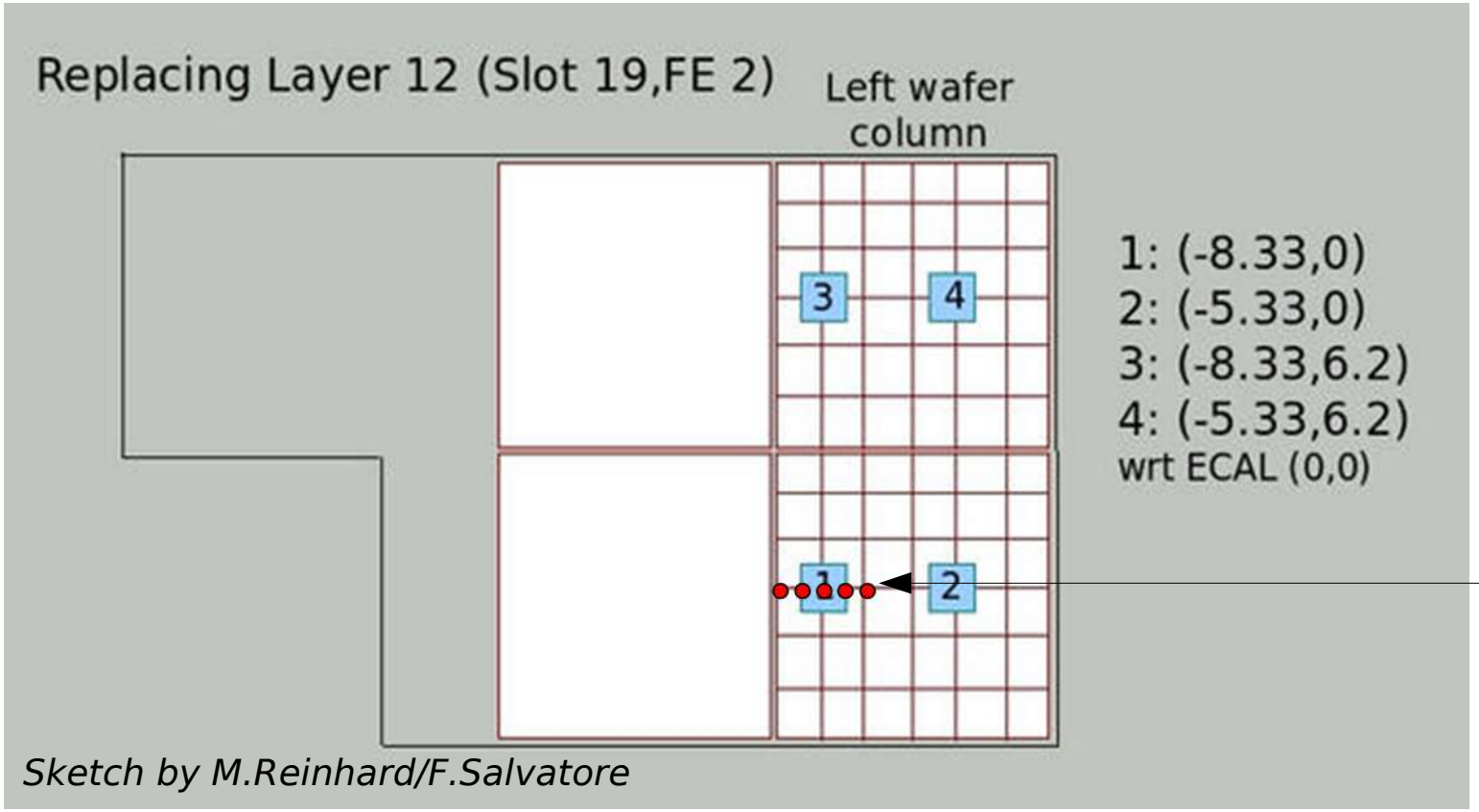
Usual Slab

Picture courtesy of B.Lutz

Special PCB in Ecal Prototype during CERN 07 testbeam – Experimental Setup II

- PCB positioned at place of layer 12 in Ecal ~ shower maximum
  x,y position identical to layer 2

- Schematic view of test PCB - 'Expect' signals from 72 pads, 4x18 = 2 Wafer



Nominal positions of Chips

Scanning points

- 2.6 10^6 Events with 90 GeV Electrons (- 5.8 10^5 with 70 GeV Electrons)
  At least 70 K at each scanning point (Details see later)
  Runs 331462 – 331518
  Today: **Full Statistics**

- First Step: Runs were subject to the same data processing chain as 'usual' runs

Disabling of zero suppression in reco output

- Three Scenarios:

1) No pedestal correction
2) Full pedestal Corrections
3) Pedestal Corrections restricted to signals from Chips
Remember that there are still 216 entries for the layer in the data files

- General Methodology:

Subdivision of Runs into BeamTrigger and
Pedestal Trigger Events (Oscillator Trigger) interleaved with beam events
Corrections are applied (or not) to pedestal as well as to signal events

Note: The reconstruction s/w had to be tweaked a bit for that

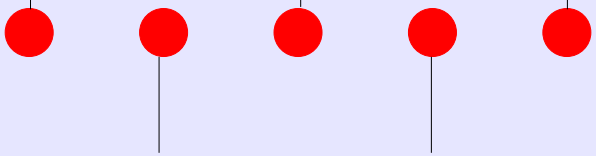
Statistics of Analysis

Scan 3

Run331513: e- 90 GeV
Signal: 216877 Evts.
Pedestal: 9831 Evts.

Run331518: e-90 GeV
Signal: 90395 Evts.
Pedestal: 4347 Evts.

Run331511: e-?? GeV
Signal: 86989 Evts.
Pedestal: 3909 Evts.



Run331516: e- 90 GeV
Signal: 228138 Evts.
Pedestal: 10926 Evts.

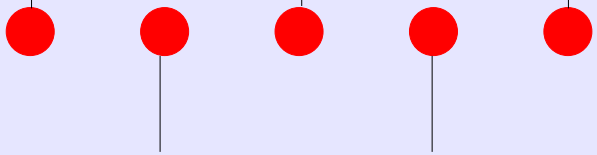
Run331512: e- 90 GeV
Signal: 218519 Evts.
Pedestal: 9462 Evts.

Scan 4

Run331495: e-90 GeV
Signal: 314275 Evts.
Pedestal: 15264 Evts.

Run331498: e- 90 GeV
Signal: 66655 Evts.
Pedestal: 4223 Evts.

Run331493: e- 90 GeV
Signal: 85884 Evts.
Pedestal: 4949 Evts.



Run331497: e- 90 GeV
Signal: 214418 Evts.
Pedestal: 13666 Evts.

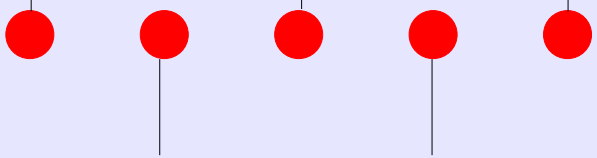
Run331494: e- 90 GeV
Signal: 217415 Evts.
Pedestal: 11698 Evts.

Scan 1

Run331473: e- 70 GeV
Signal: 209312 Evts.
Pedestal: 38361 Evts.

Run331470: e- 70 GeV
331471
Signal: 78293 Evts.
Pedestal: 14624 Evts.

Run331479: e- 90 GeV
Signal: 85543 Evts.
Pedestal: 4306 Evts.



Run331472: e- 70 GeV
Signal: 189966 Evts.
Pedestal: 37137 Evts.

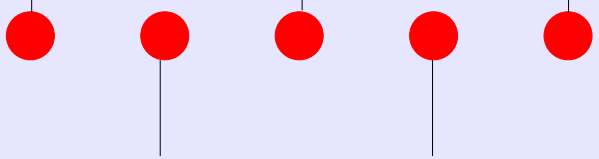
Run331478: 90 e- GeV
Signal: 65249 Evts.
Pedestal: 3602 Evts.

Scan 2

Run331488: e- 90 GeV
Signal: 213369 Evts.
Pedestal: 13719 Evts.

Run331480: e- 90 GeV
Signal: 85188 Evts.
Pedestal: 4678 Evts.

Run331492: e- 90 GeV
Signal: 89435Evts.
Pedestal: 4254 Evts.



Run331486: e- 90 GeV
Signal: 129778 Evts.
Pedestal: 6146 Evts.

Run331491: e- 90 GeV
Signal: 217711Evts.
Pedestal: 11053 Evts.

On Run Selection and Observations

- Run Selected according to entries in the logbook
  No comments on bad quality by Shift Crew

- Switch of energy between Run 331473 and Run 331478
  - Change in Pedestal Rate
    20% of all events -> 5% of all events
    Still at least 3500 of (valuable) pedestal events

- at least 70k Events at each point
  - mostly 90 kEvents for off center runs
  - > 200k at (nominal) Chip Center

Calculation of upper Limits

- Aim: Upper Limits/Probabilities as a function of the Threshold

- Requires calculation of limits with underlying background

Probability Density Function (Frequentist Approach):

$$f'(n;\lambda_S+\lambda_B)=f(n;\lambda_S+\lambda_B)/\sum_{n_B=0}^{k} f(n_B;\lambda_B) \quad \text{f, f' are Poissonnian Densities}$$

Presence of Background via numerator (Approach á la Zech NIM A277)

Using this pdf the Confidence Limits/Upper Limits
can be calculated using regular statistics techniques

Here: S. Brandt, Datenanalyse, pp.183

Developed ("c++ fied") program to calculate upper limits in the presence of known background.

Estimation of Background

Several Approaches:

- "Gaussian Background"

  Assume gaussian distribution of noise spectra
  mean and sigma from measured noise, i.e. pedestal spectra

- "Detailed Background"

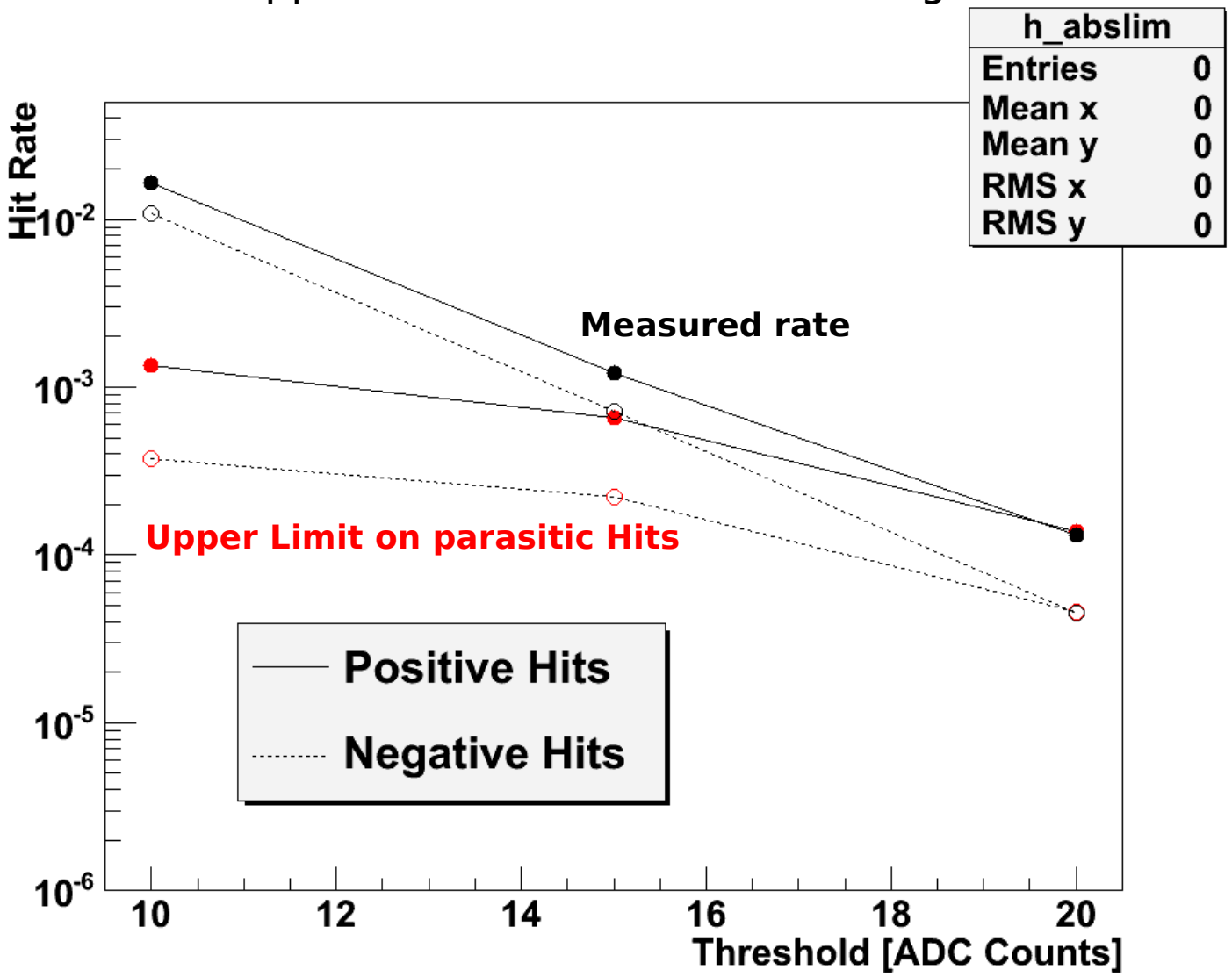
  Create pdf from measured noise spectra and generate
  noise background from these pdfs

- "Cross Modelled Background"

  Create pdf of a Chip x from measured Signal spectra when
  scanned over a Chip opposite to Chip x
  E.g. spectra for Chip 1 from Scan over Chip 4

Starting point today

Absolute Upper Limits as shown on Meeting 8/2/10

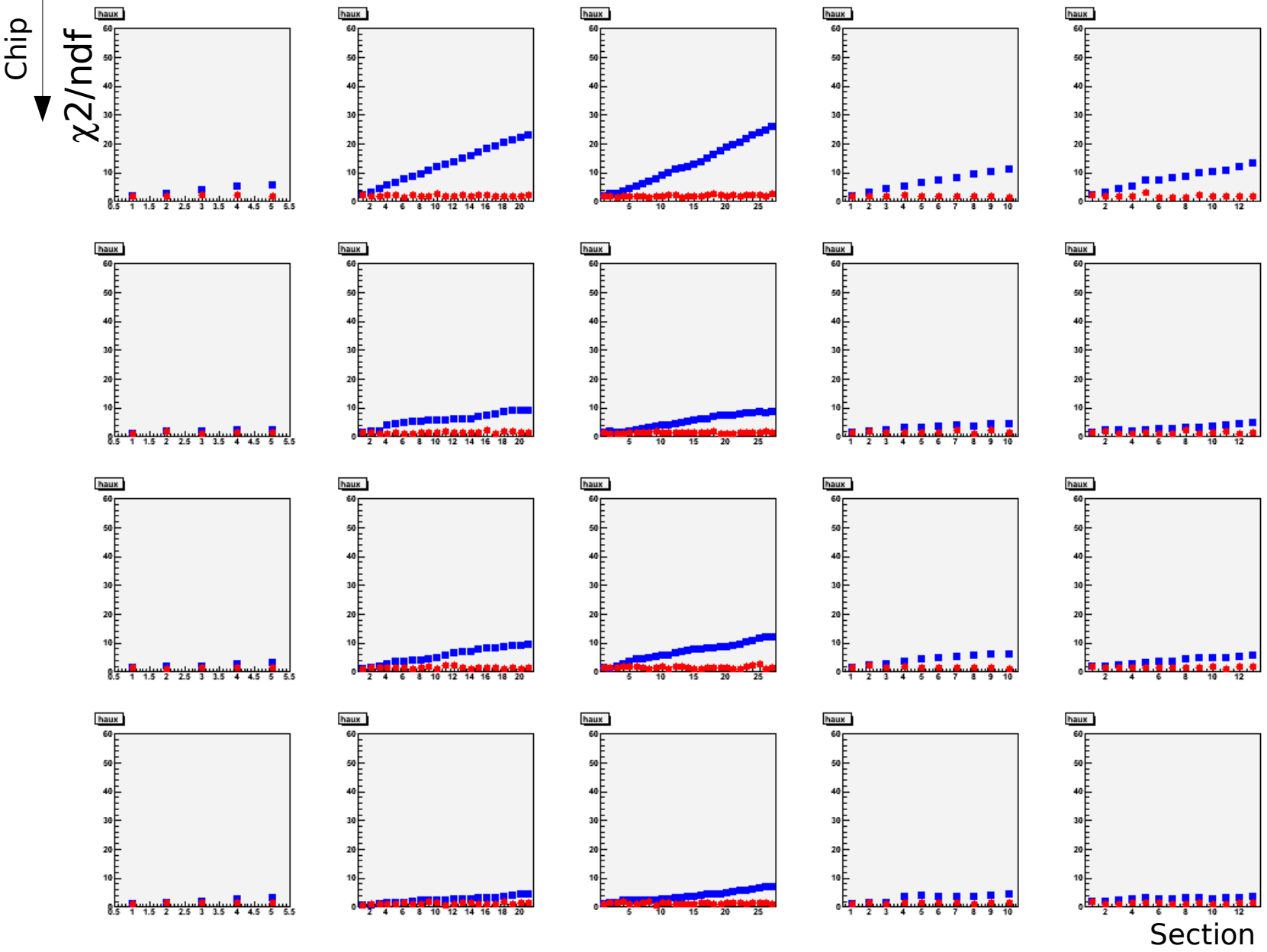


Limits correct but unreasonably high
For 15 ADC Counts at least by a factor of 10

The Problem I

History of χ2/ndf of Gaussian fit within runs for e.g. Scan 1 – Signal Events

(Subdivision into sections of 5000 events)



Blue:
"Accumulated" χ2/ndf

Red:
"Individual" χ2/ndf

– χ2/ndf gets progressively worse as run goes on

- Individual Sections Look ok

- Approximating final distribution by gaussian is too naïve

The Problem II

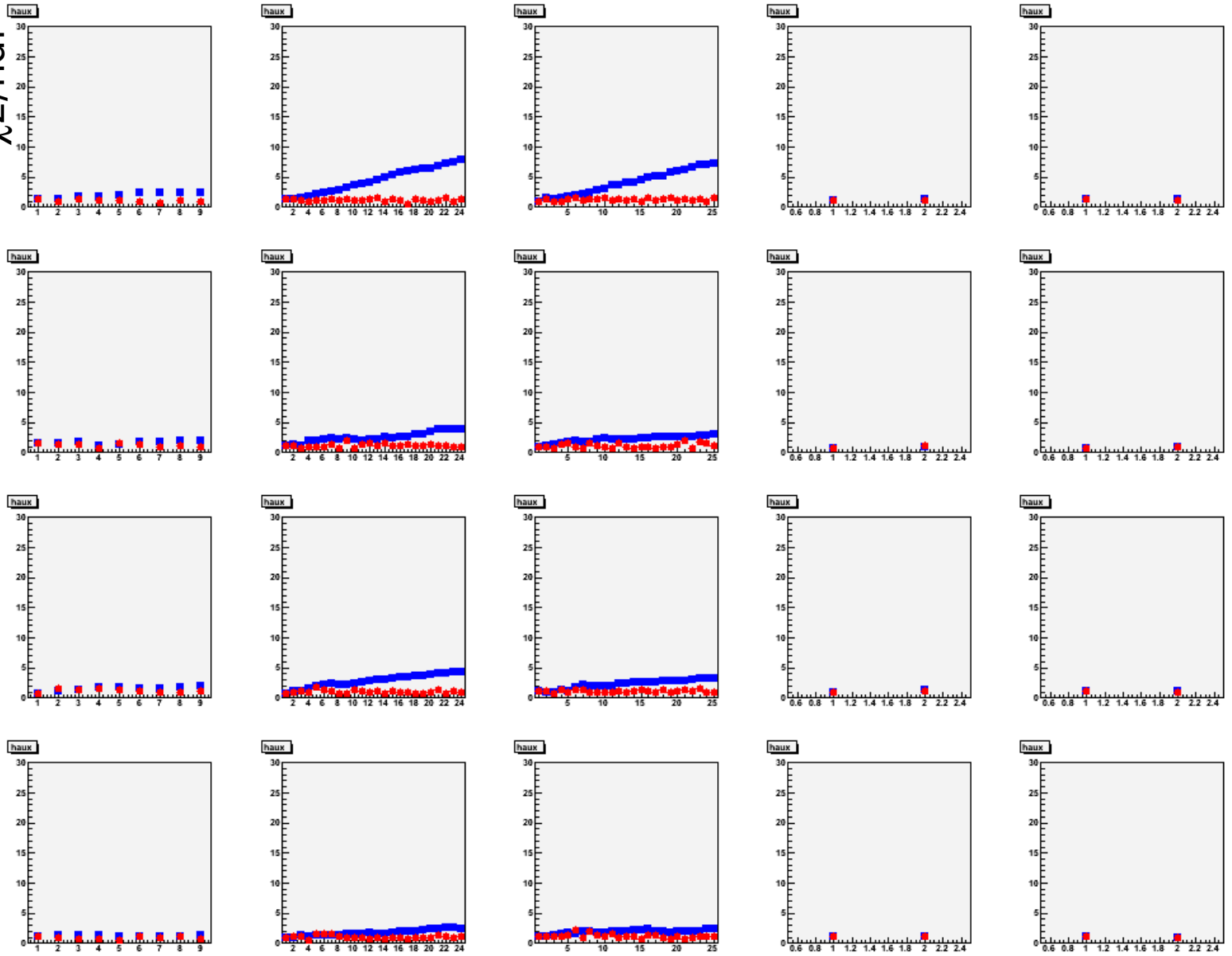
Scan Point

History of $\chi 2$/ndf of Gaussian fit within runs for e.g. Scan 1 – Pedestal Events

(Subdivision into sections of 1500 events)

Chip

$\chi 2$/ndf



Section

Blue:
"Accumulated" $\chi 2$/ndf

Red:
"Individual" $\chi 2$/ndf

– $\chi 2$/ndf gets progressively worse as run goes on

- Individual Sections Look ok

- Effect less pronounced for Pedestals since less events

Still tendency rather similar

Two potential reasons for distorted χ2/ndf values

1) Residual fluctuations of baseline

2) Coherent Noise
(Hint by CdlT)

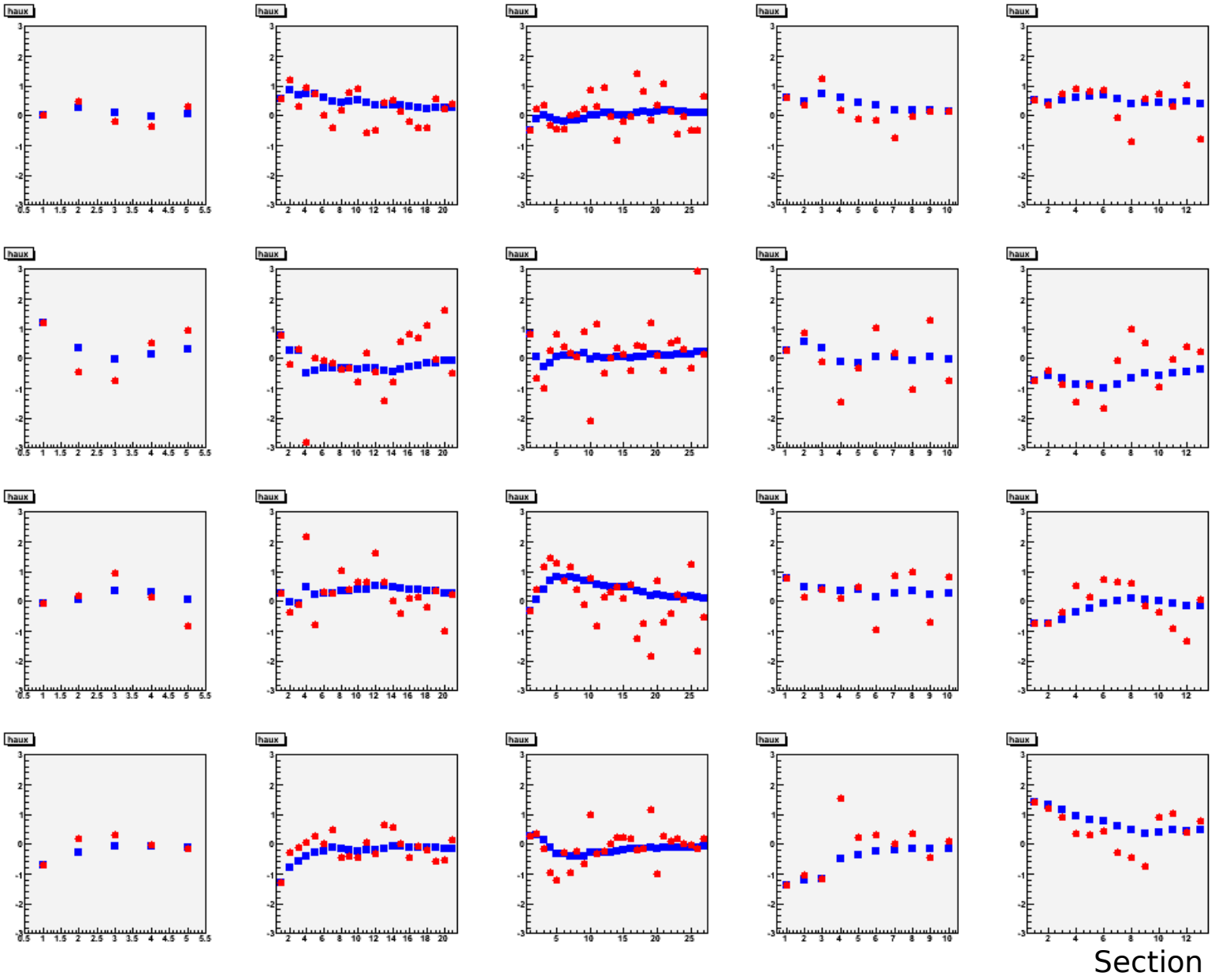
On residual Baseline Fluctuations I

Scan Point

History of mean of gaussian fit within runs for e.g. Scan 1 – Signal Events
(Subdivision into sections of 5000 events)

