CDF Triggers

…as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns - - the ones we don't know we don't know.

…it is the latter category that tend to be the difficult ones.

Known Trigger Expert →

Special Thanks!

- I have spoken to these people, who deserve my special thanks:
  1. Jonathan Lewis (from FNAL, who would love to come here and talk about triggers sometime).
  2. Dave Waters
  3. Farrukh Azfar

I've also stolen slides from Jonathan and Dave.

Overview

- Brief description of the system.
- Current trigger performance
  - Moving target
- Some of the problems
- How CDF is solving them
- Some approaches that went awry.

Apart from the occasional heart attack, I've never felt better!

←Trigger and Quail-Hunting Expert

Trigger Rates as we thought they would be BEFORE the run.

- Level 1
- Hardware

- 2.5MHz in
- 40KHz out

- Rejection ~50

- Level 2
- Hardware/ software

- 40KHz in
- 500Hz out

- Rejection ~100

- Level 3
- Software

- 500Hz in
- 75Hz out

- Rejection ~5-10

Trigger Rates as They actually are ($L=2x10^{32}cm^{-2}$ common)

- Level 1
- Hardware/ Firmware
- 20-30KHz

- Level 2
- Hardware/ software
- 900Hz out
- The Bottleneck

- Level 3
- Software
- 150Hz to staging disk and then to tape

Trigger Cross Section

For Physics: Rate = σ x L

A given trigger also has a rate, so you can define a cross section for that trigger.

Advantage: Ideally, trigger cross section would be constant, even though the rate would increase linearly with increasing Luminosity.

An Increasing Trigger Cross section indicates a loss of purity.

What Do We Have To Guide Us

- RunIIb Physics Priority & Triggers Committee's **Straw Table**.

Straw Table @ 3E32; Ristori et al.

Level 1						Level 2		
		nb	*Hz*	*ovl*			*nb*	*Hz*
Central Electron	CEM8_PT8	3259	978	1		CEM18_PT8_A_R	96	29
Central Muon	CMUP6_PT4	7437	2231	1		CMUP6_PT16	285	86
Muon Extension	CMX6_PT8_CSX	3272	982	1		CMX6_PT15_JET10	200	60
Single Jet/Electron-70	JET20	2800	840	0.37		JET90_NOROF	40	12
Single Isolated Photon	EM12	5000	1500	1		PHOTON_25	123	37
Missing Et	MET25	8045	2414	1		MET35_JET5	79	24
e-central e-central	TWO_CEM4_PT4	3855	1157	1		CEM4_CEM8	50	15
e-central mu-central	CEM4_PT4_&_CMU1.5_PT4	2000	600	1		CEM8_CMUP4+CEM4_CMUP8	8	2
e-central mu-extension	CEM4_PT4_&_CMX1.5_PT4_CSX	450	135	1		CEM8_CMX4+CEM4_CMX8	16	5
e-central e-plug	TWO_EM8	3400	1020	1		CEM4_PEM8	137	41
mu-central mu-central	TWO_CMU1.5_PT4	2000	600	1		CMUP4_CMUP8	4	1
mu-central mu-extension	CMU1.5_PT_4_CMX1.5_PT4_CSX	700	210	1		CMUP4_CMX4	6	2
e-plug mu-central	EM8_&_CMU1.5_PT4	700	210	1		CMUP4_PEM8	13	4
e-plug mu-extension	EM8_&_CMX1.5_PT4_CSX	160	48	1		CMX4_PEM8	20	6
Tau+electron	CEM8_PT8	3259	978	0		CEM+TAU	158	47
Tau+muon central	CMUP6_PT4	7437	2231	0		CMUP+TAU	106	32
Tau+muon extension	CMX6_PT8_CSX	3272	982	0		CMX+TAU	122	37
Plug e + Missing Et	EM12	5000	1500	0		MET15_PEM20	50	15
Super Photon-70	JET20	2800	840	0		EM70	60	18
Di-Gamma/Z-notrack	EM12	5000	1500	0		TWO_EM_16	17	5
Top Multijet	JET20	2800	840	0		FOUR_JET15_SUMET175	57	17
		TOTAL	12395.8				TOTAL	495

= done (was already there or recently implemented)

= not yet done

= not neeeded (yet)

Trigger Steering Group

Group's remit sets trigger priorities based on the Experiment's main physics goals.

Group has Spokespeople and Senior members of the Collaboration as well as the Physics Coordinator and the leaders of the Analysis groups.

People who will be taken seriously during operations when things start to go wrong.

On-line needs clear guidelines regarding trigger priorities to be prepared for:

The Unexpected

Level 1						Level 2		
		nb	*Hz*	*ovl*			*nb*	*Hz*
Central Electron	CEM8_PT8	3259	978	1		CEM18_PT8_A_R	96	29
Central Muon	CMUP6_PT4	7437	2231	1		CMUP6_PT16	285	86
Muon Extension	CMX6_PT8_CSX	3272	982	1		CMX6_PT15_JET10	200	60
Single Jet/Electron-70	JET20	2800	840	0.37		JET90_NOROF	40	12
Single Isolated Photon	EM12	5000	1500	1		PHOTON_25	123	37
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e-central e-central	TWO_CEM4_PT4	3855	1157	1		CEM4_CEM8	50	15
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e-central e-plug	TWO_EM8	3400	1020	1		CEM4_PEM8	137	41
mu-central mu-central	TWO_CMU1.5_PT4	2000	600	1		CMUP4_CMUP8	4	1
mu-central mu-extension	CMU1.5_PT_4_CMX1.5_PT4_CSX	700	210	1		CMUP4_CMX4	6	2
e-plug mu-central	EM8_&_CMU1.5_PT4	700	210	1		CMUP4_PEM8	13	4
e-plug mu-extension	EM8_&_CMX1.5_PT4_CSX	160	