Chip

Mean



Blue:
"Accumulated" Mean

Red:
"Individual" Mean

- Non neglible residual baseline fluctuations throughout run

On residual Baseline Fluctuations II

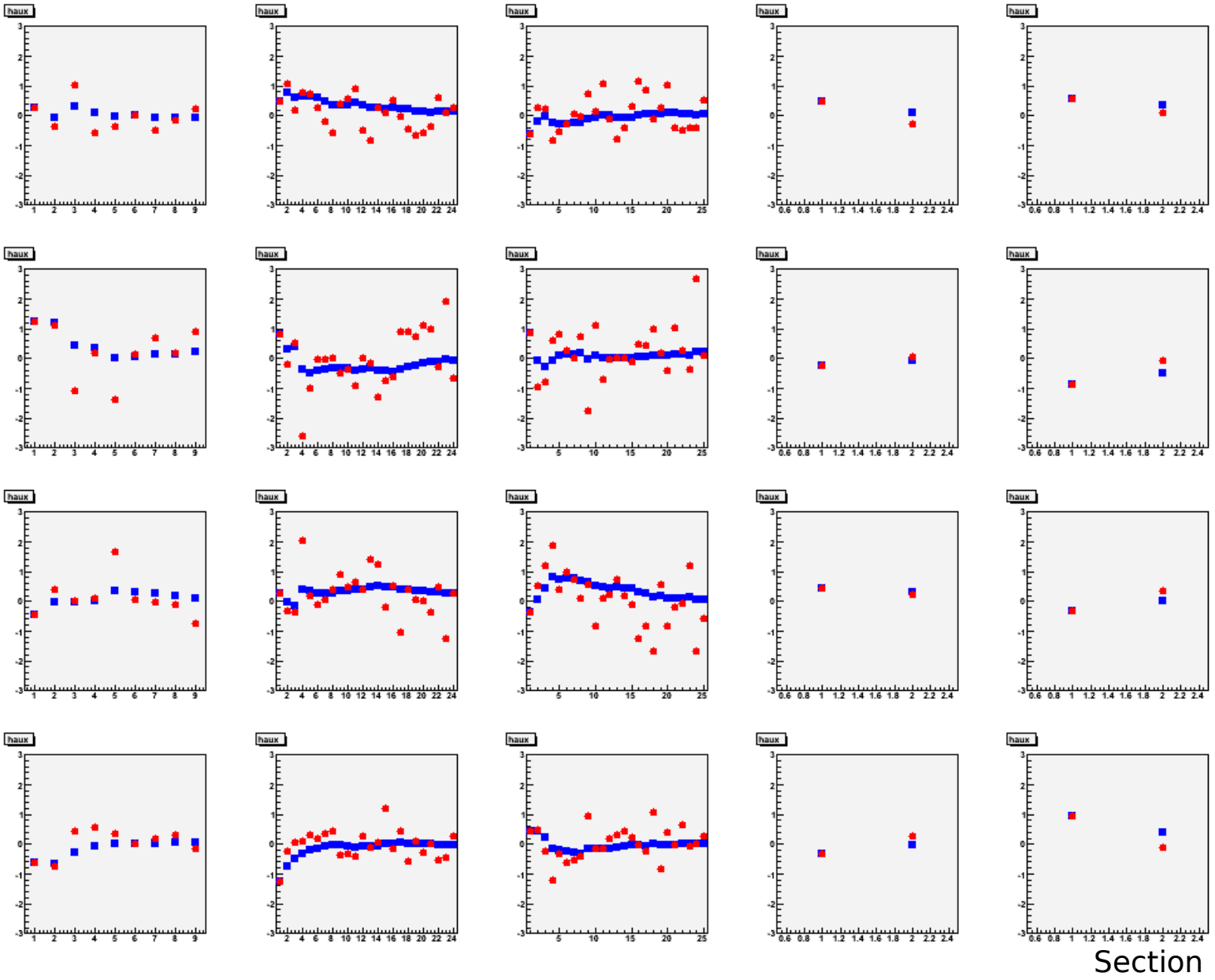
History of mean of gaussian fit within runs for e.g. Scan 1 – Pedestal Events

(Subdivision into sections of 1500 events)

Scan Point

Chip

Mean



Section

Blue:
"Accumulated" Mean

Red:
"Individual" Mean

- are fairly well reproduced by Pedestals ...

- Caveat:
  Less pedestals in Scans 2, 3, 4
  Monitoring less precise

On Coherent Noise

(I have investigated) 2 ways to determine coherent noise

1) Simple method based on distribution of direct and alternating sums of noise

$$X_{dir} = \sum_{i=1}^{N} x_i \qquad X_{alt} = \sum_{i=1}^{N} (-1)^i x_i$$

N=Number of Channels

Incoherent Noise:

$$X_{ic} = s(X_{alt}) / \sqrt{N}$$

Coherent Noise:

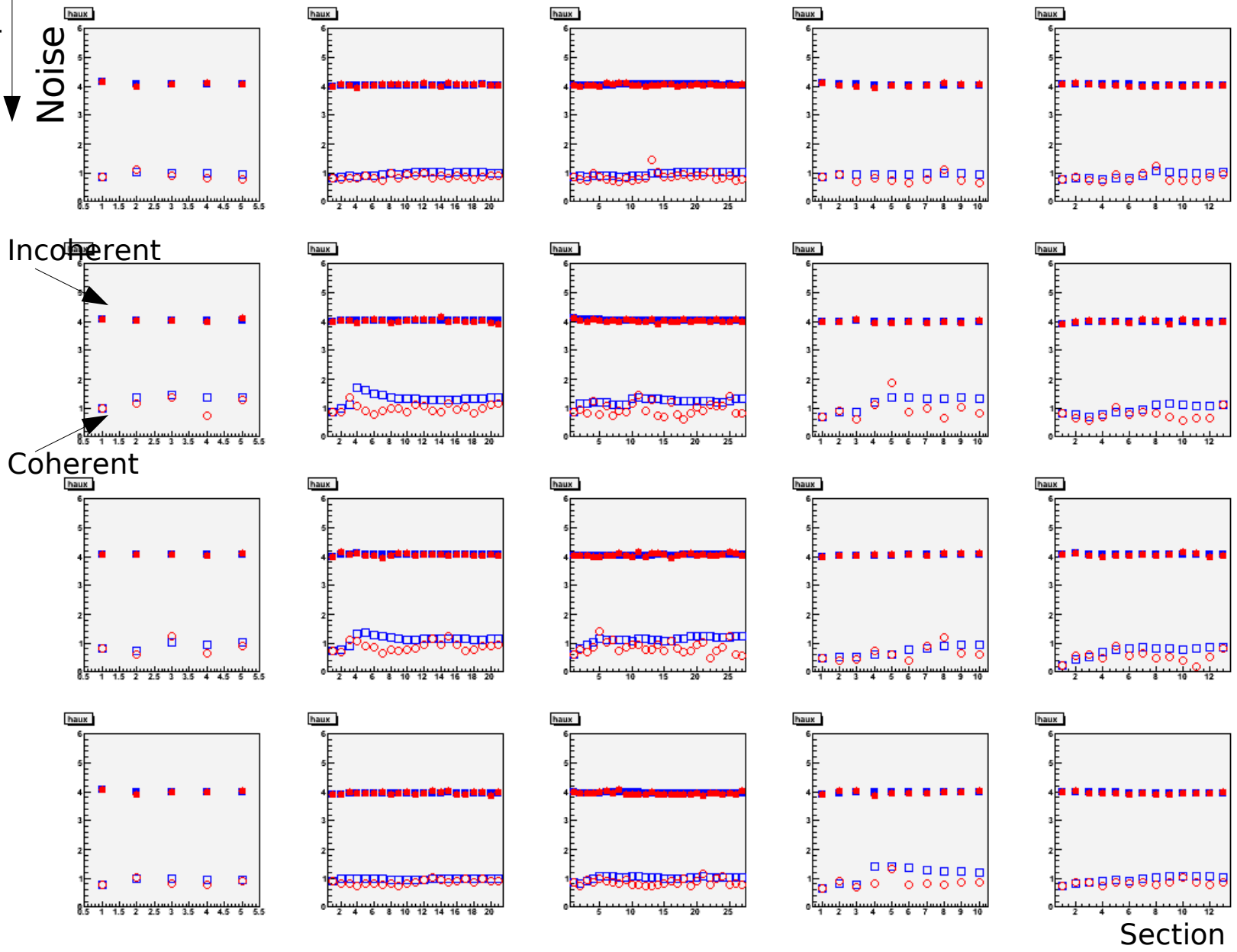
$$X_{cn}^2 = (s^2(X_{dir}) - s^2(X_{alt})) / N^2$$

2) Principal Component Analysis
Standard technique to find patterns in data of high dimensions
Applications in fields such as face recognition and image compression
Follow a 'Cooking Recipe' published in ATL-LARG-99-006
(Details see below)

Simple Method I

History of coh./incoh. Noise within runs for e.g. Scan 1 – Signal Events

(Subdivision into sections of 5000 events)



Blue:
"Accumulated" Noise

Red:
"Individual" Noise

- noise level stable during runs

- Coherent Noise ~1 ADC Count

Simple Method II

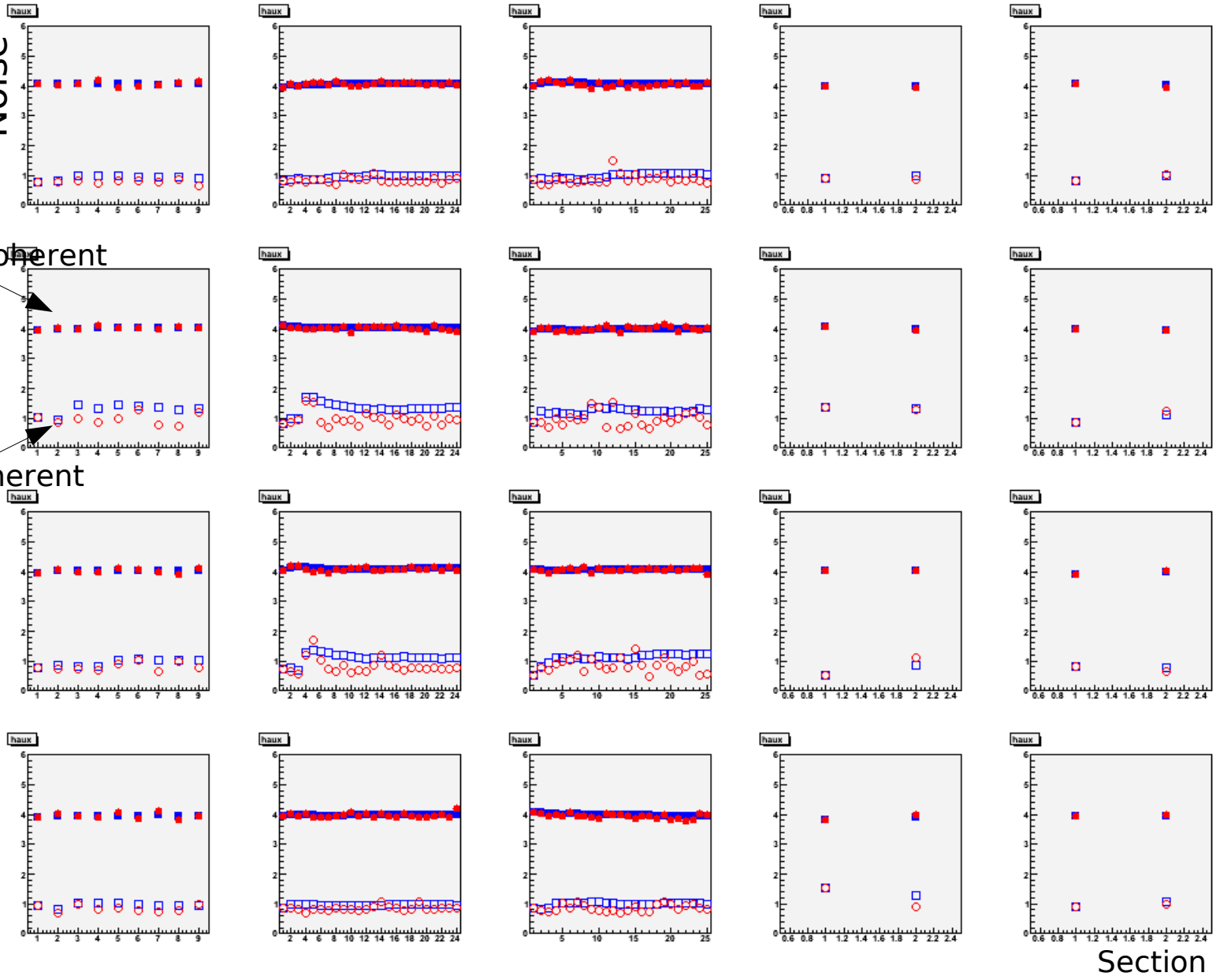
History of coh./incoh. noise within runs for e.g. Scan 1 – Pedestal Events

(Subdivision into Sections of 1500 events)

Scan Point

Chip

Noise



Incoherent

Coherent

Section

Blue:
"Accumulated" Noise

Red:
"Individual" Noise

- noise level stable during runs

- Coherent Noise ~1 ADC Count

- In agreement with observations for Signal Events

But:

$$\sqrt{\sigma_{ic}^2+\sigma_{cn}^2}\approx\sqrt{4.1^2+1}\approx4.2$$

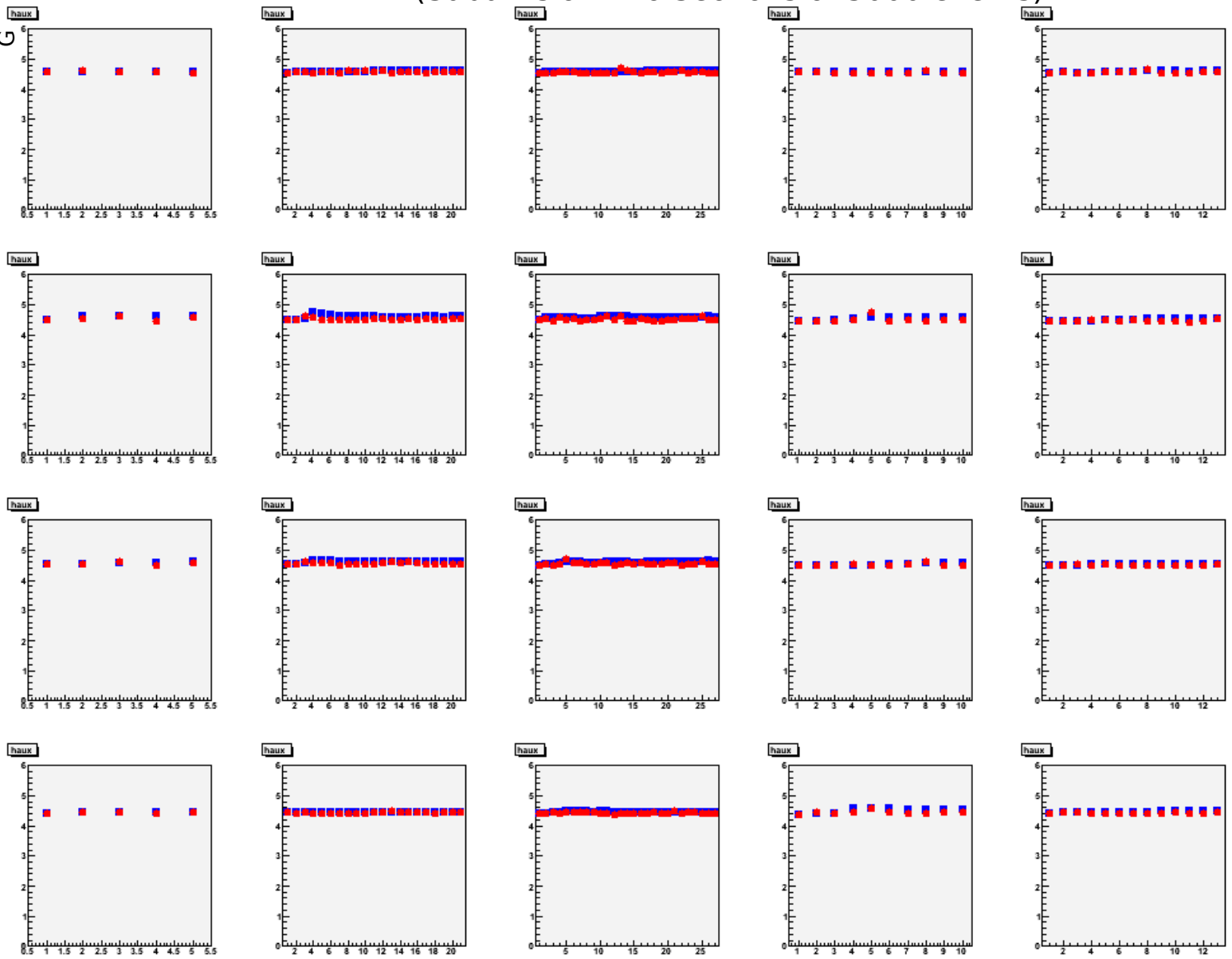
Simple Method III

Scan Point History of σ_G of gaussian Fit within runs for e.g. Scan 1 – Signal Events

(Subdivision into Sections of 5000 events)

Chip

σ_G



Section

Blue:
"Accumulated" σ_G

Red:
"Individual" σ_G

- **σ_G stable during runs**

- σ_G ≈4.6 ADC Counts

- In disagreement with result from coherent noise analysis

See above:

$$\sqrt{\sigma_{ic}^2+\sigma_{cn}^2} \approx \sqrt{4.1^2+1} \approx 4.2$$

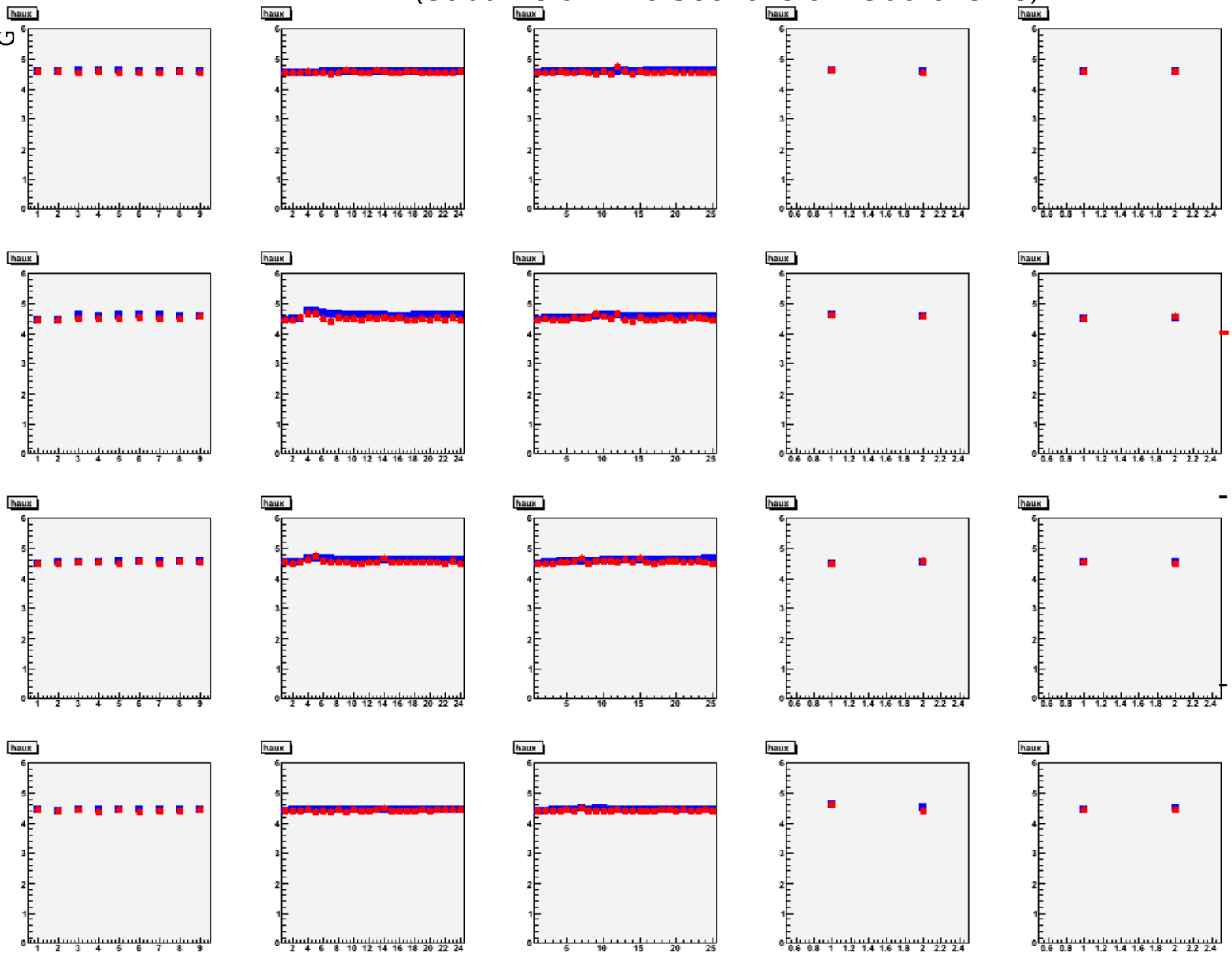
Simple Method IV

Scan Point History of σ_G of gaussian fit within runs for e.g. Scan 1 – Pedestal Events

(Subdivision into Sections of 1500 events)

Chip

σ_G



Section

Blue:
"Accumulated" σ_G

Red:
"Individual" σ_G

- **σ_G stable during runs**
- σ_G ≈4.6 ADC Counts agreement with signal
- In disagreement with result from coherent noise analysis

See above:

$$\sqrt{\sigma_{ic}^2+\sigma_{cn}^2}\approx\sqrt{4.1^2+1}\approx4.2$$

Simple Method - Conclusions

- Noise analysis exhibits incoherent and coherent noise level consistent for signal and pedestal events

- But:

Sum of retrieved coherent and incoherent noise component cannot (!!!) reproduce measured noise level

=> Simple method does not lead to reliable results
(General warning for analyses)
CALICE has shown results based on simple method at EPS07

Non-Reliability of simple method has been observed/reported in the literature

See e.g.:
ATL-LARG-99-006
ATL-TILECAL-PUB-2008-011

=> Need to examine more sophisticated method

Principal Component Analysis - PCA

Following 'cooking recipe' a la ATL-LARG-99-009
(Mathematical 'proof' for the following in my lab book)

1) Noise Vector: $\vec{b} = \vec{u} + c\,\vec{\alpha}$

Incoherent noise

Magnitude and 'direction' of coherent noise

2) Covariance Matrix: $B = \sigma^2 \cdot I + \sigma_c^2 \vec{\alpha}\,\vec{\alpha}^T$

With: $\langle u_i u_j \rangle = \sigma^2 \delta_{ij}$ incoherent noise

σ_c^2 = Variance of c

3) Eigenvalues and Eigenvectors of covariance matrix:

$\vec{\alpha}$ is eigenvector to (largest) eigenvalue $\sigma^2 + \sigma_c^2$

Any other eigenvector (orthogonal) to $\vec{\alpha}$ is eigenvector to eigenvalue σ^2

=> Expect flat spectrum of matrix B except for one (or few) eigenvalue associated with α

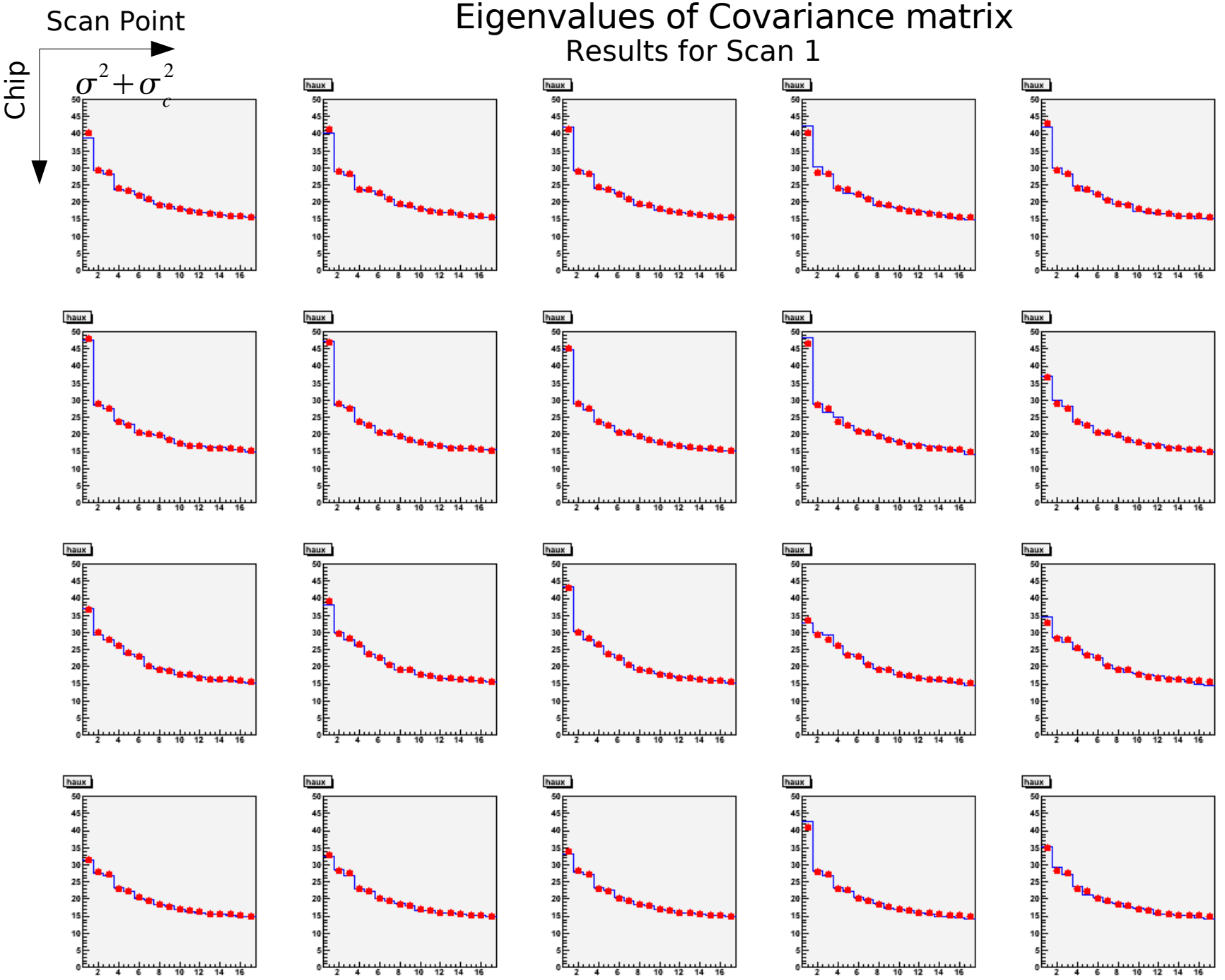
Coherent channel noise via $\sigma_c \cdot \vec{\alpha}$

4) Incoherent Channel noise via: $B' = B - \sigma_c^2 \alpha\,\alpha^T$

=> Matrix with incoherent channel noise on diagonal and off-diagonal elements flat and zero

Eigenvalues of Covariance matrix

Results for Scan 1



Blue:Pedestals
Red: Signal

- Mostly clear prominent eigenvalues

=> Coherent noise

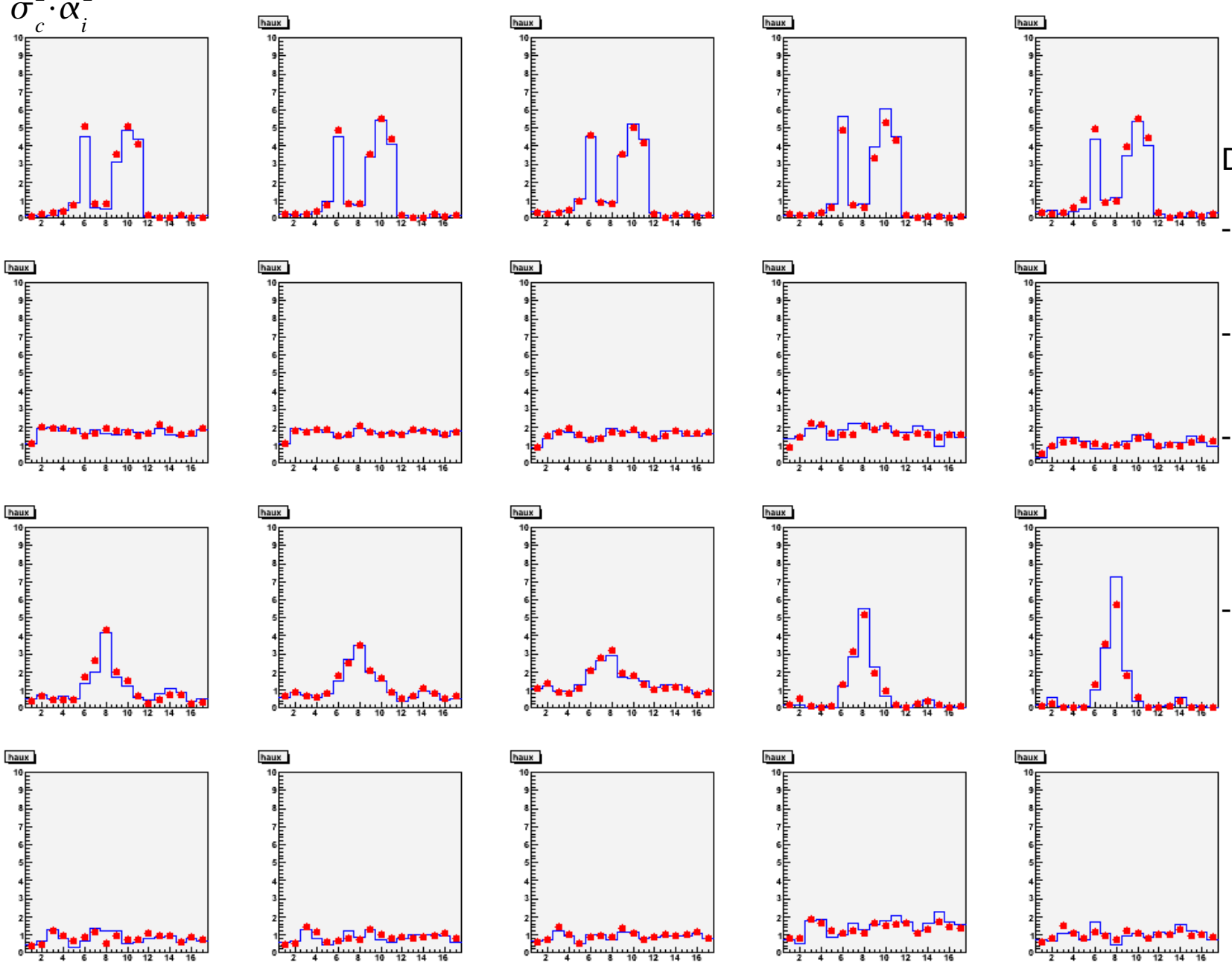
- Where less prominent: Still visible step

- Fairly flat spectrum of other eigenvalues

- Excellent agreement between Signal and Pedestal

Coherent Noise Level

Results for Scan 1



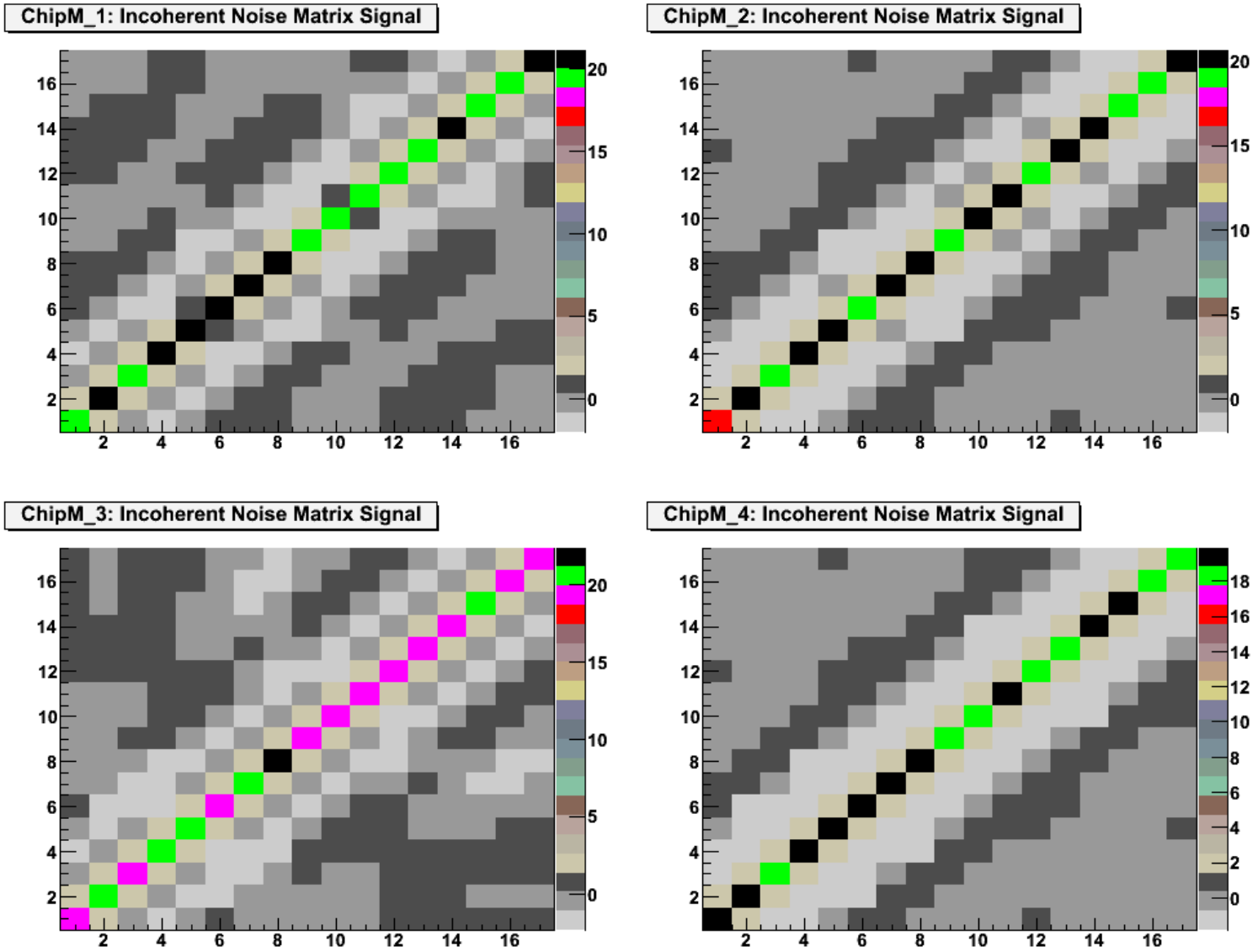
Blue:Pedestals
Red: Signal

Different Patterns

- Concentrated for Chip 1 and Chip 3
- Flat spectrum for Chip 2 and 4
- Excellent agreement between Signal and Pedestal
- Coherent Noise level ~1 ADC Count in agreement with simple analysis

Matrix B'

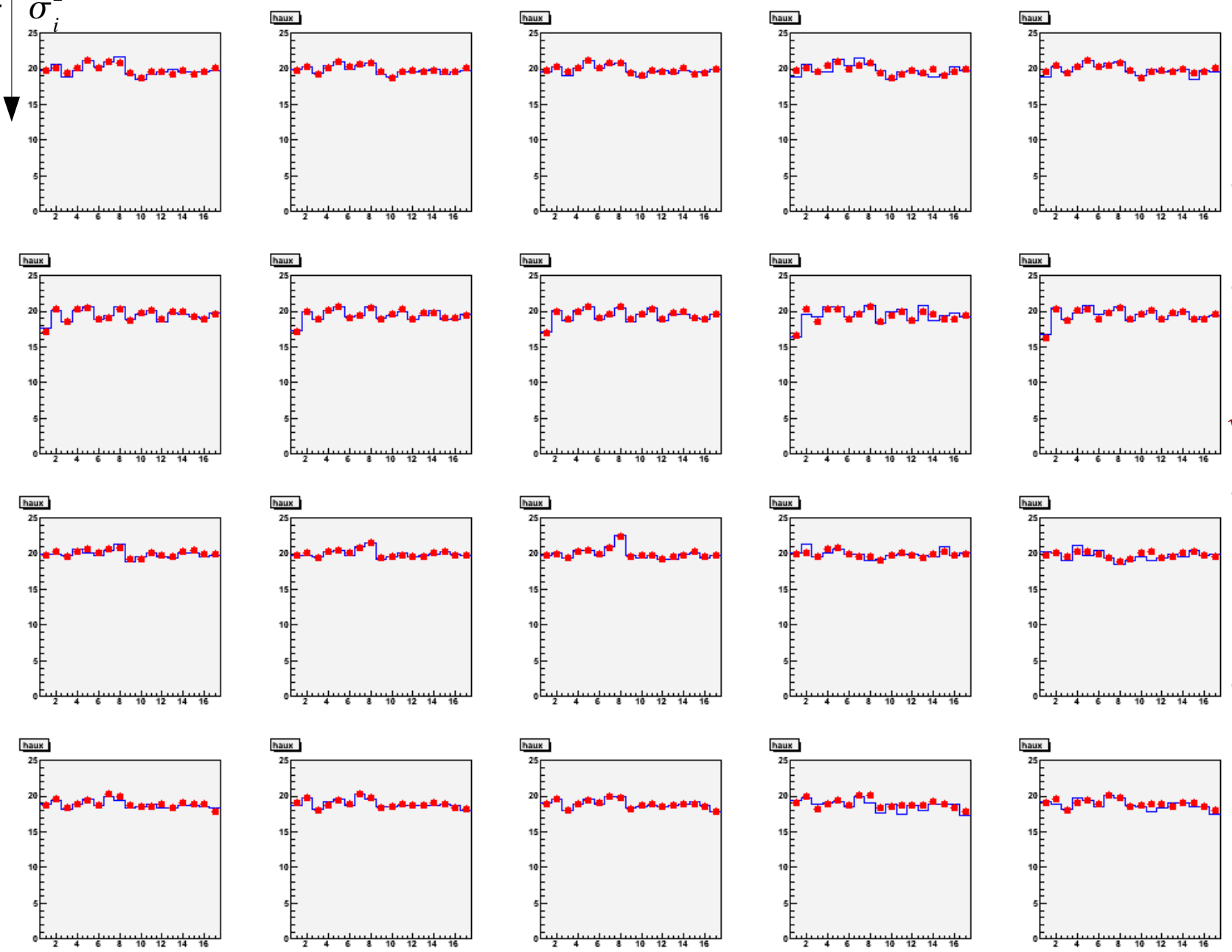
Example for central impact Scan 1 – Signal Events



Diagonal: Prominent with value ~20 (ADC Counts)^2
Off-Diagonal: Flat with value ~0

Incoherent Noise Level

Results for Scan 1



Blue:Pedestals
Red: Signal

- Flat spectrum for all Chips 2
- Incoherent Noise level ~√20 ~4.5 ADC C.

$$\sqrt{\sigma_{ic}^2+\sigma_{cn}^2}\approx\sqrt{4.5^2+1}\approx4.6$$

- In agreement with σ_G (see above) and rms (see earlier)
- Excellent agreement between Signal and Pedestal

Summary and Conclusion

- No new limits today :-(

But ...

- Detailed monitoring of mean of noise distributions
  and
  noise analysis based on PCA gives confidence that pedestals
  can well be used to model the chip responses
  (In contrast to my earlier worries)

- I think I know how (Not shown/realised part 5 of cooking recipe) stay tuned

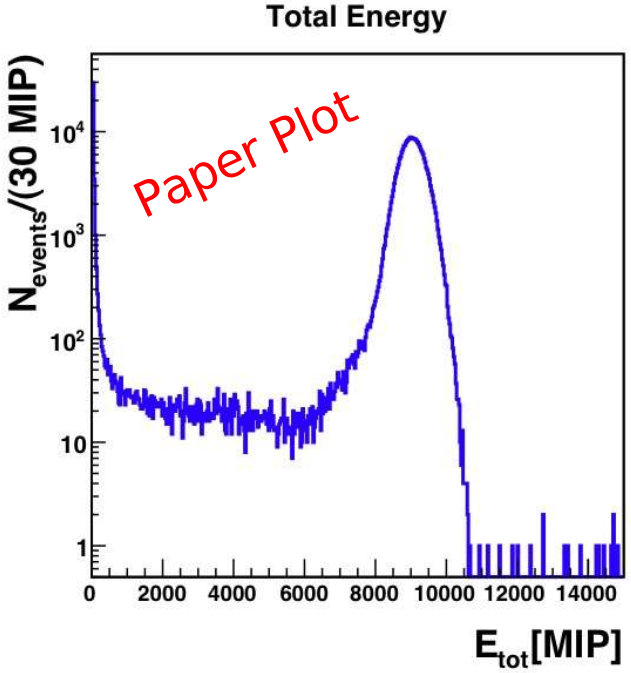
- Analysis still gives no evidence that beam in VFE distorts signals
  What is missing is the full quantitative result <=> limits (see above)

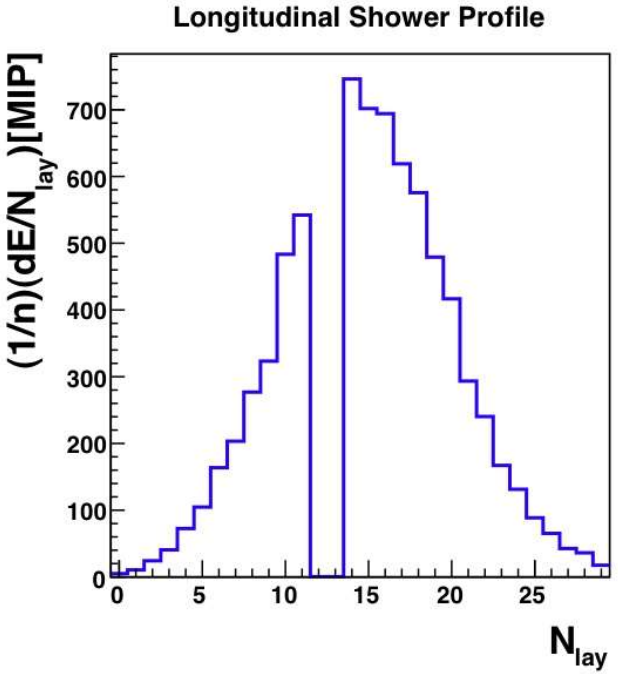
- As fruitful side goodie of analysis:

  - Algorithms at hand for “professional” noise analysis of at least all analogue calorimeters of calice!!!!
  - Can be transformed into general “Noise analysis suite” (after cleaning and structuring of my code)
  - Be very careful with simple analysis to obtain coherent noise (Not reliable)

Backup Slides

Basic Spectra and Alignment

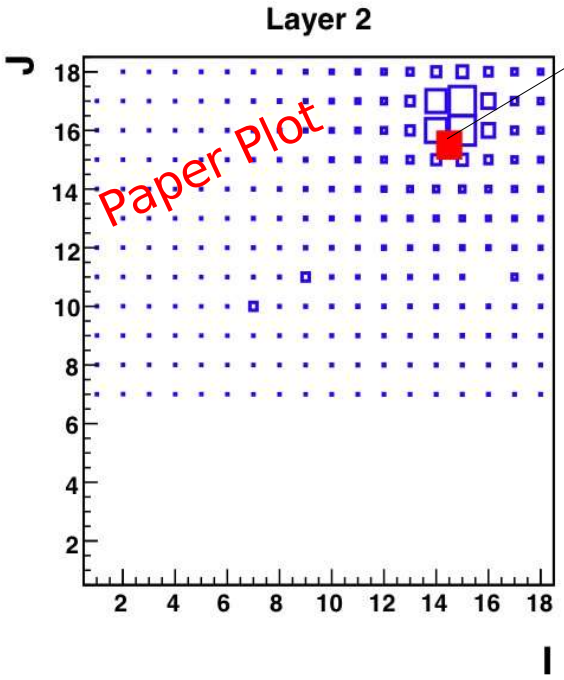


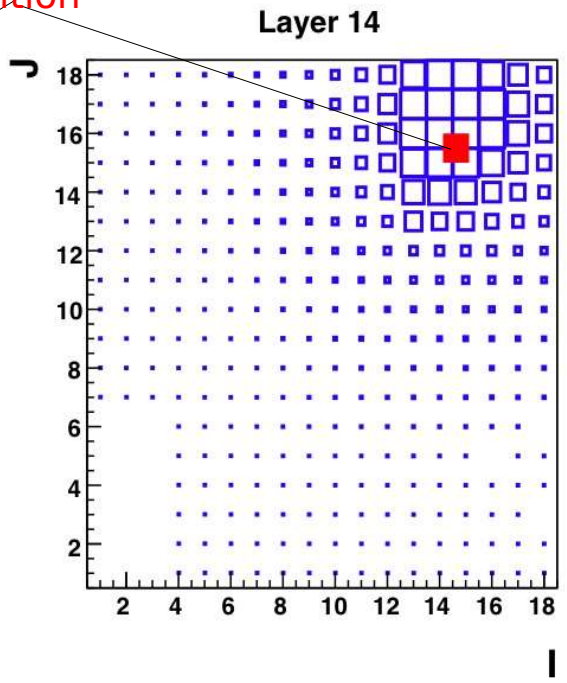


90 GeV run (331495)

- Clear Energy Peak
- Special Board place at ~ shower maximum

Projected Chip Position





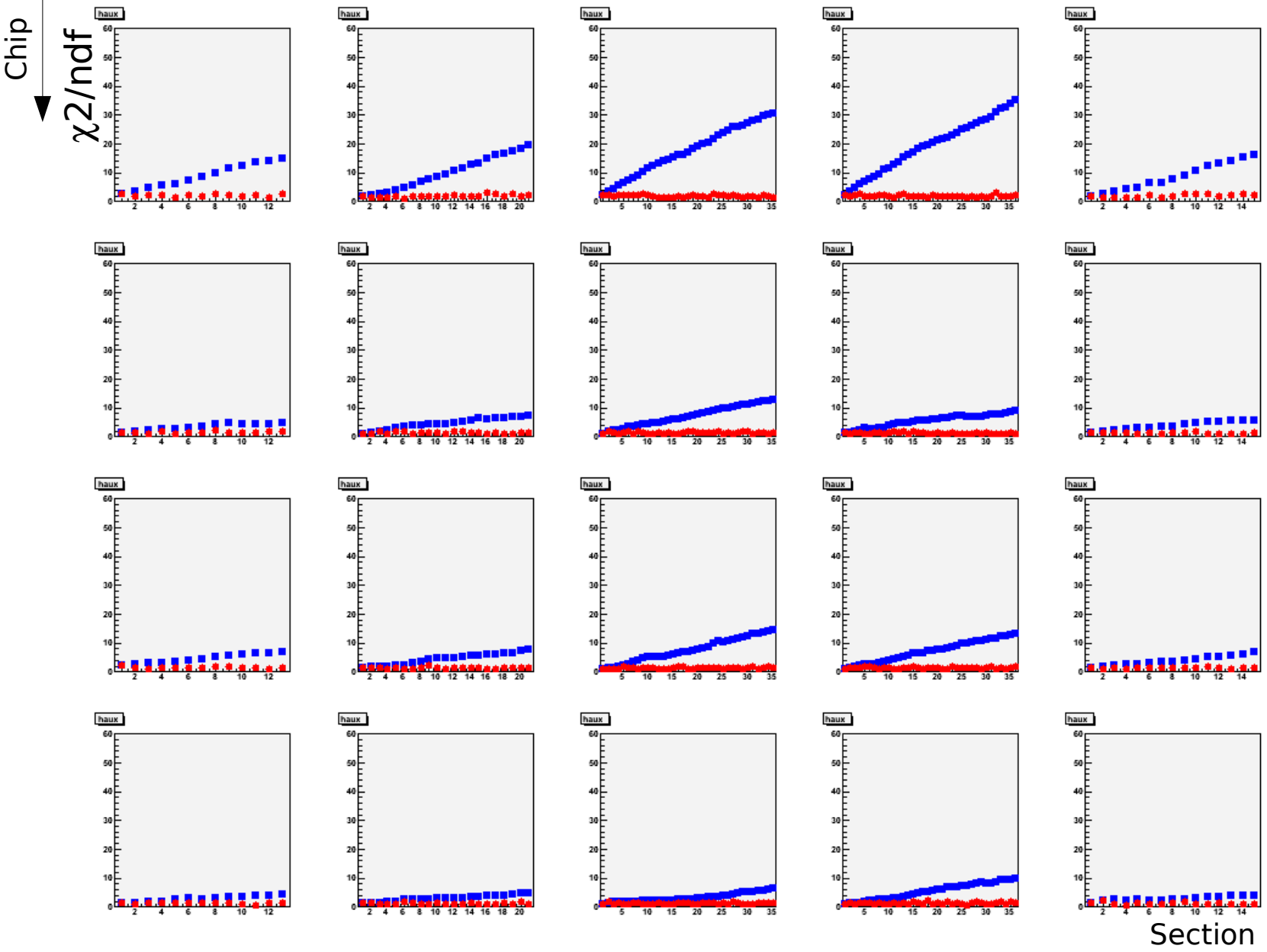
Hit Maps

- Layer 2
  Same xy-Position as Special Board
- Layer 14
  First instrumented Layer after Special board

Chip(s) well within lateral shower extension

The Problem I

History of $\chi 2$/ndf of Gaussian fit within runs for e.g. Scan 2 – Signal Events
(Subdivision into Sections of 5000 events)



Blue:
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– $\chi 2$/ndf gets progressively worse as run goes on

- Individual Sections Look ok

- Approximating final distribution by gaussian is too naïve

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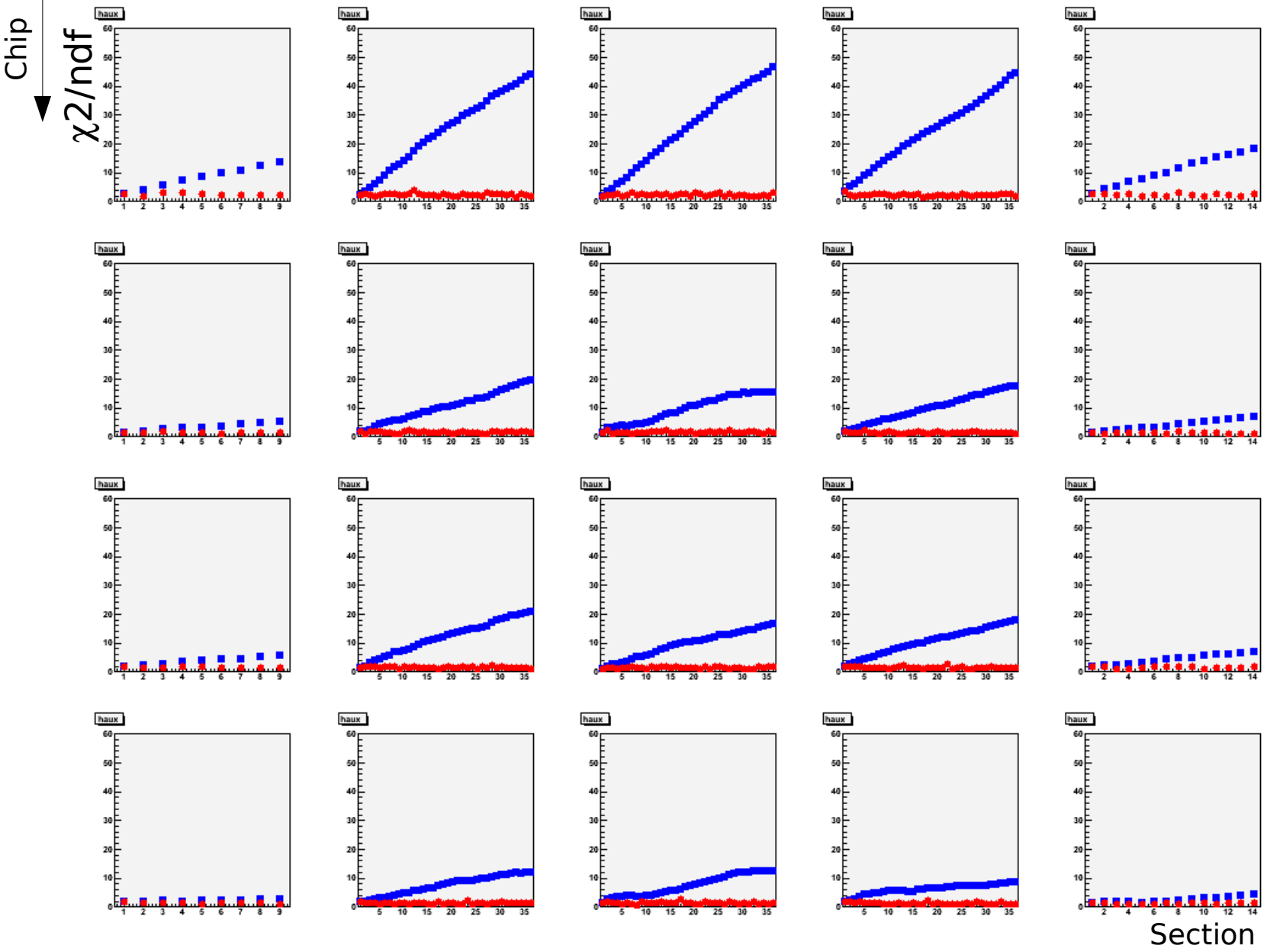
History of $\chi 2$/ndf of Gaussian fit within runs for e.g. Scan 3 – Signal Events

(Subdivision into Sections of 5000 events)



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– $\chi 2$/ndf gets progressively worse as run goes on

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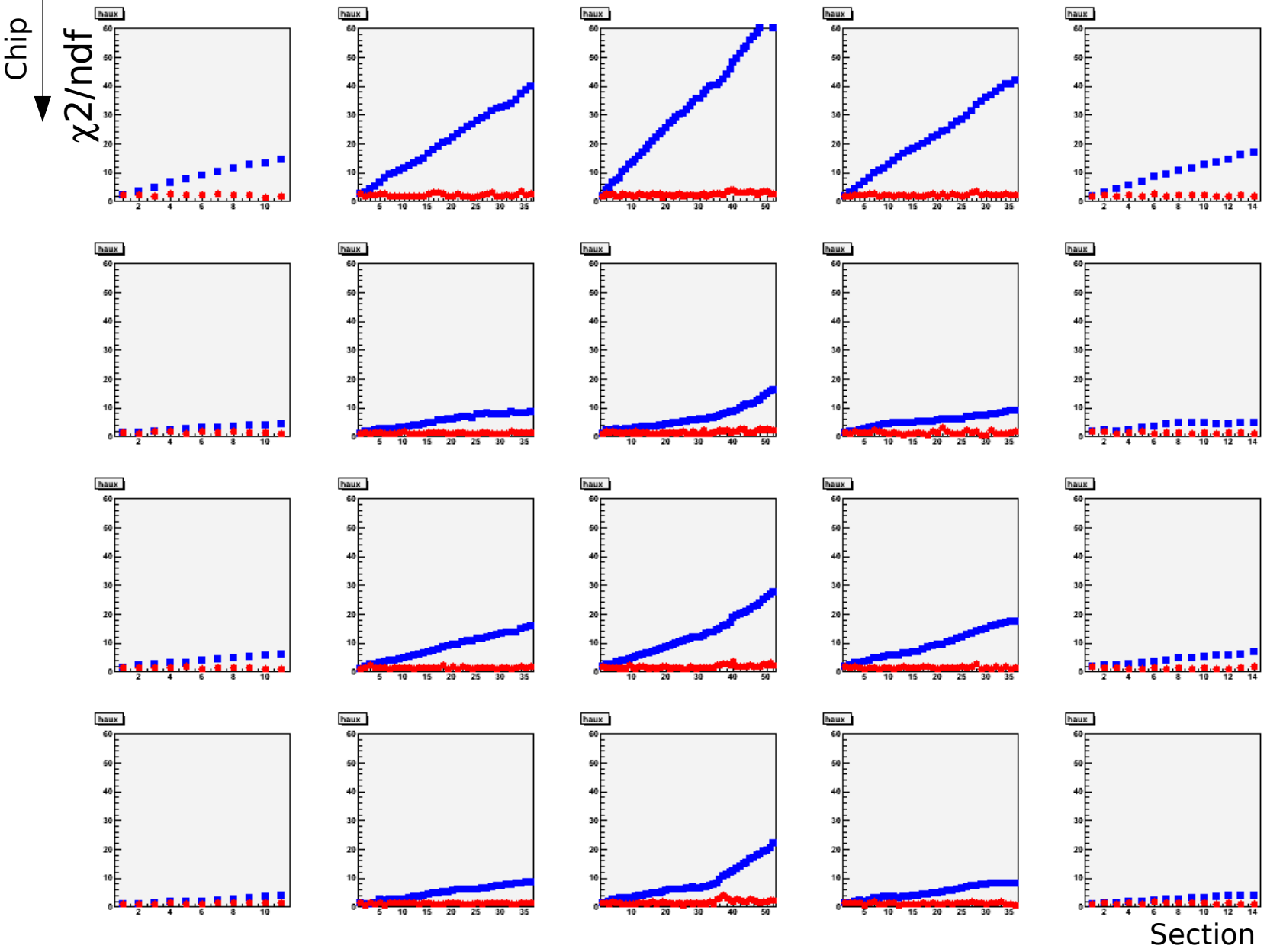
The Problem I

History of $\chi 2$/ndf of Gaussian fit within runs for e.g. Scan 4 – Signal Events
(Subdivision into Sections of 5000 events)



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The Problem II

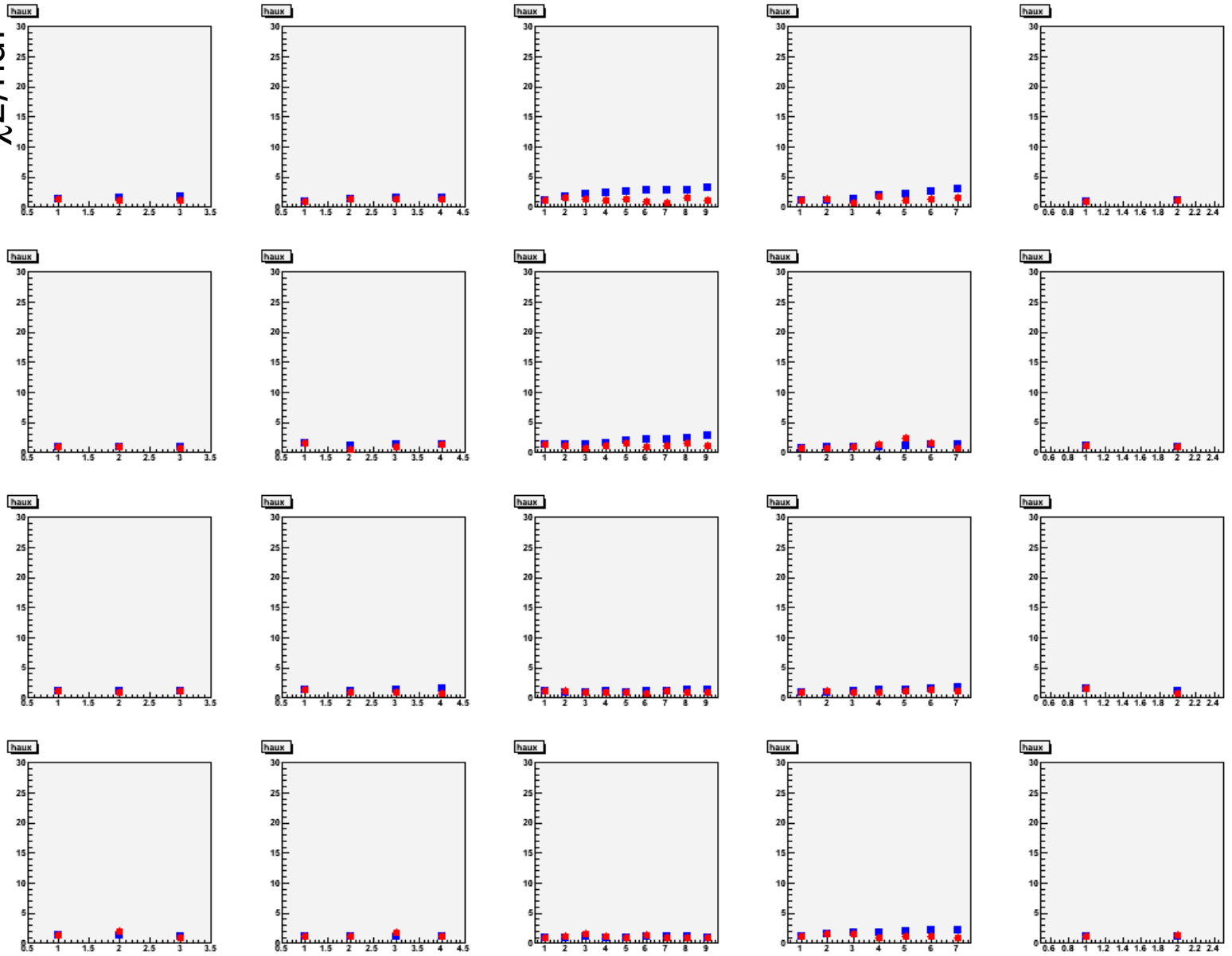
Scan Point

History of $\chi 2$/ndf of Gaussian fit within runs for e.g. Scan 2 – Pedestal Events

(Subdivision into Sections of 1500 events)

Chip

$\chi 2$/ndf



Section

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Still tendency rather similar

The Problem II

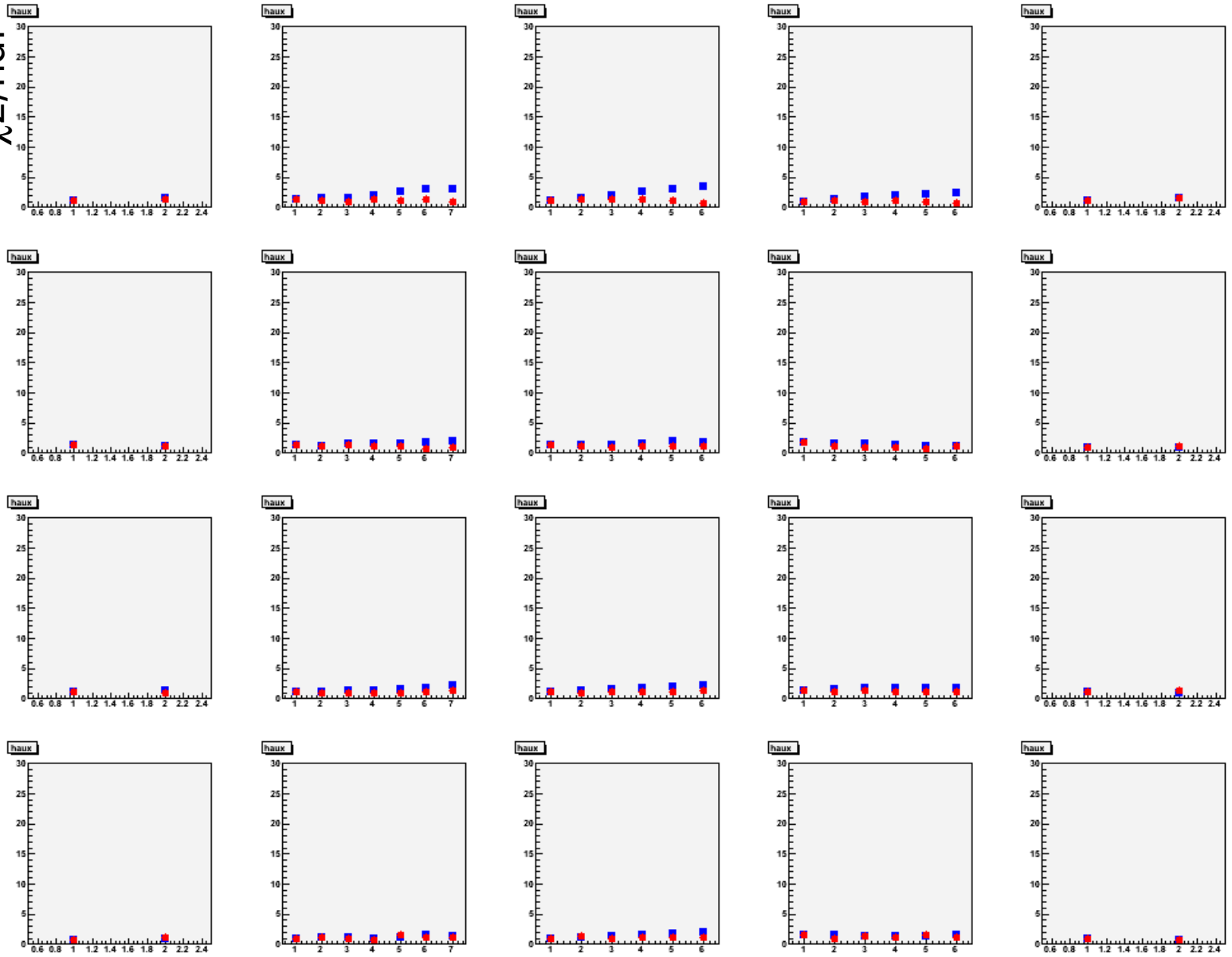
Scan Point

History of χ2/ndf of Gaussian fit within runs for e.g. Scan 3 – Pedestal Events

(Subdivision into Sections of 1500 events)

Chip

χ2/ndf



Section

Blue:
"Accumulated" χ2/ndf

Red:
"Individual" χ2/ndf

– χ2/ndf gets progressively worse as run goes on

- Individual Sections Look ok

- Effect less pronounced for Pedestals since less events

Still tendency rather similar

The Problem II

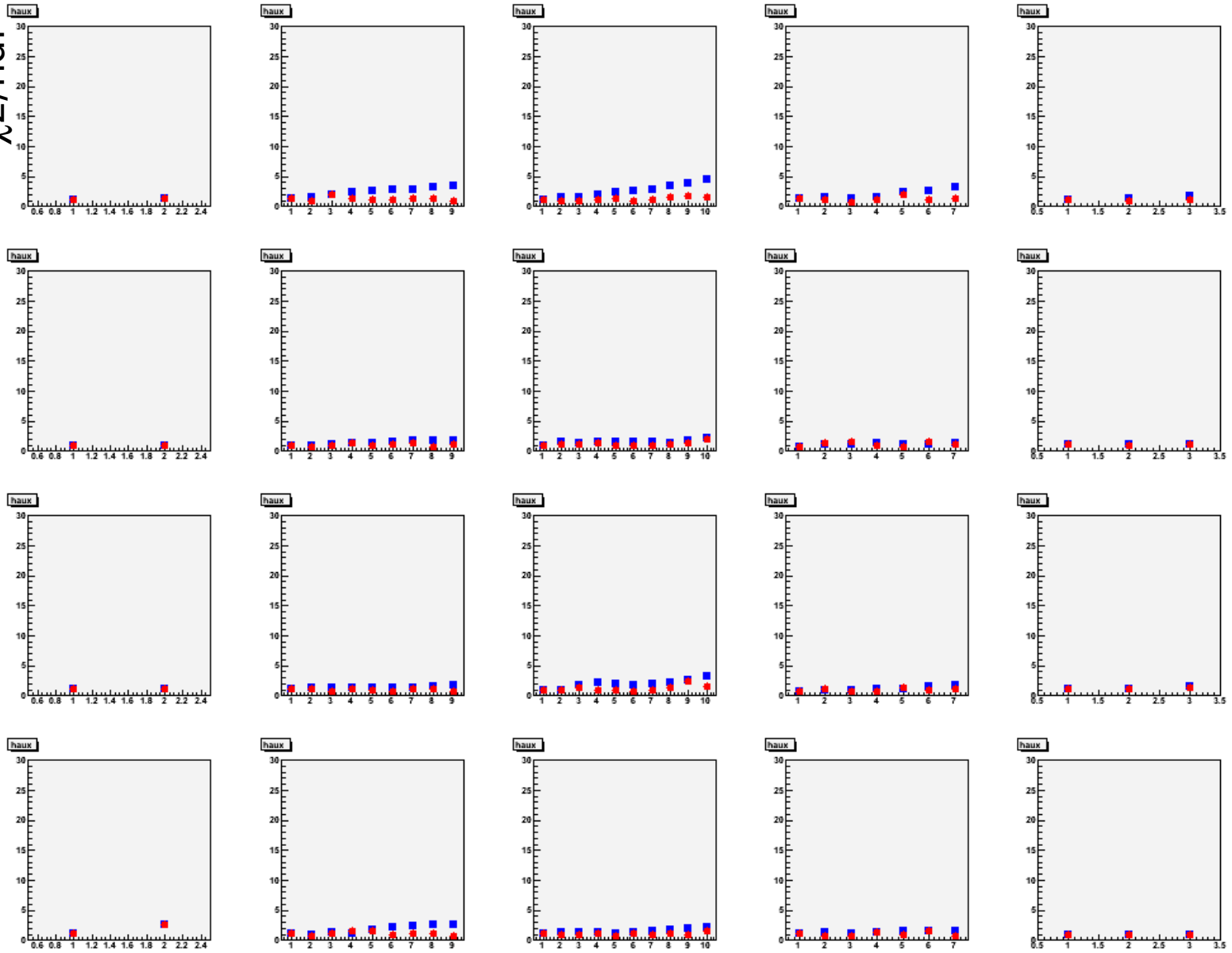
Scan Point

History of $\chi 2$/ndf of Gaussian fit within runs for e.g. Scan 4 – Pedestal Events

(Subdivision into Sections of 1500 events)

Chip

$\chi 2$/ndf



Section

Blue:
"Accumulated" $\chi 2$/ndf

Red:
"Individual" $\chi 2$/ndf

– $\chi 2$/ndf gets progressively worse as run goes on

- Individual Sections Look ok

- Effect less pronounced for Pedestals since less events

Still tendency rather similar

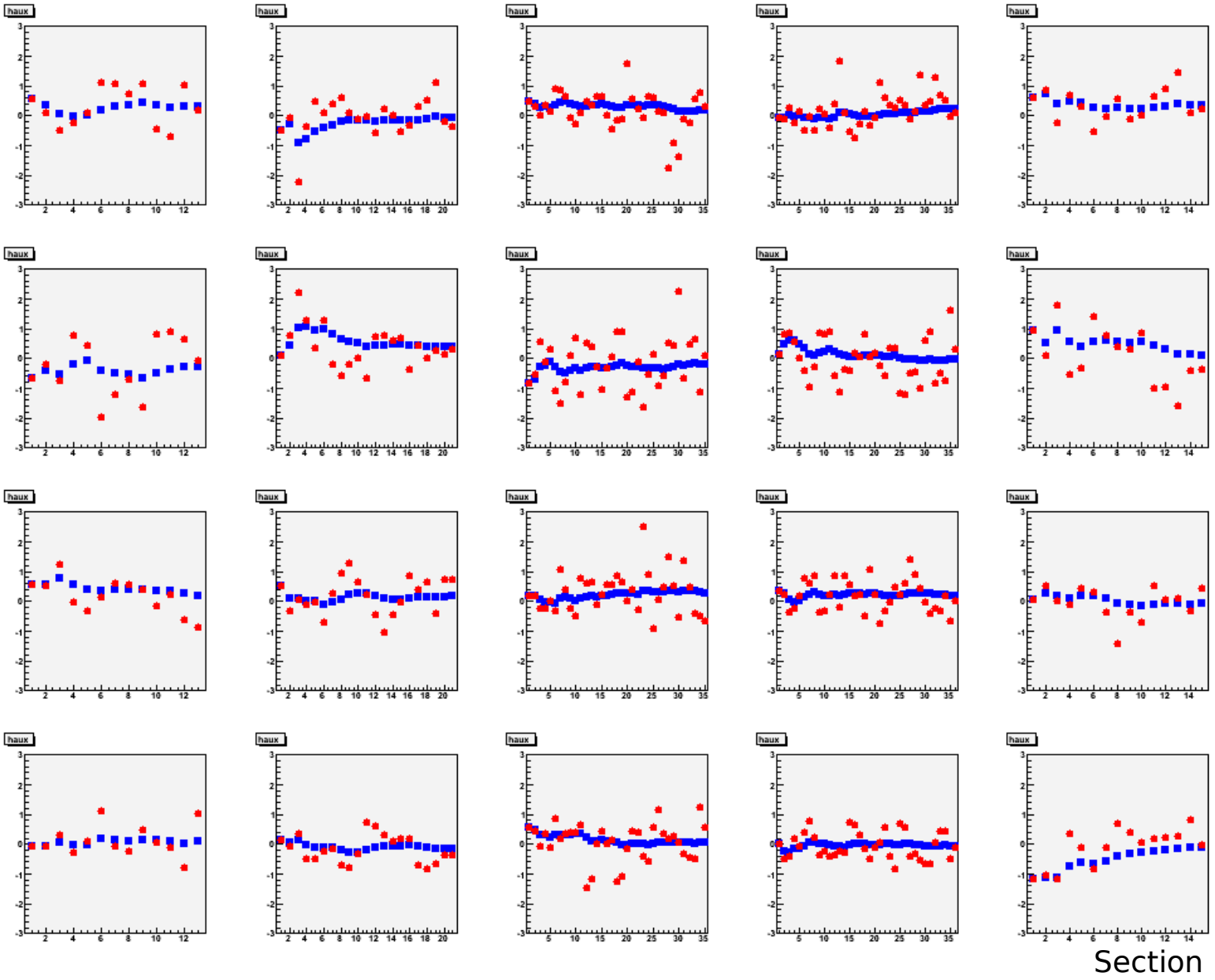
On residual Baseline Fluctuations I

Scan Point

History of Mean of Gaussian fit within runs for e.g. Scan 2 – Signal Events
(Subdivision into Sections of 5000 events)

Chip

Mean



Section

Blue:
"Accumulated" Mean

Red:
"Individual" Mean

- Non neglible residual baseline fluctuations throughout run

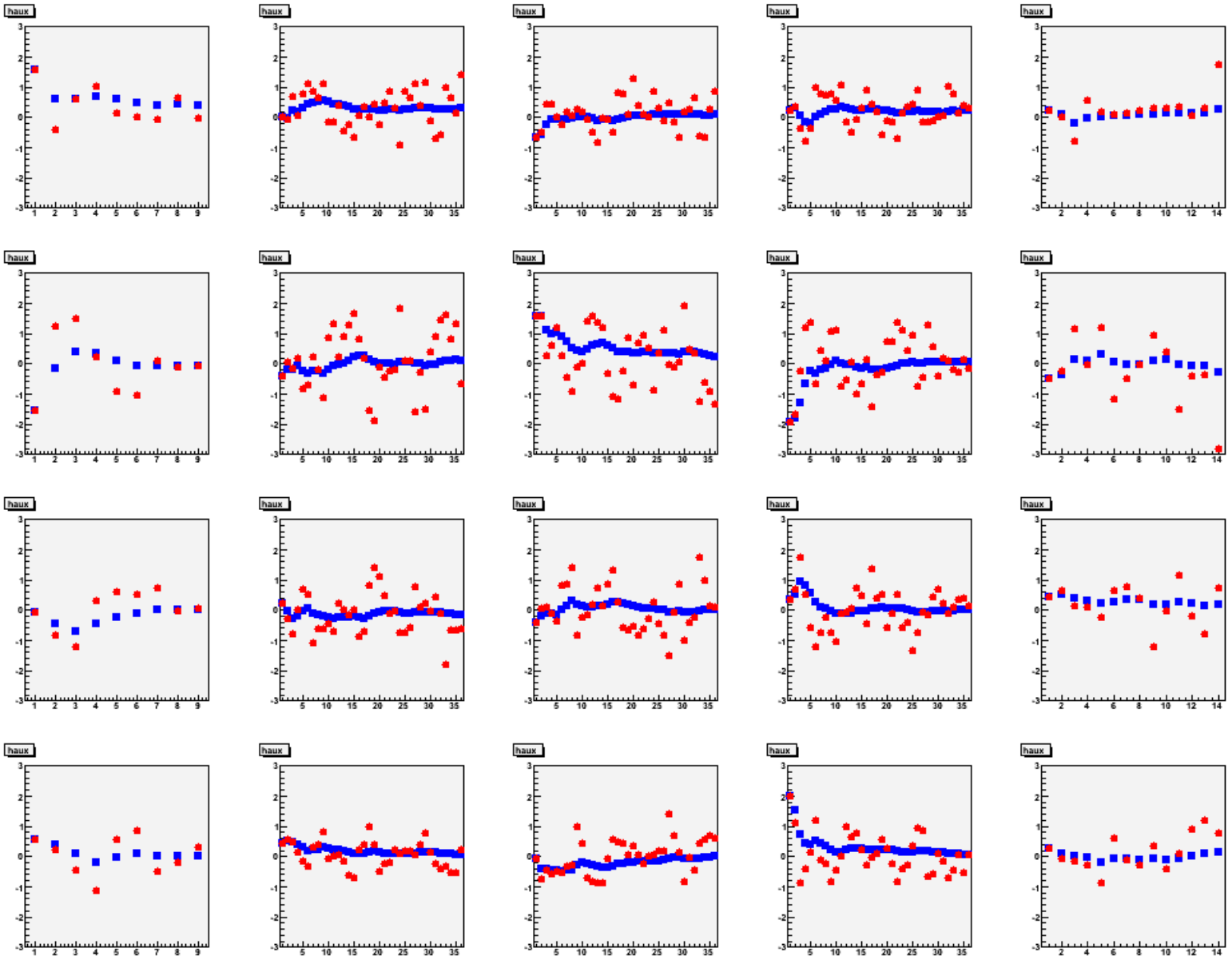
On residual Baseline Fluctuations I

Scan Point

History of Mean of Gaussian fit within runs for e.g. Scan 3 – Signal Events
(Subdivision into Sections of 5000 events)

Chip

Mean



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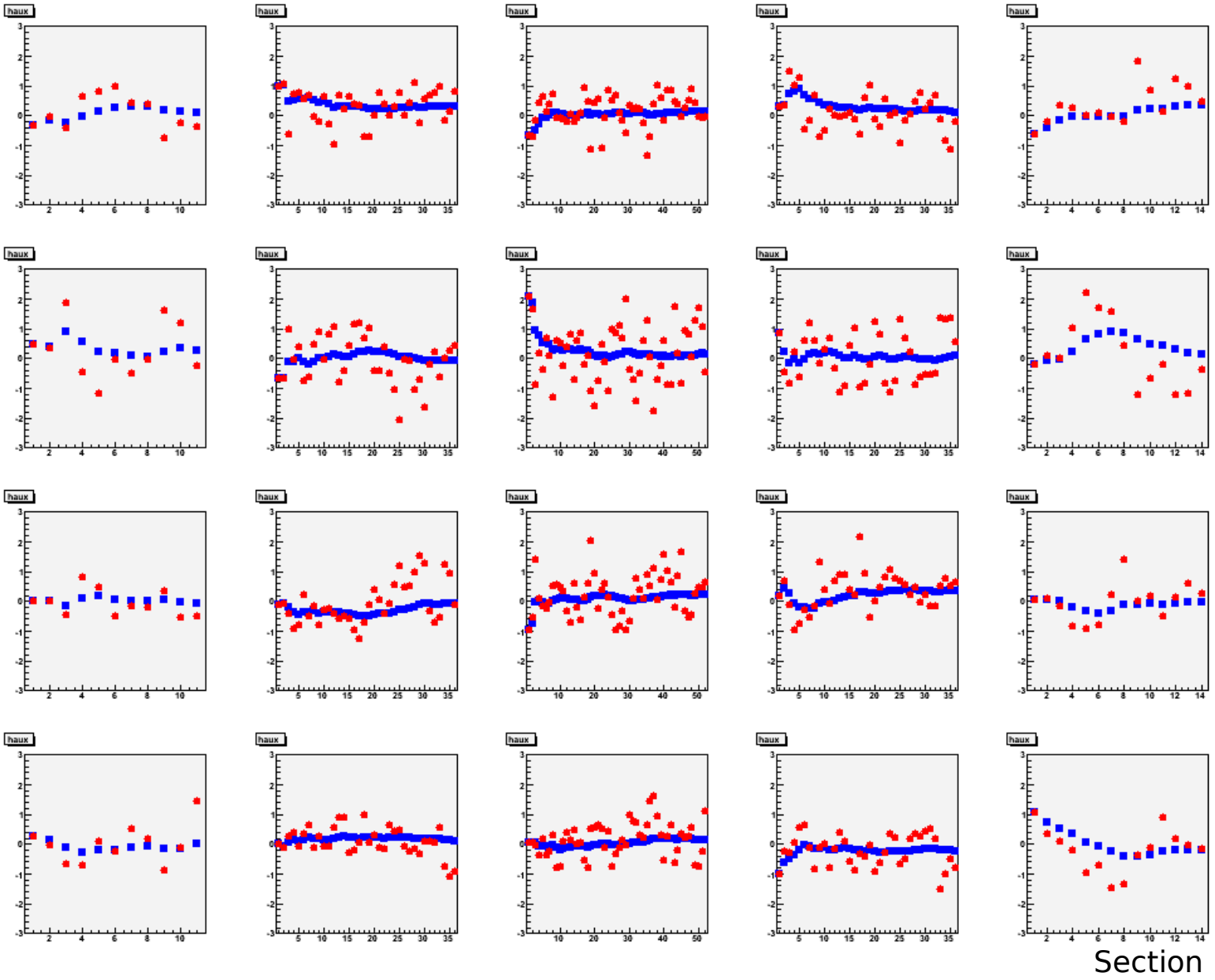
On residual Baseline Fluctuations I

Scan Point

History of Mean of Gaussian fit within runs for e.g. Scan 4 – Signal Events
(Subdivision into Sections of 5000 events)

Chip

Mean



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"Accumulated" Mean

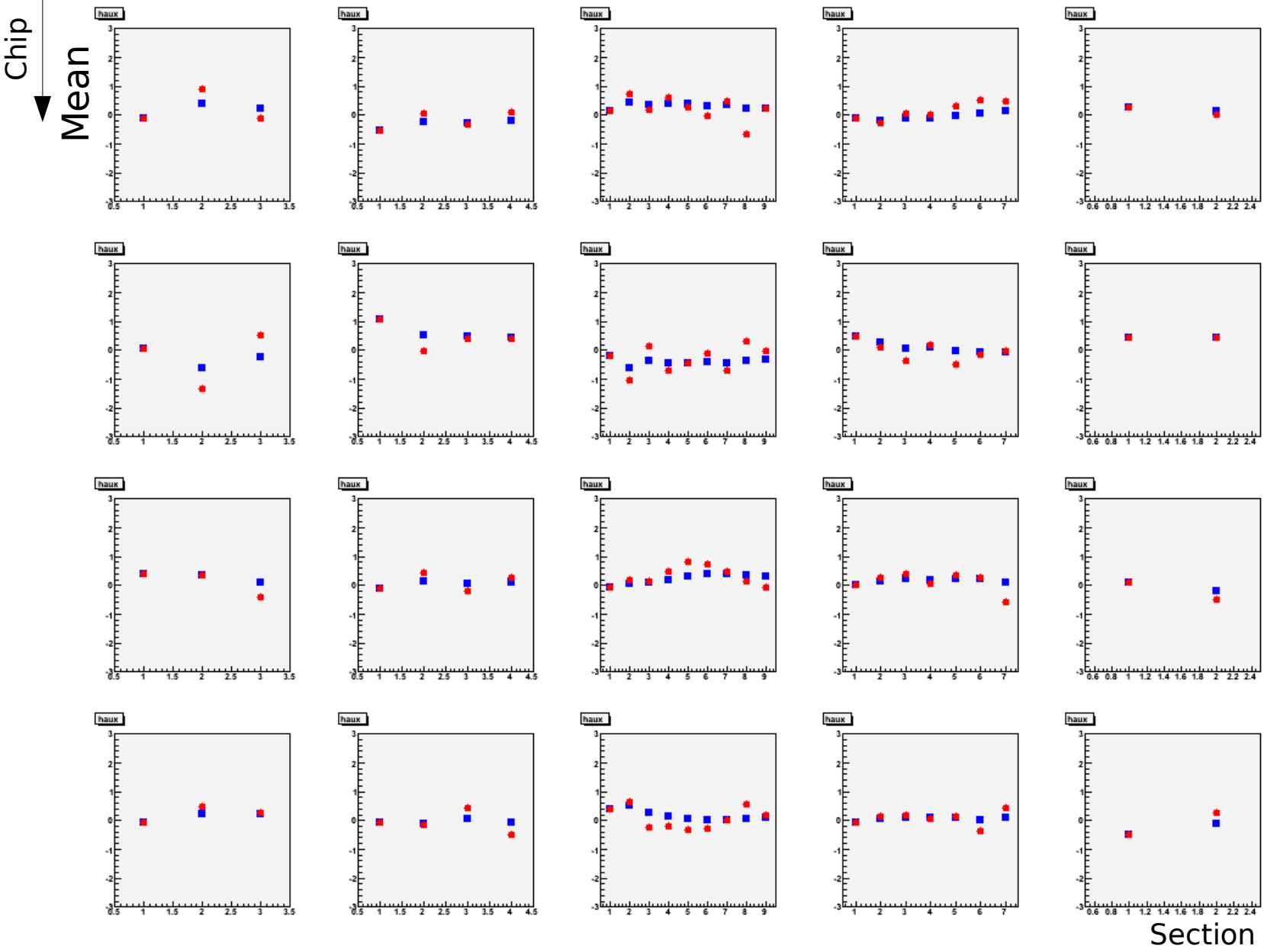
Red:
"Individual" Mean

- Non neglible residual baseline fluctuations throughout run

On residual Baseline Fluctuations II

History of Mean of Gaussian fit within runs for e.g. Scan 2 – Pedestal Events

(Subdivision into Sections of 1500 events)



Blue:
"Accumulated" Mean

Red:
"Individual" Mean

- are fairly well reproduced by Pedestals ...

On residual Baseline Fluctuations II

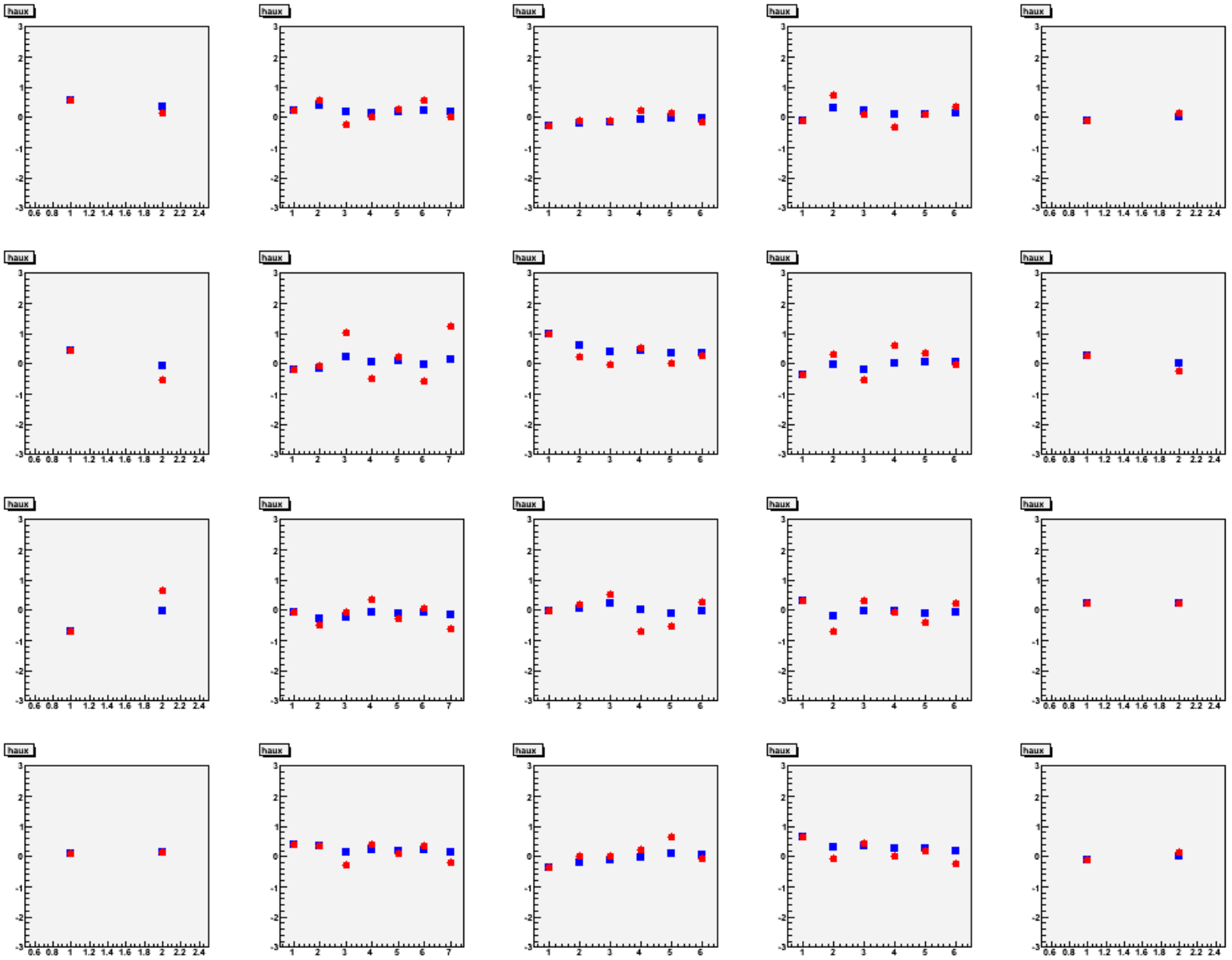
History of Mean of Gaussian fit within runs for e.g. Scan 3 – Pedestal Events

(Subdivision into Sections of 1500 events)

Scan Point

Chip

Mean



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On residual Baseline Fluctuations II

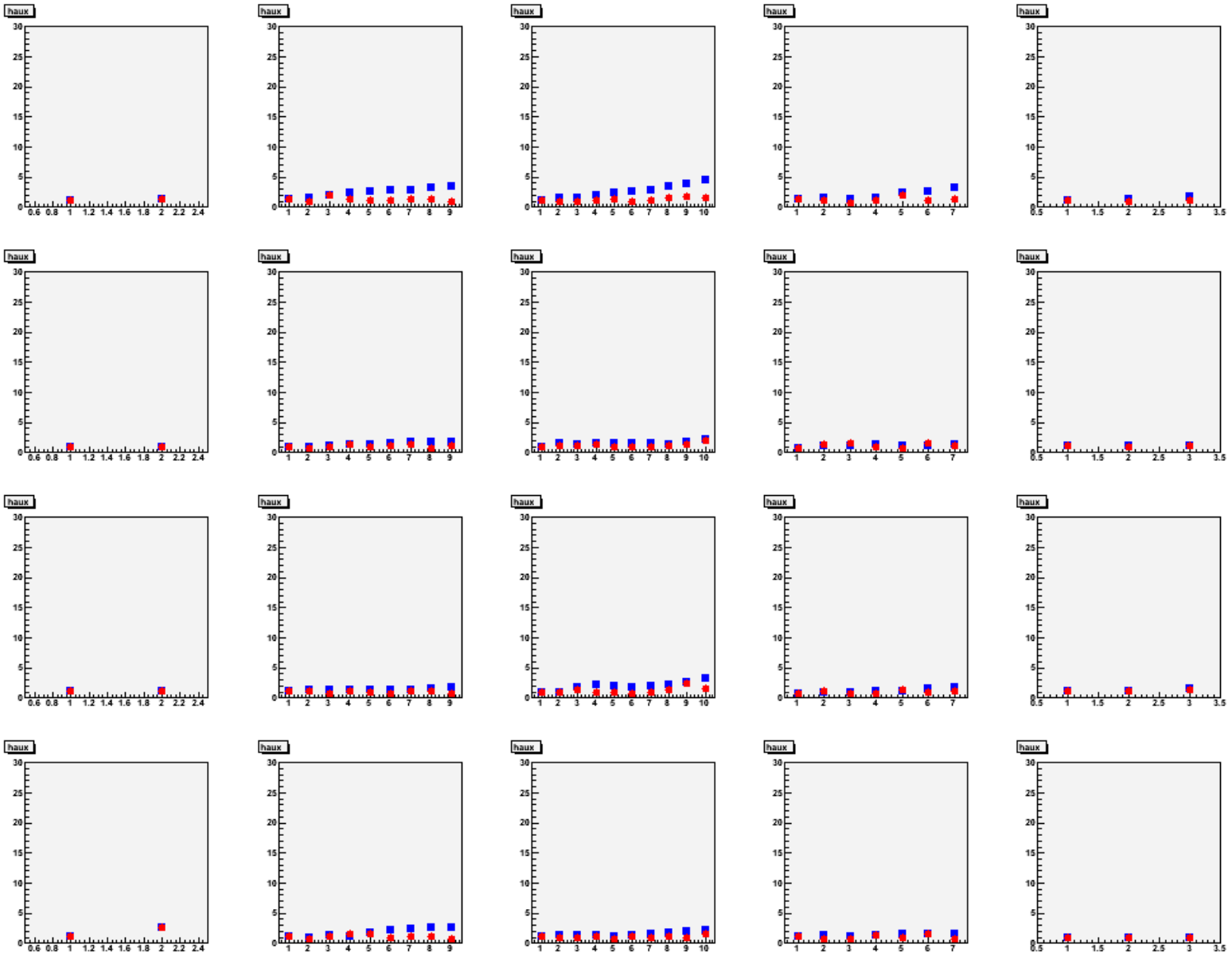
History of Mean of Gaussian fit within runs for e.g. Scan 4 – Pedestal Events

(Subdivision into Sections of 1500 events)

Scan Point

Chip

Mean



Section

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"Accumulated" Mean

Red:
"Individual" Mean

- are fairly well reproduced by Pedestals ...

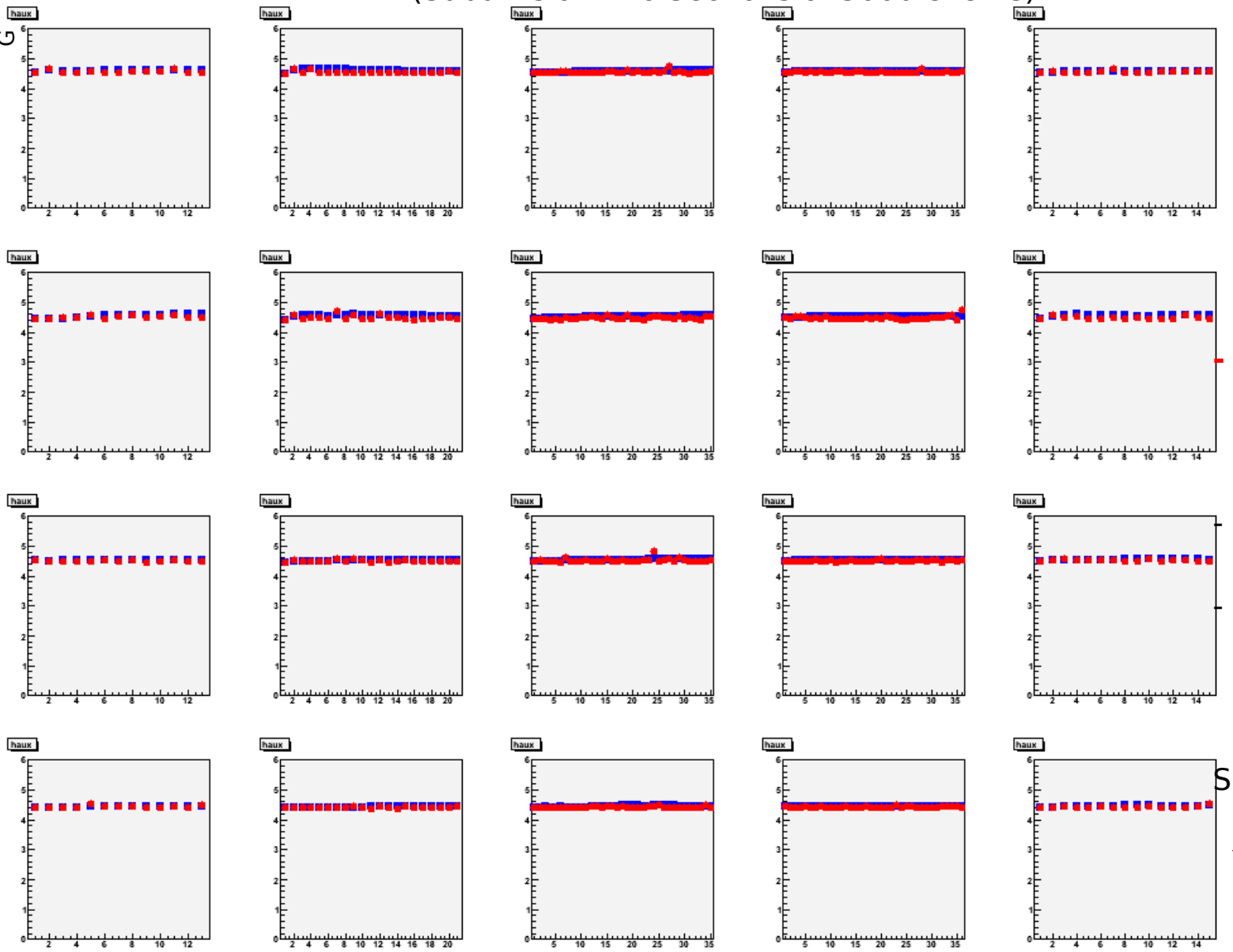
Simple Method III

Scan Point History σ_G of gaussian fit within runs for e.g. Scan 2 – Signal Events

(Subdivision into Sections of 5000 events)

Chip

σ_G



Section

Blue:
"Accumulated" σ_G

Red:
"Individual" σ_G

- **σ_G stable during runs**
- **σ_G** ≈4.6 ADC Counts
- In disagreement with result from coherent noise analysis

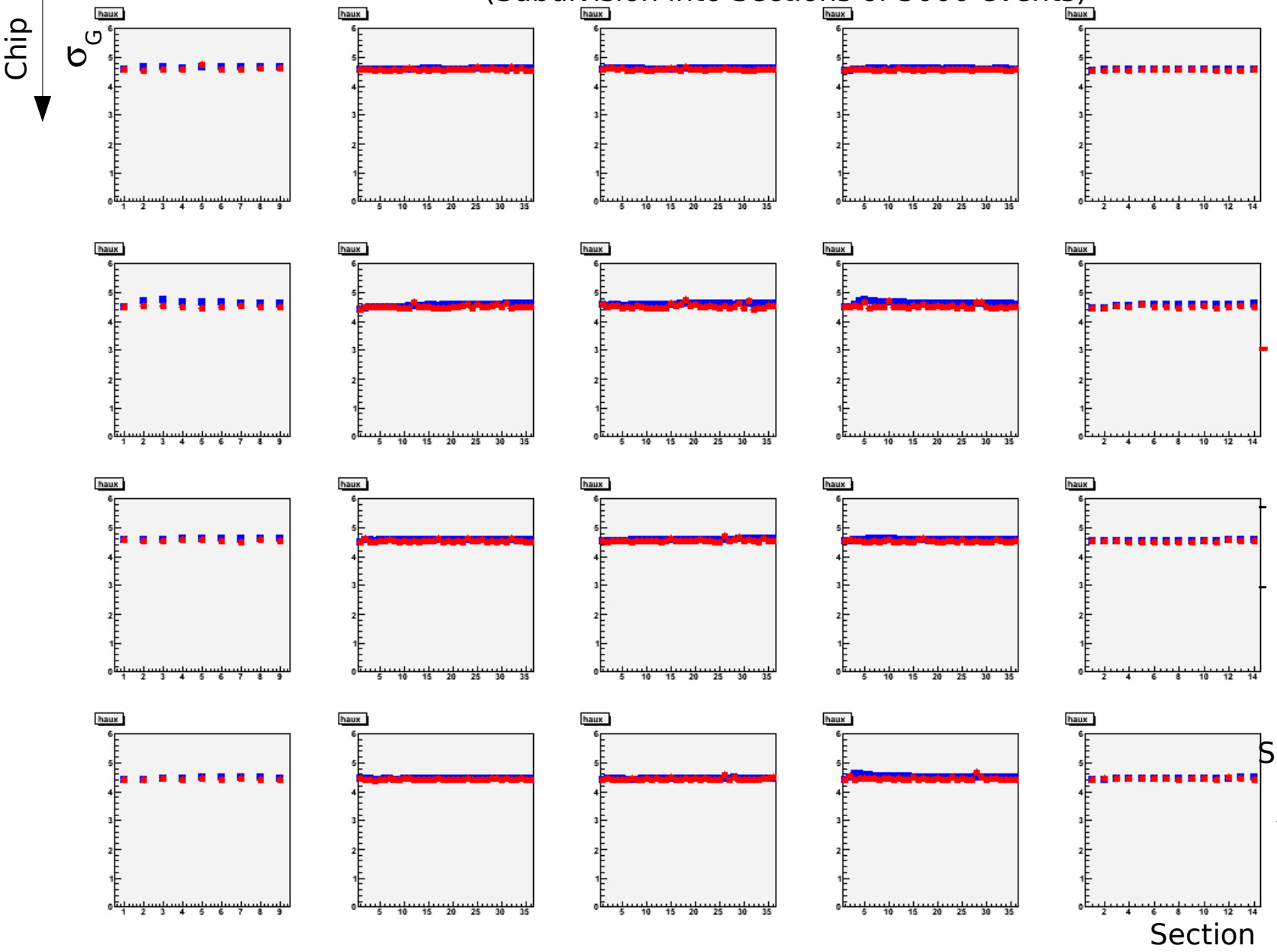
See above:

$$\sqrt{\sigma_{ic}^2+\sigma_{cn}^2} \approx \sqrt{4.1^2+1} \approx 4.2$$

Simple Method III

Scan Point History of σ_G gaussian fit within runs for e.g. Scan 3 – Signal Events

(Subdivision into Sections of 5000 events)



Blue:
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Red:
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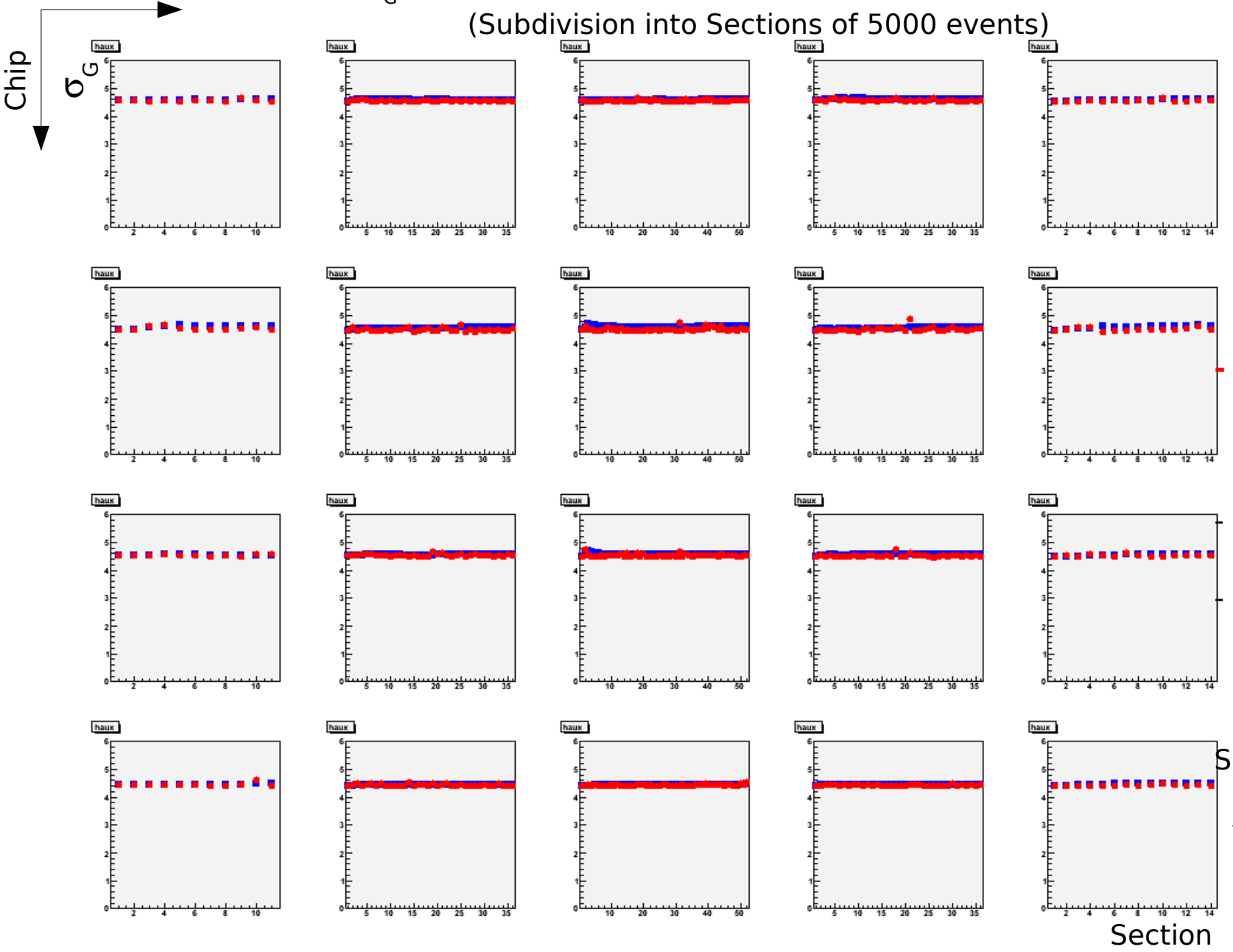
(Subdivision into Sections of 5000 events)



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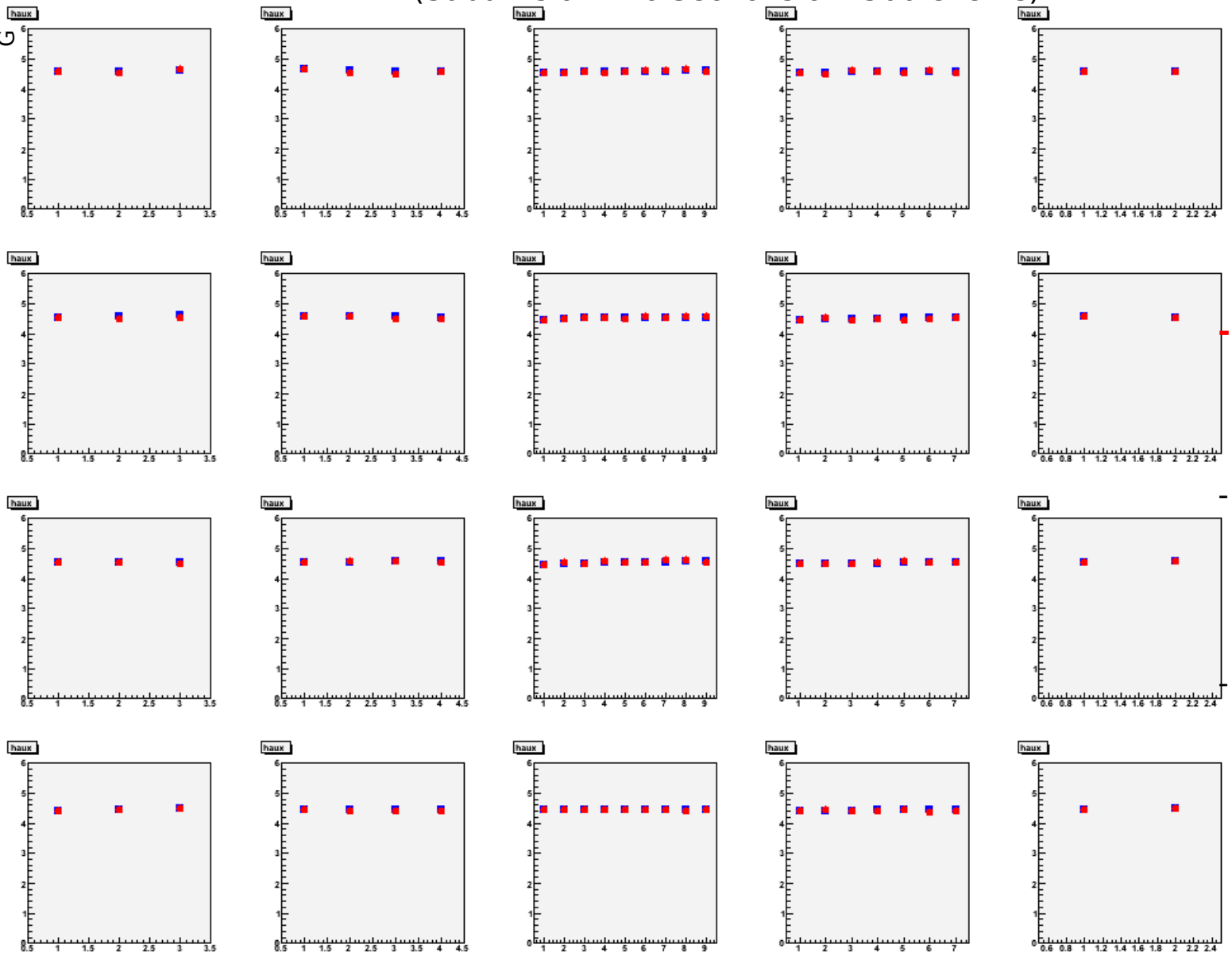
Simple Method IV

Scan Point History of σ_G of gaussian fit within runs for e.g. Scan 2 – Pedestal Events

(Subdivision into Sections of 1500 events)

Chip

σ_G



Section

Blue:
"Accumulated" σ_G

Red:
"Individual" σ_G

- **σ_G stable during runs**
- **σ_G** ≈4.6 ADC Counts agreement with signal
- In disagreement with result from coherent noise analysis

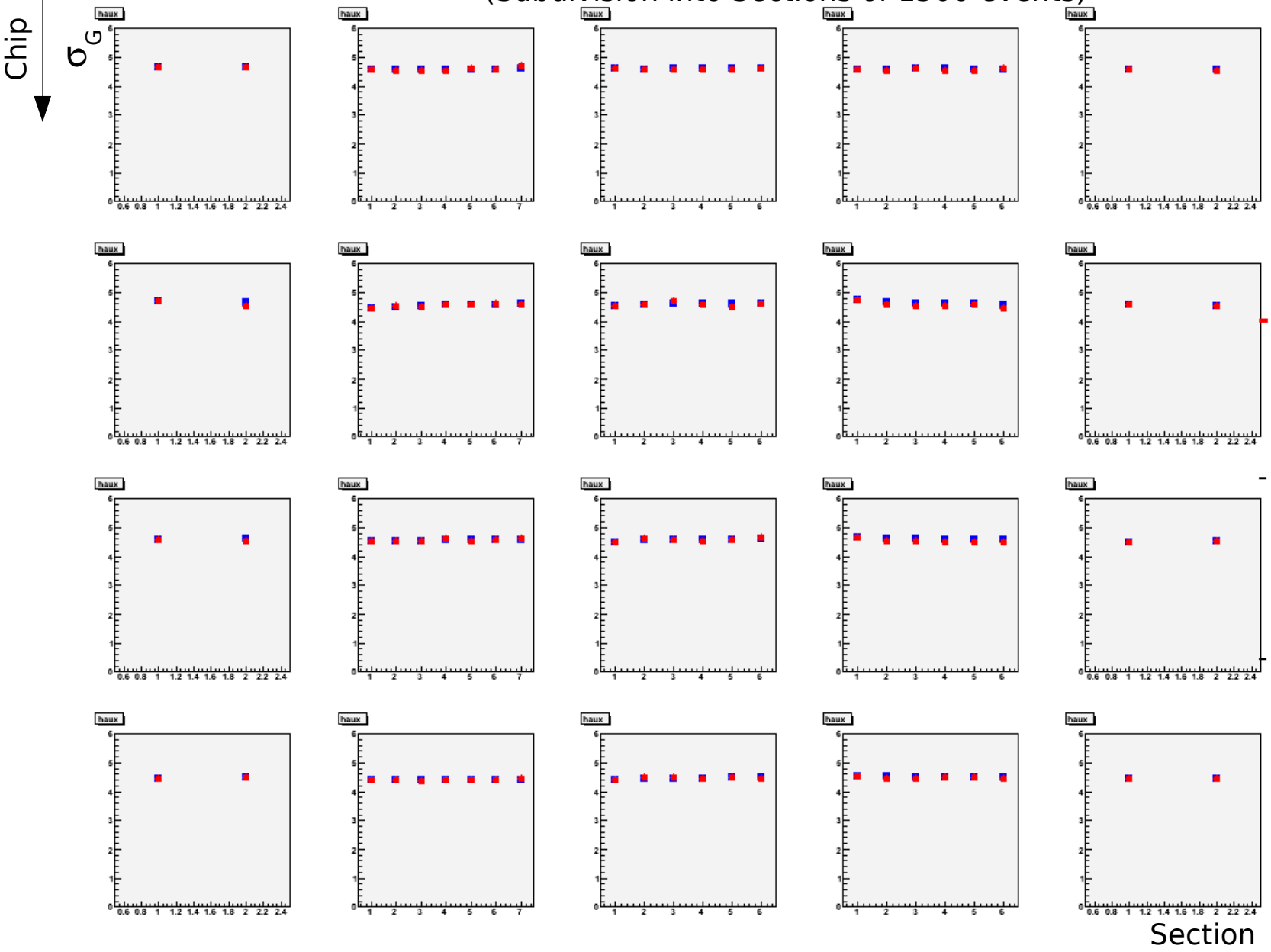
See above:

$$\sqrt{\sigma_{ic}^2+\sigma_{cn}^2}\approx\sqrt{4.1^2+1}\approx4.2$$

Simple Method IV

History of σ_G of gaussian fit within runs for e.g. Scan 3 – Pedestal Events

(Subdivision into Sections of 1500 events)



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"Accumulated" σ_G

Red:
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Simple Method IV

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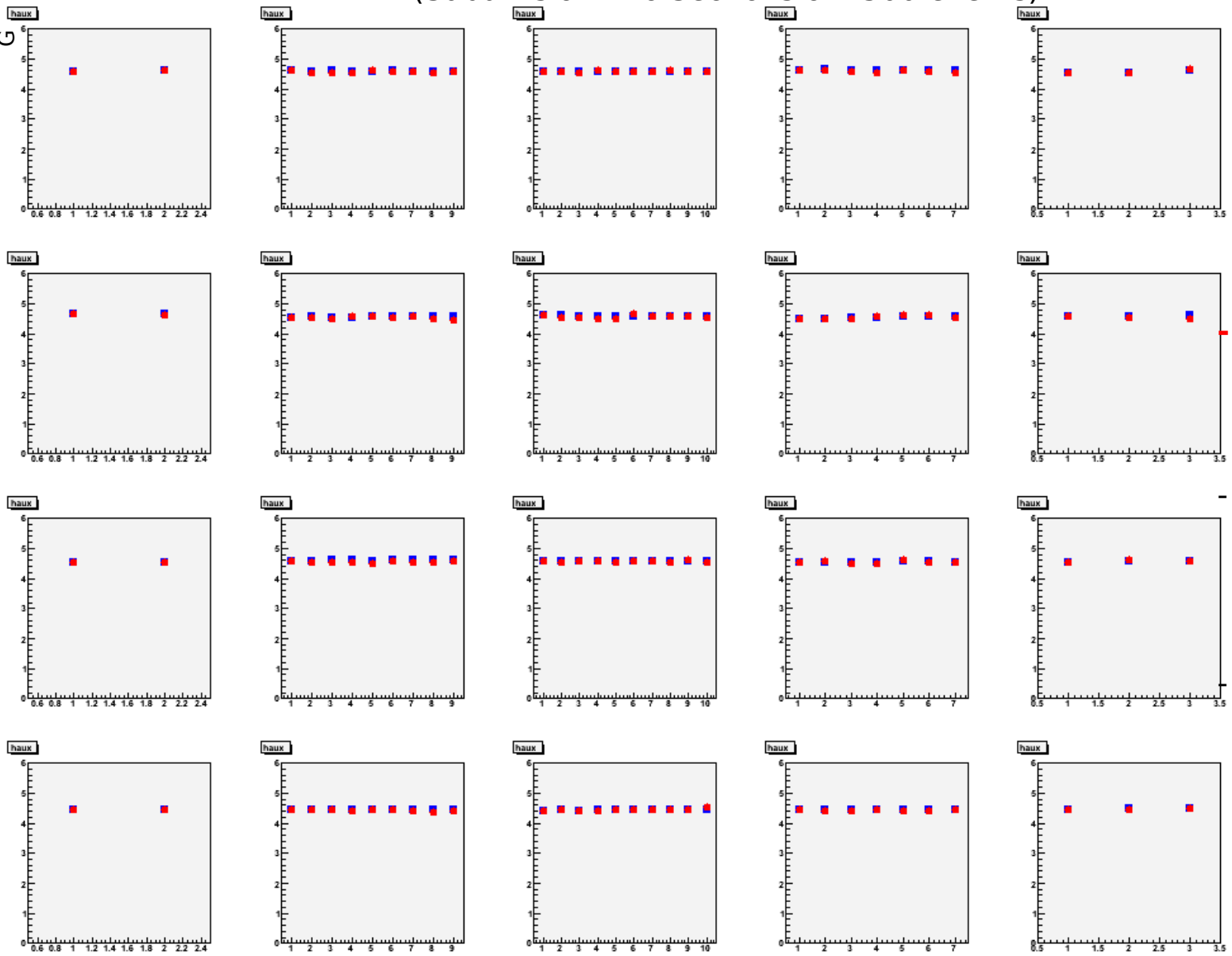
(Subdivision into Sections of 1500 events)

Scan Point

Chip

σ_G



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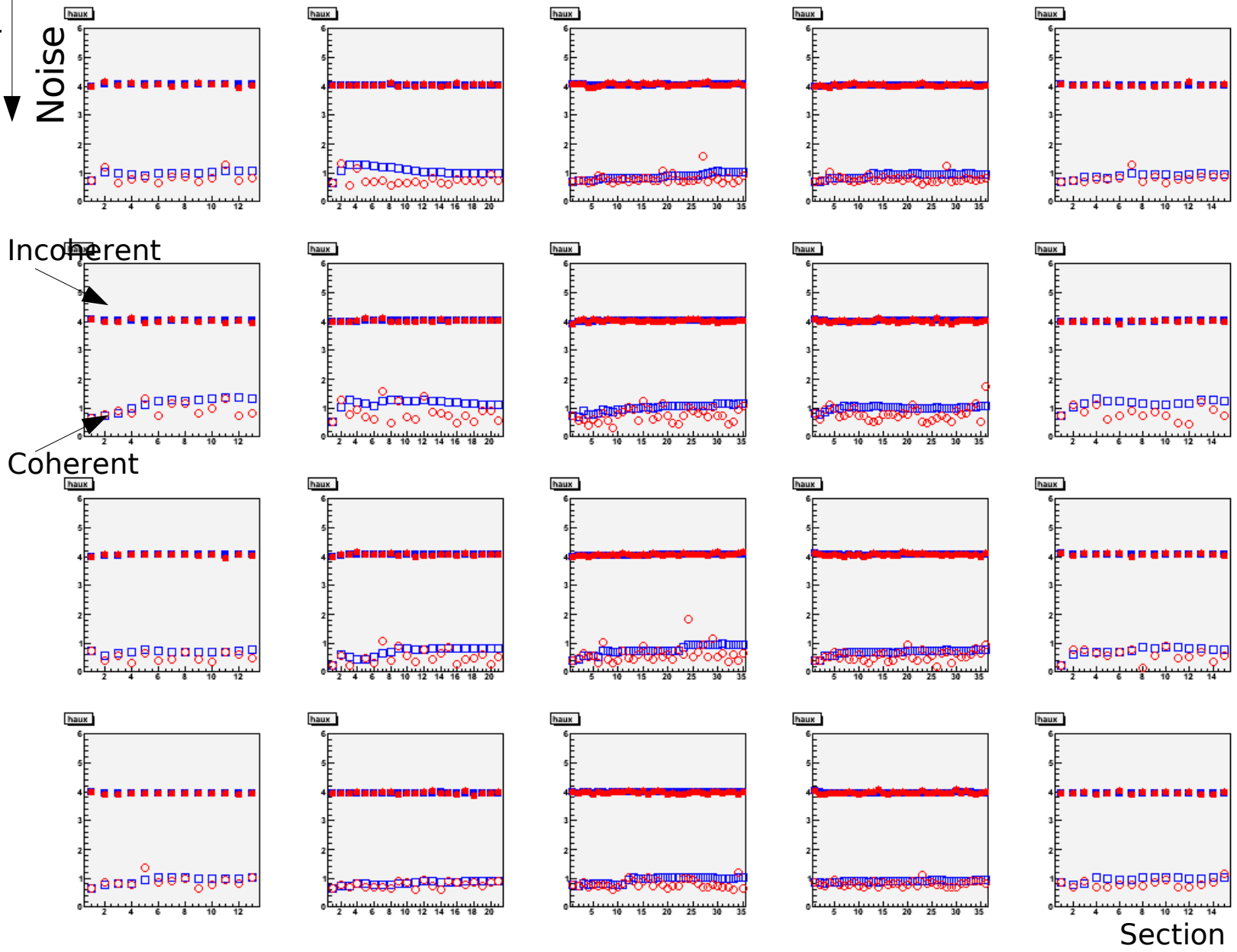
$$\sqrt{\sigma_{ic}^2+\sigma_{cn}^2}\approx\sqrt{4.1^2+1}\approx4.2$$

Simple Method I

History of coh./incoh. Noise within runs for e.g. Scan 2 – Signal Events

(Subdivision into Sections of 5000 events)



Blue:
"Accumulated" Noise

Red:
"Individual" Noise

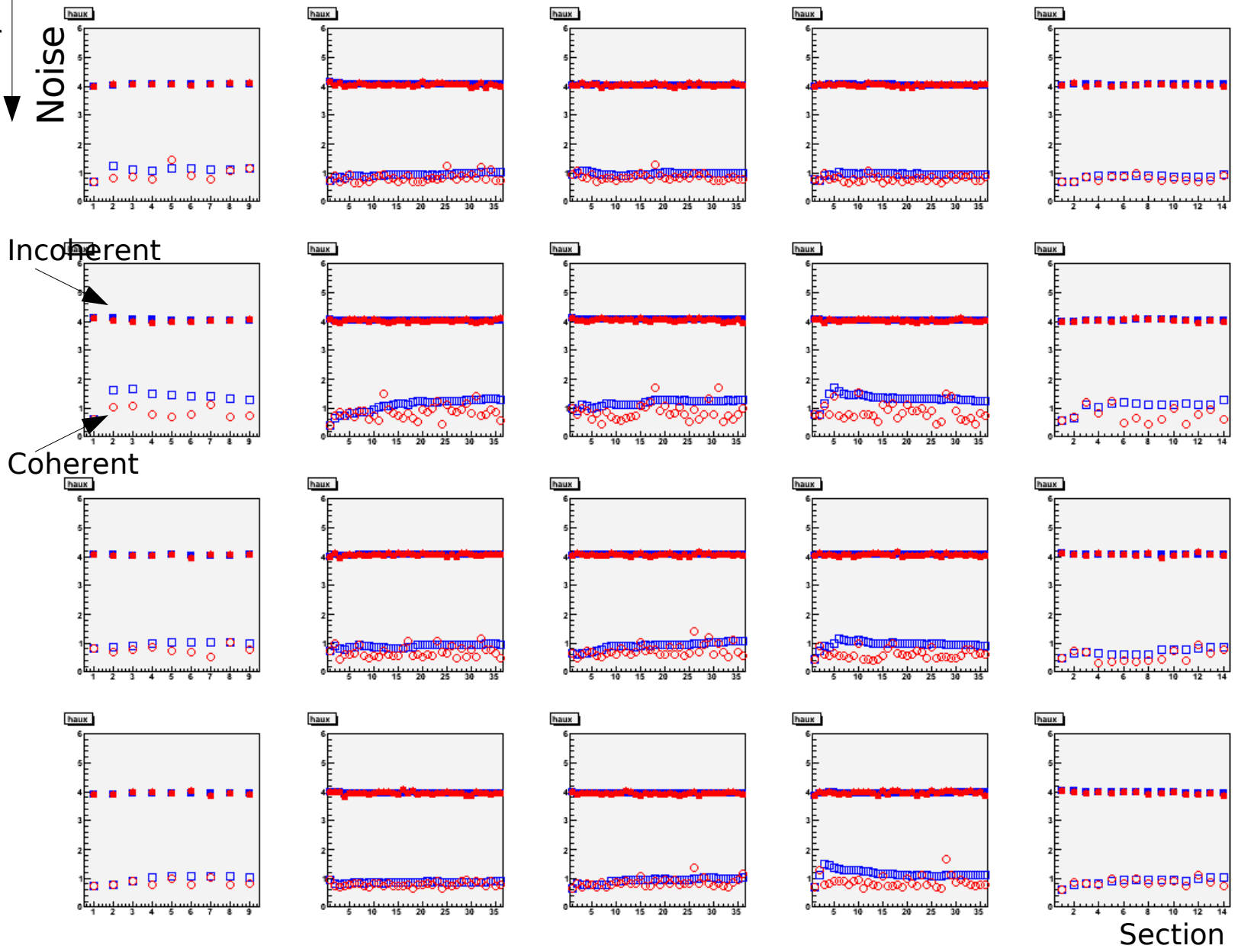
- noise level stable during runs

- Coherent Noise ~1 ADC Count

Simple Method I

History of coh./incoh. Noise within runs for e.g. Scan 3 – Signal Events

(Subdivision into Sections of 5000 events)



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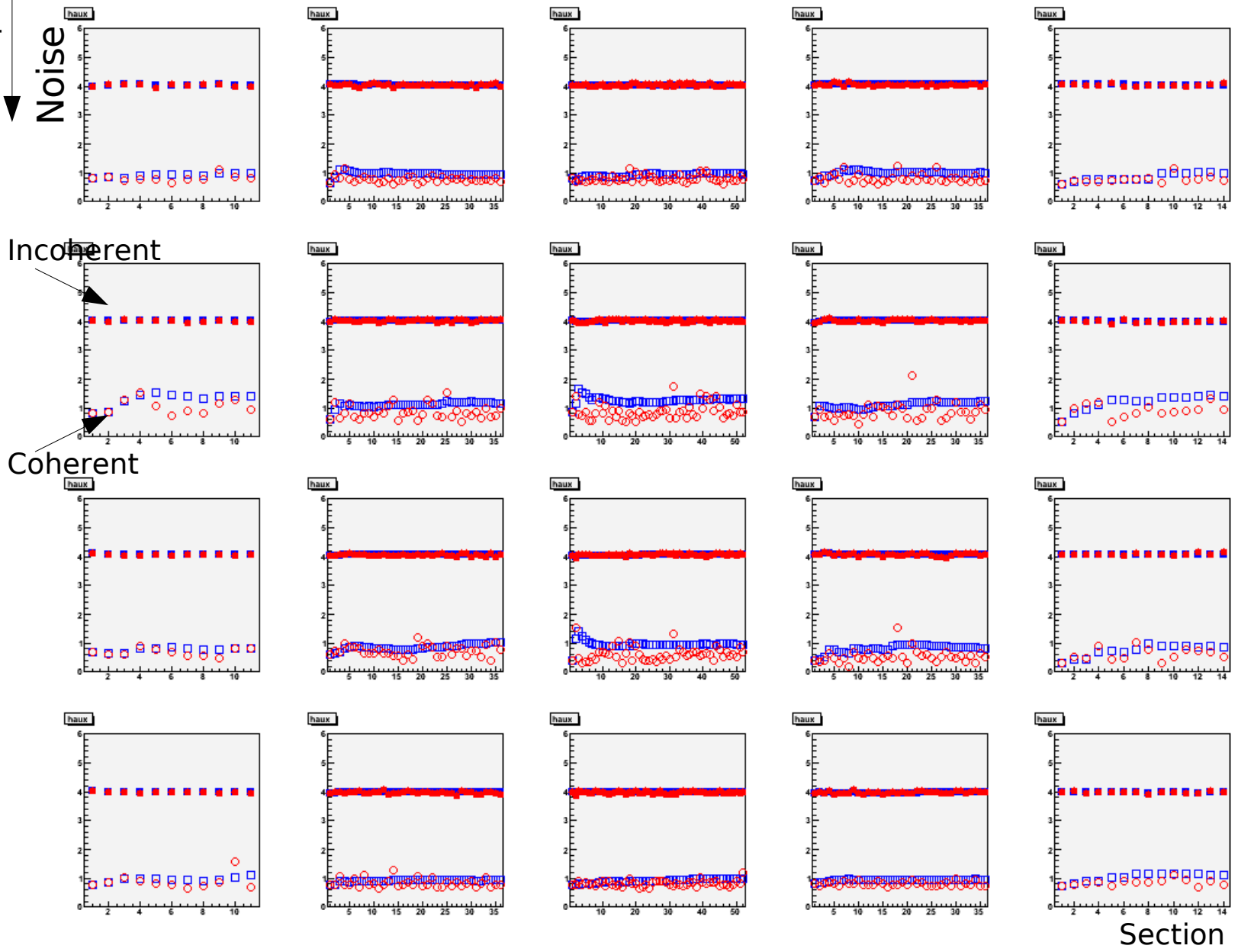

Blue:
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Red:
"Individual" Noise

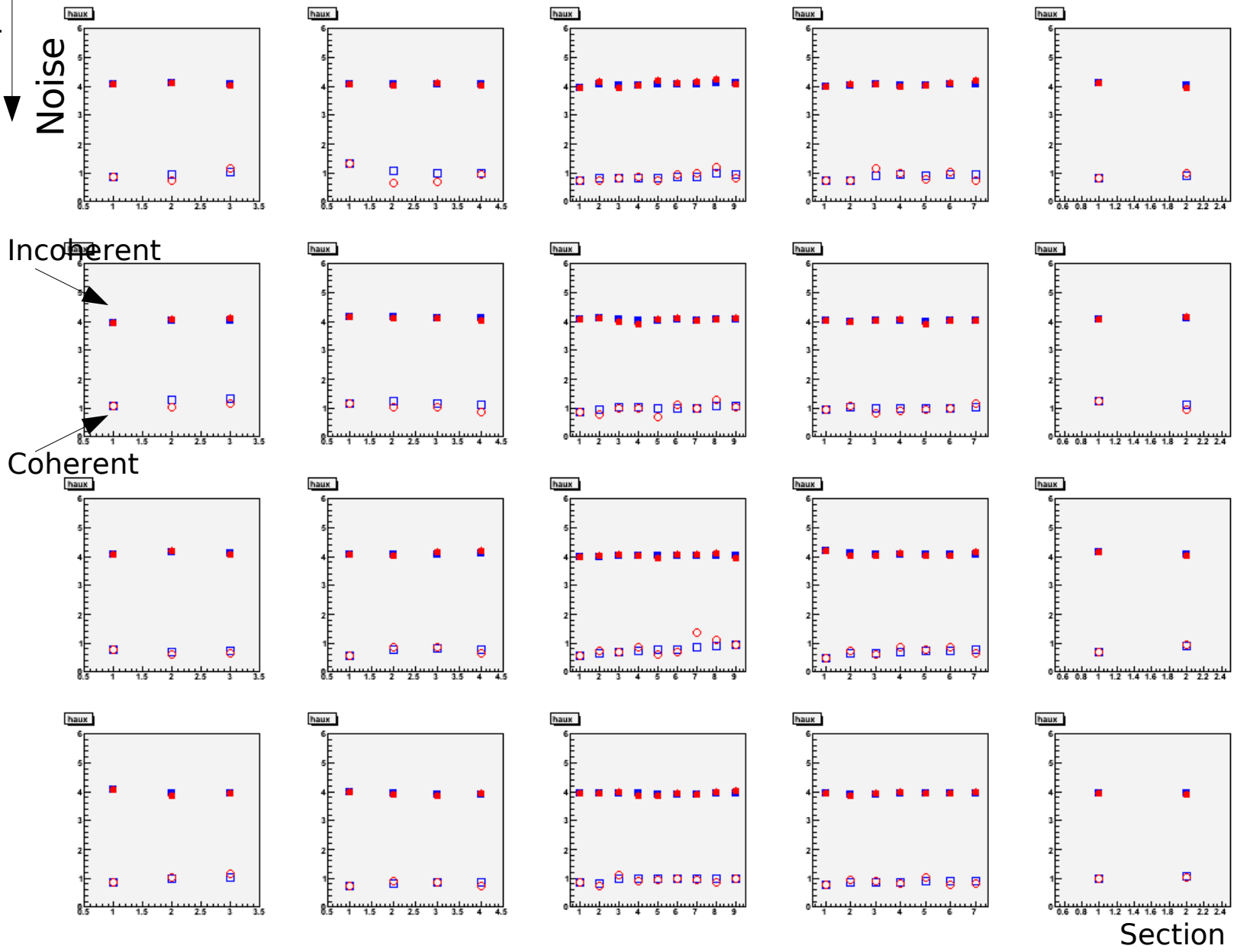
- noise level stable during runs

- Coherent Noise ~1 ADC Count

Simple Method II

History of coh./incoh. Noise within runs for e.g. Scan 2 – Pedestal Events

(Subdivision into Sections of 1500 events)



Blue:
"Accumulated" Noise

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- noise level stable during runs

- Coherent Noise ~1 ADC Count

- In agreement with observations for Signal Events

But:

$$\sqrt{\sigma_{ic}^2+\sigma_{cn}^2}\approx\sqrt{4.1^2+1}\approx4.2$$

Simple Method II

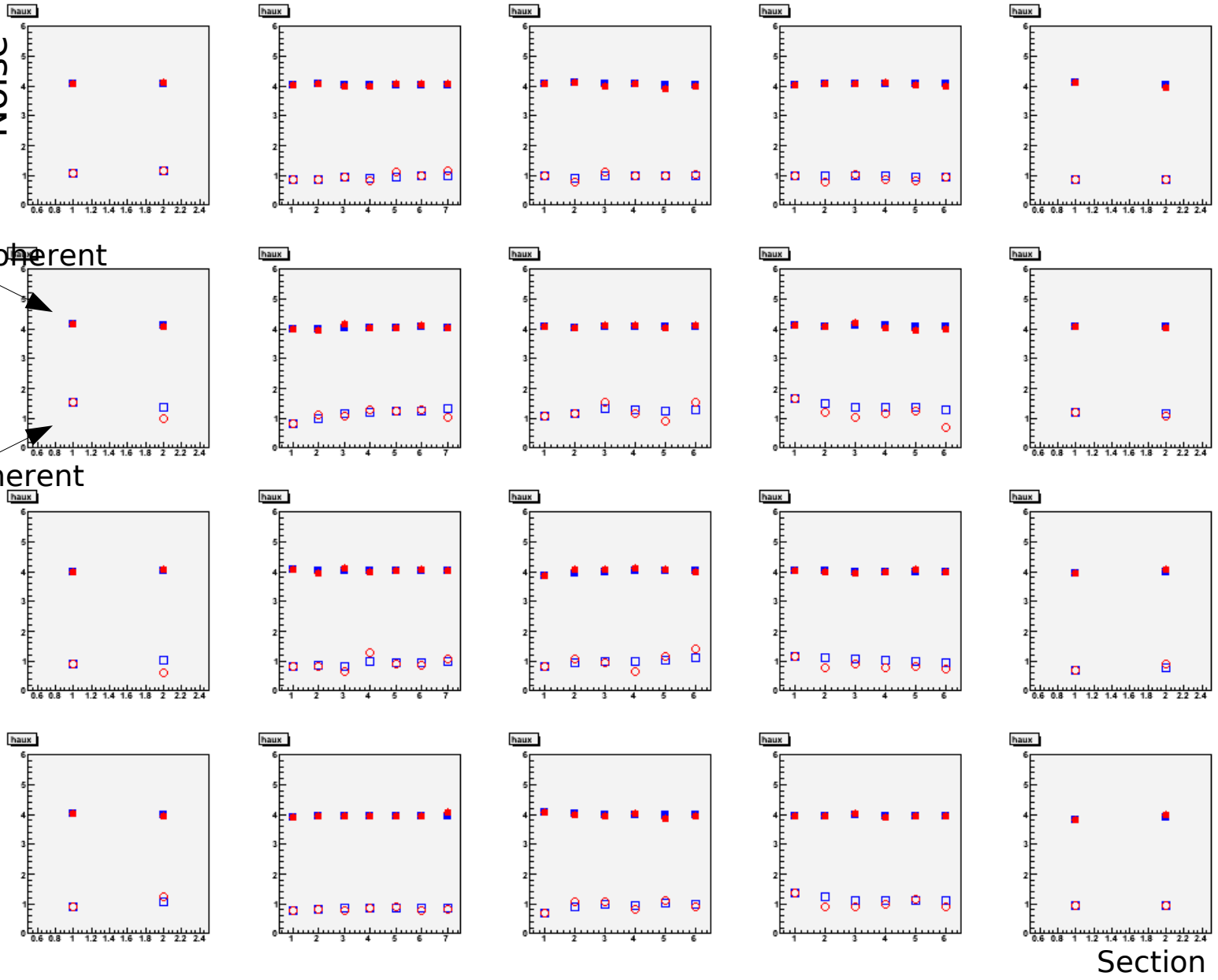
History of coh./incoh. Noise within runs for e.g. Scan 3 – Pedestal Events

(Subdivision into Sections of 1500 events)

Scan Point

Chip

Noise



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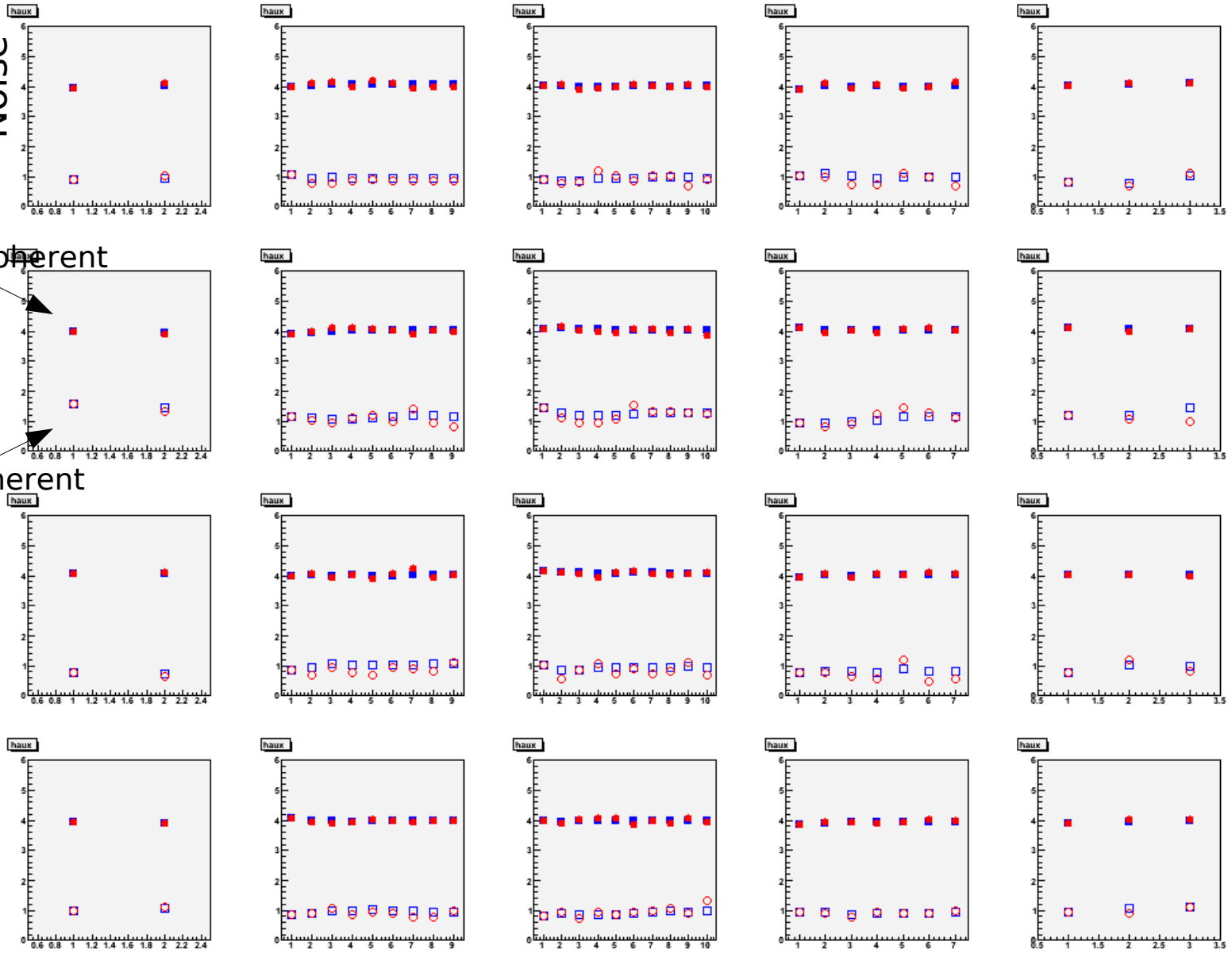
(Subdivision into Sections of 1500 events)

Scan Point

Chip

Noise



Incoherent

Coherent

Section

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Red:
"Individual" Noise

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- Coherent Noise ~1 ADC Count

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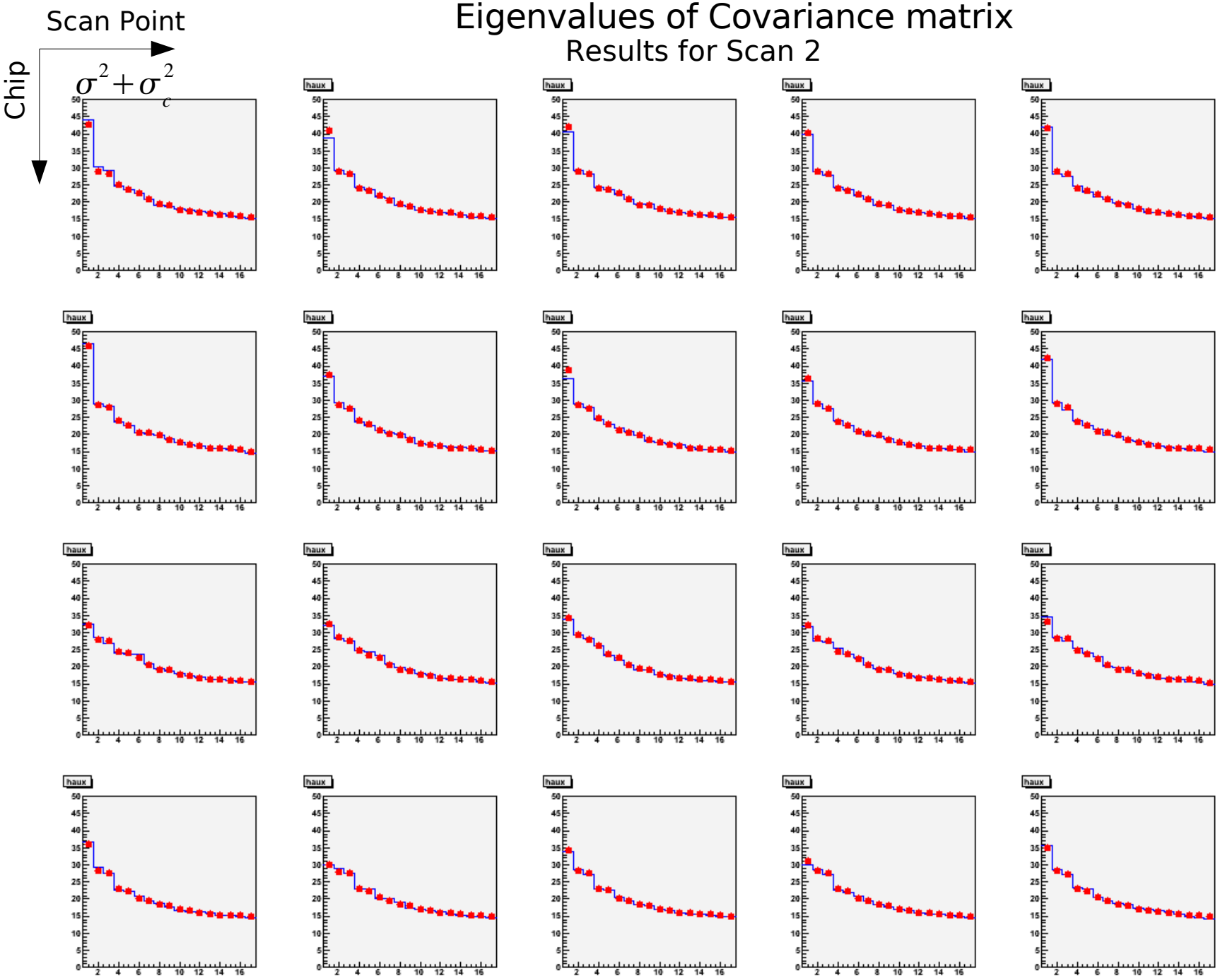
But:

$$\sqrt{\sigma_{ic}^2+\sigma_{cn}^2}\approx\sqrt{4.1^2+1}\approx4.2$$

Eigenvalues of Covariance matrix

Results for Scan 2



Blue:Pedestals
Red: Signal

- Mostly clear prominent eigenvalues

=> Coherent noise

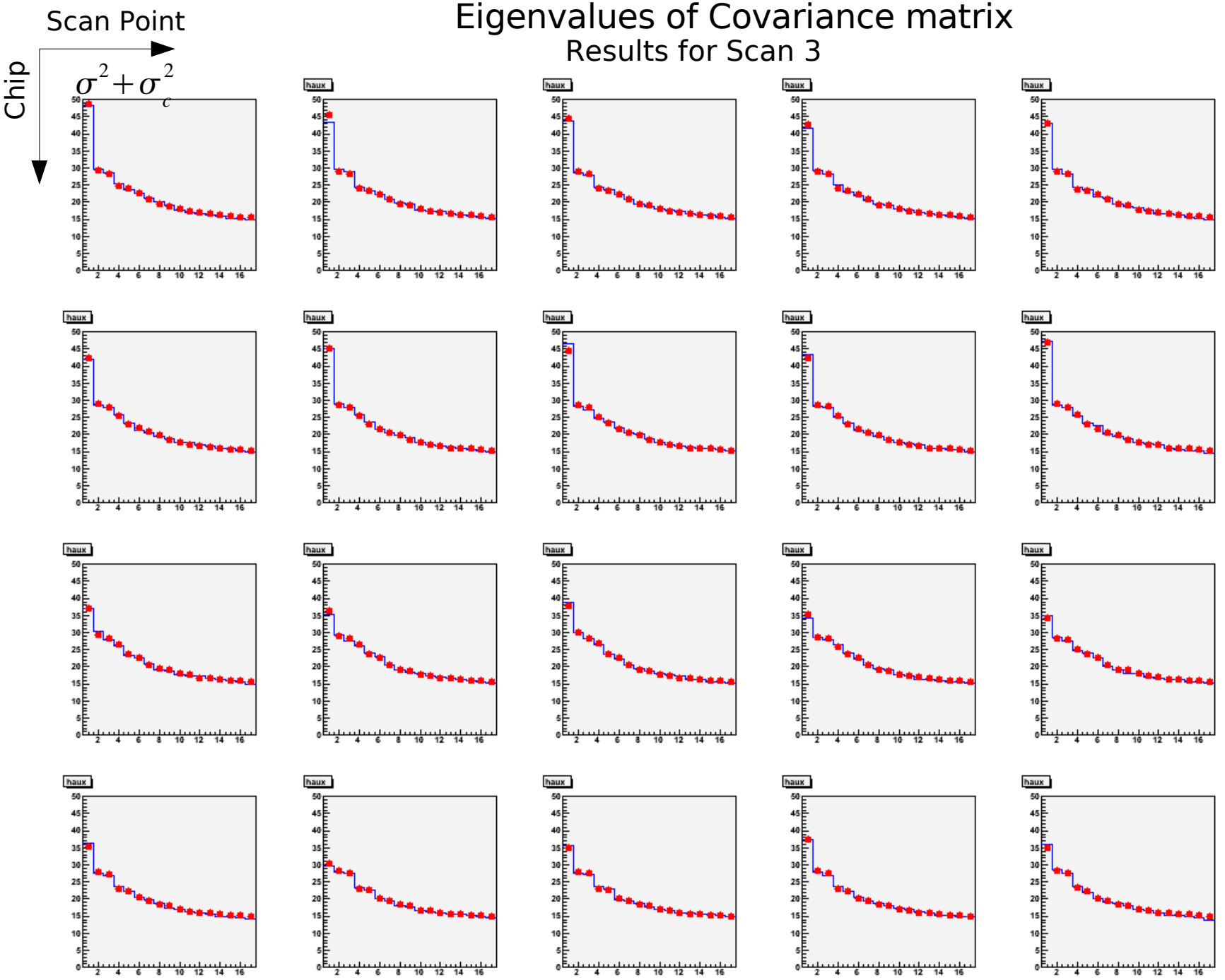
- Where less prominent: Still visible step

- Fairly flat spectrum of other eigenvalues

- Excellent agreement between Signal and Pedestal

Eigenvalues of Covariance matrix

Results for Scan 3



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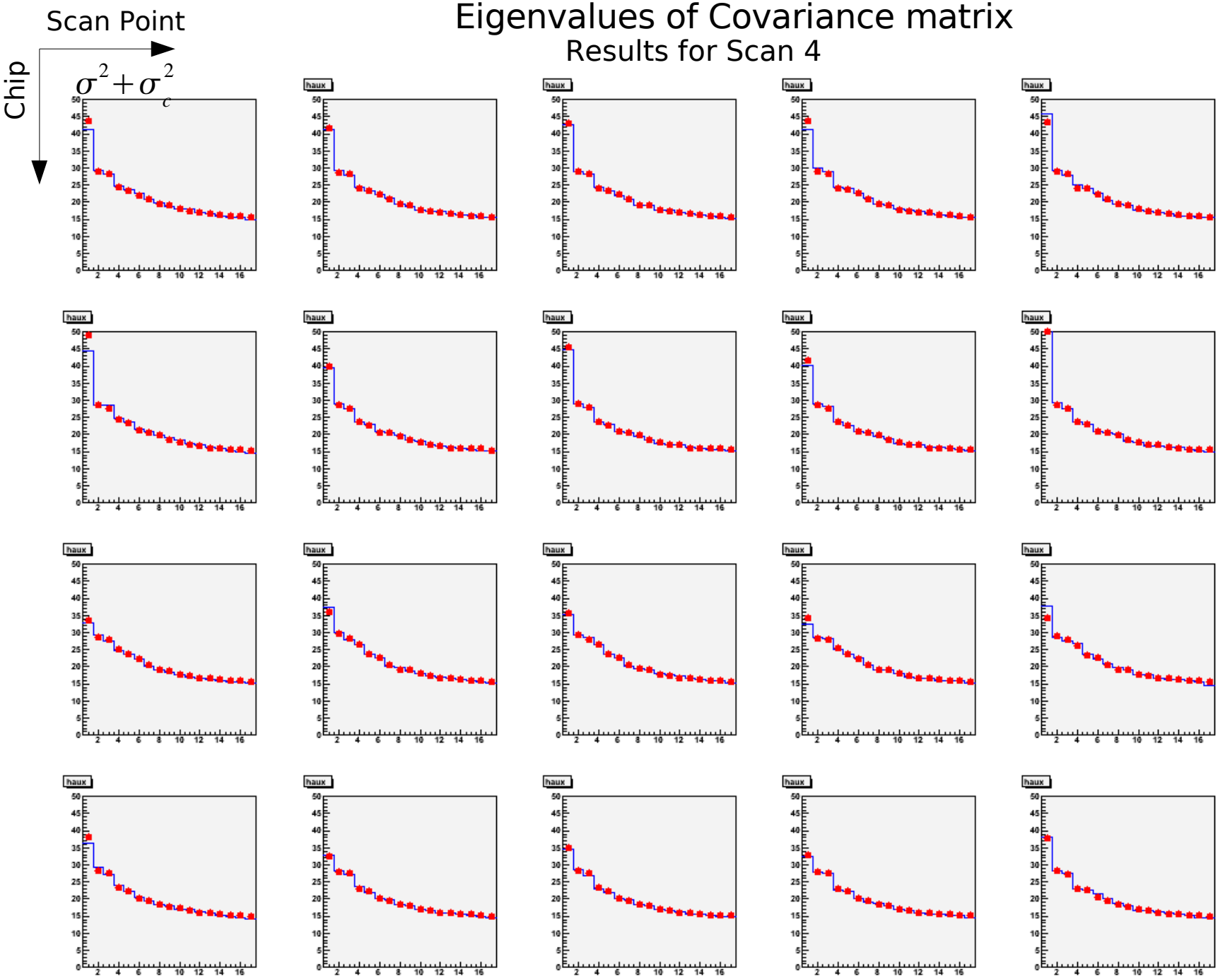
Eigenvalues of Covariance matrix

Results for Scan 4



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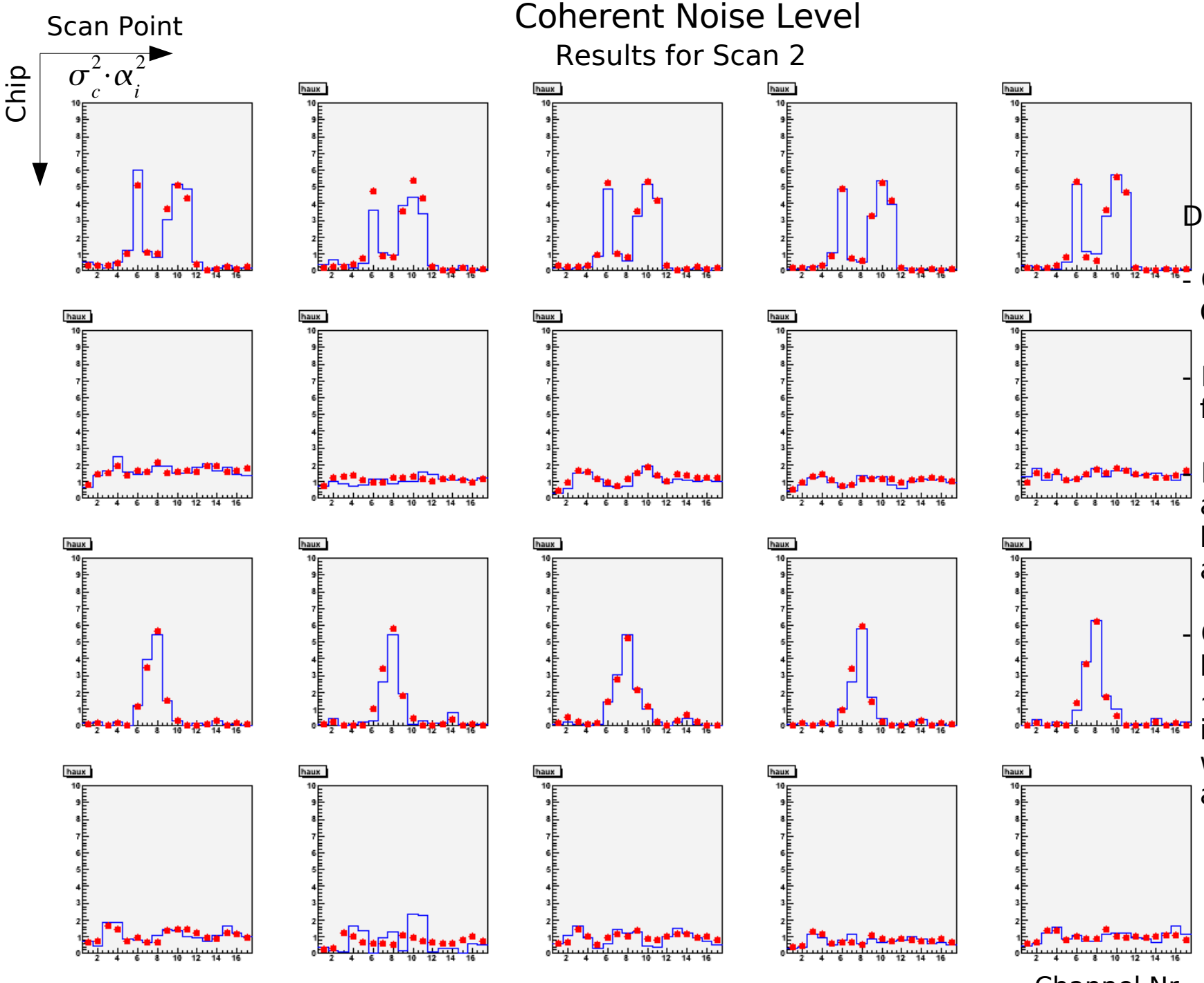
Coherent Noise Level

Results for Scan 2



Blue:Pedestals
Red: Signal

Different Patterns

- Concentrated for Chip 1 and Chip 3

- Flat spectrum for Chip 2 and 4

Excellent agreement between Signal and Pedestal

- Coherent Noise level ~1 ADC Count in agreement with simple analysis

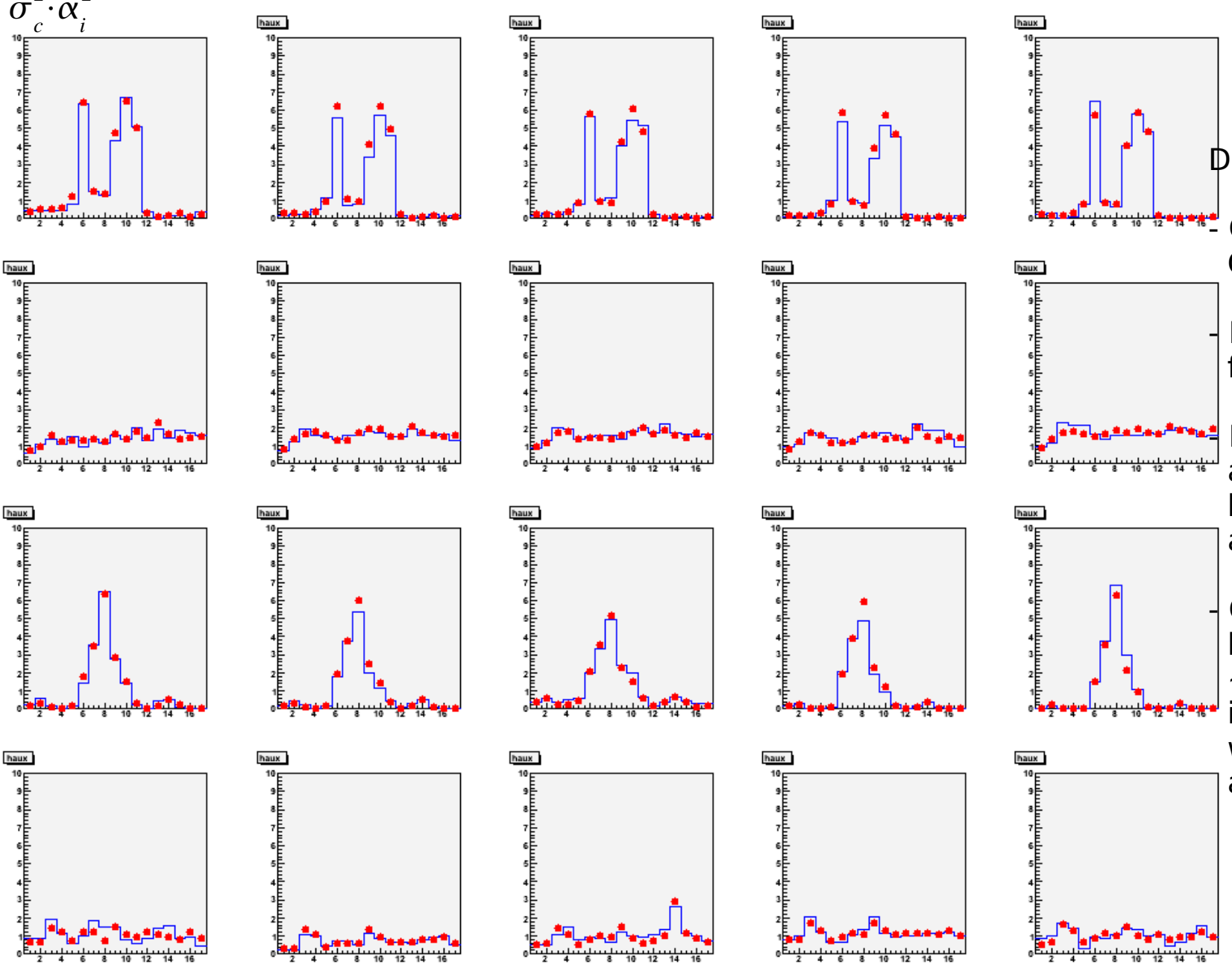
Coherent Noise Level

Results for Scan 3

Scan Point

Chip

$\sigma_c^2 \cdot \alpha_i^2$



Channel Nr.

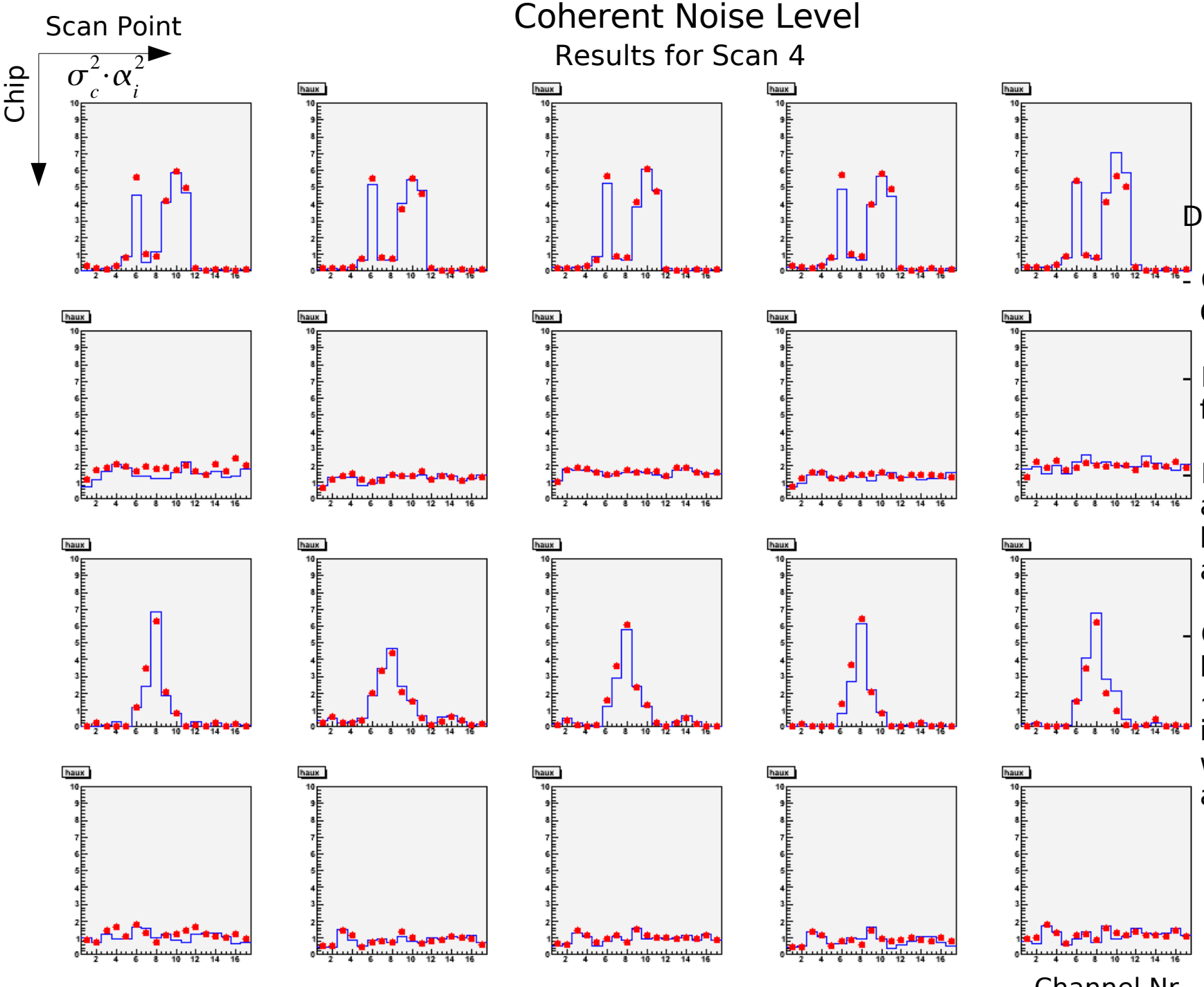
Blue:Pedestals
Red: Signal

Different Patterns

- Concentrated for Chip 1 and Chip 3
- Flat spectrum for Chip 2 and 4
- Excellent agreement between Signal and Pedestal
- Coherent Noise level ~1 ADC Count in agreement with simple analysis

Coherent Noise Level

Results for Scan 4



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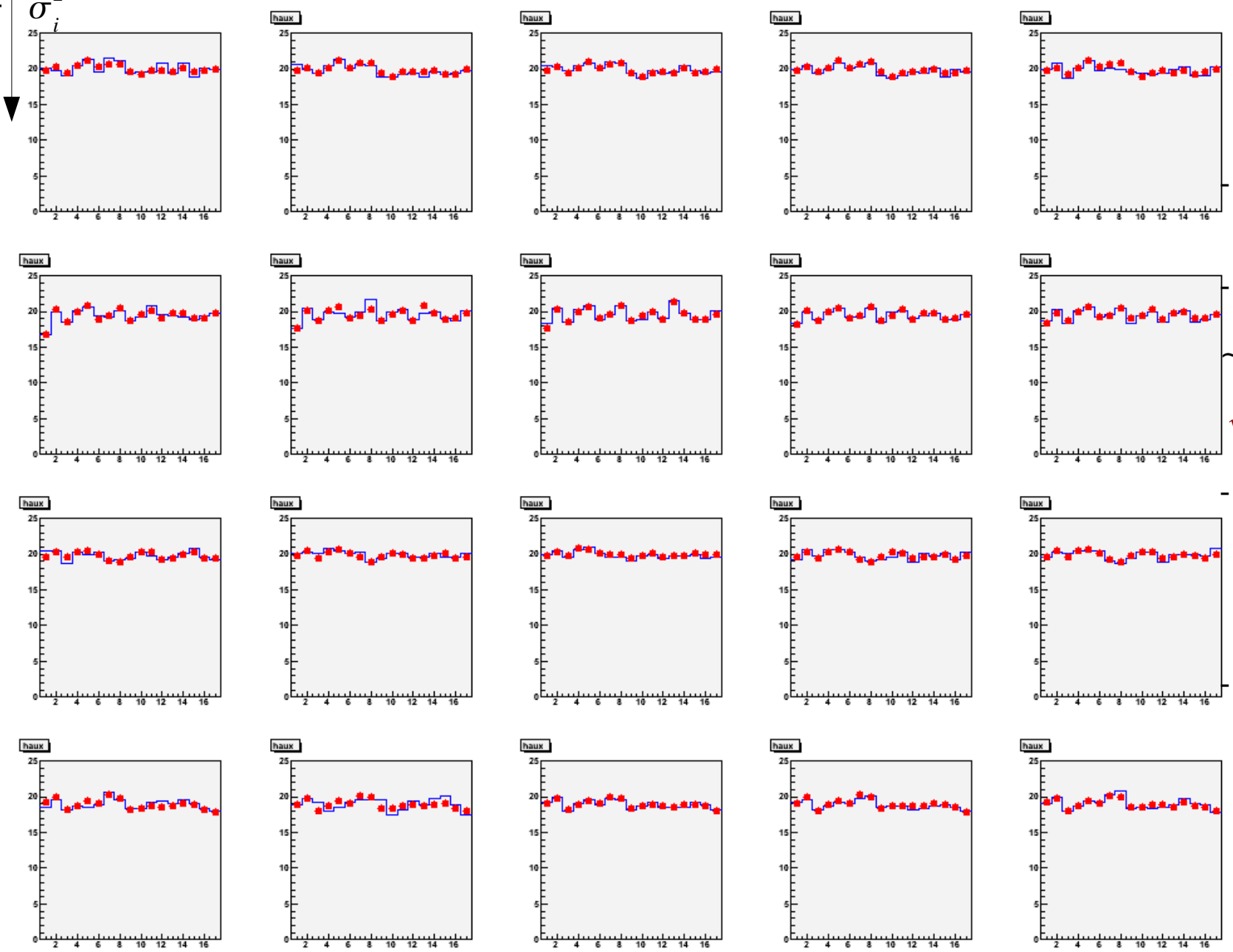
Incoherent Noise Level

Results for Scan 2

Scan Point

Chip

σ_i^2



Blue:Pedestals
Red: Signal

- Flat spectrum for all Chips 2

- Incoherent Noise level ~√20 ~4.5 ADC C.

$$\sqrt{\sigma_{ic}^2+\sigma_{cn}^2}\approx\sqrt{4.5^2+1}\approx4.6$$

- In agreement with σ_G (see above) and rms (see earlier)

- Excellent agreement between Signal and Pedestal

Channel Nr.

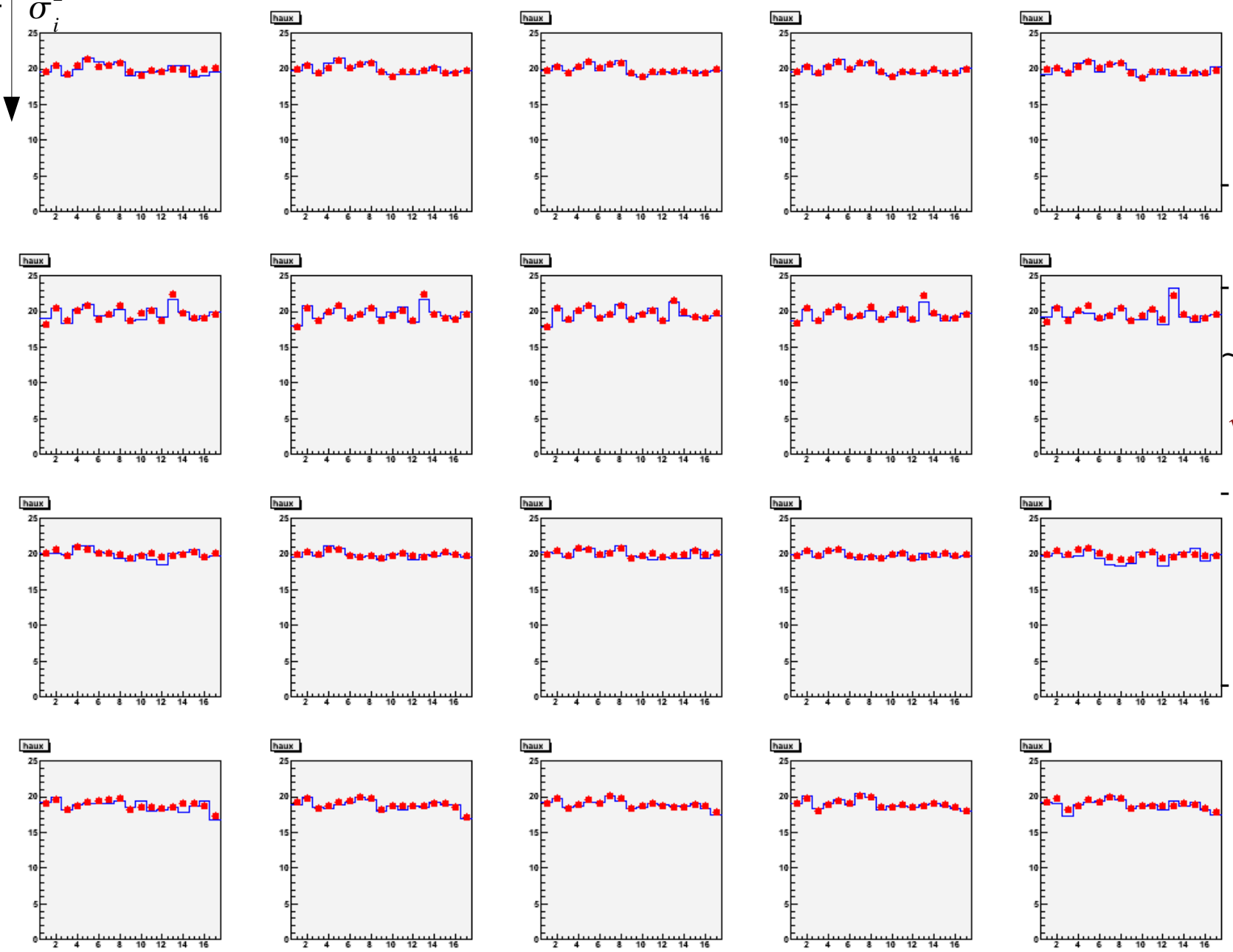
Incoherent Noise Level

Results for Scan 3

Scan Point

Chip

σ_i^2



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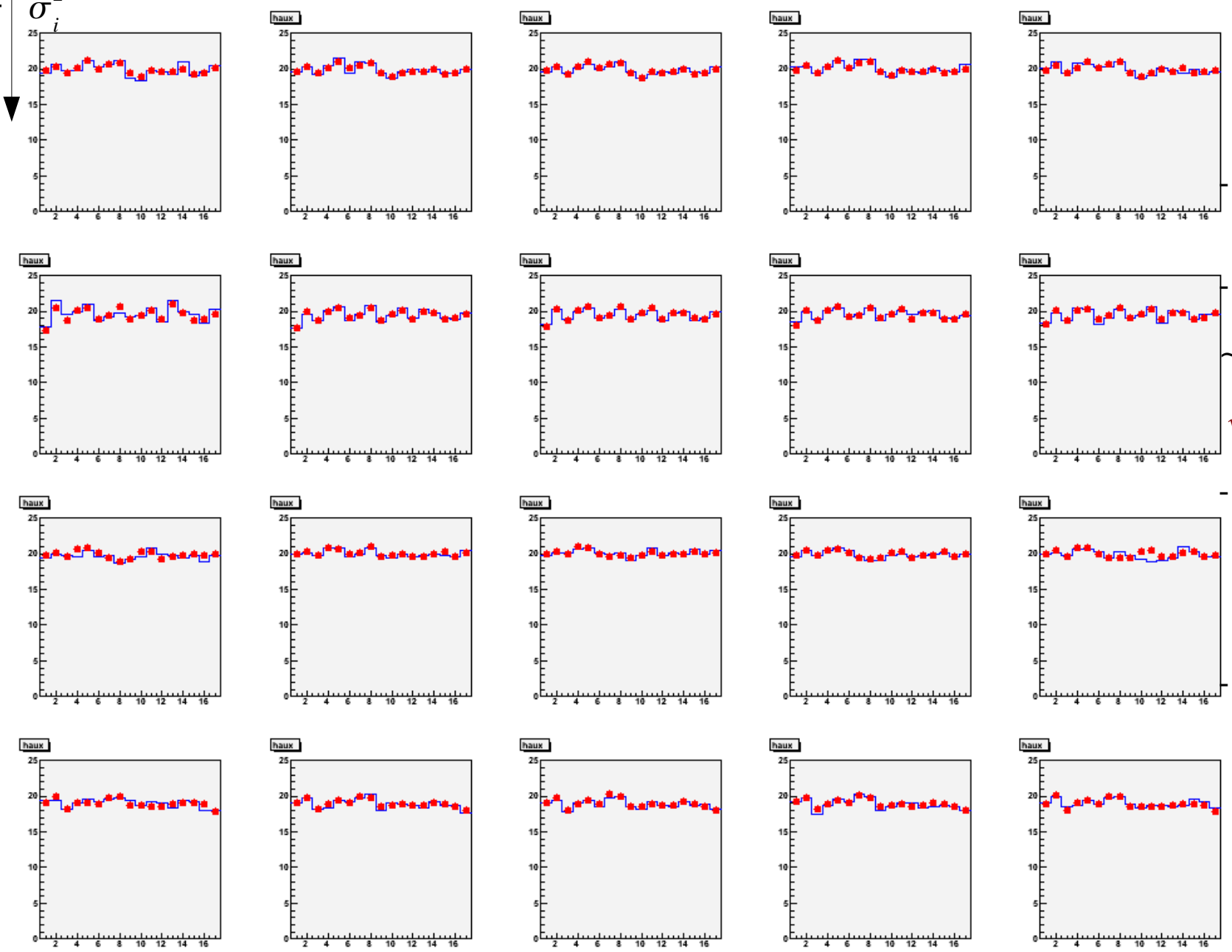
Incoherent Noise Level

Results for Scan 4



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All matrices *B*' on request ;-)
(39 more plots)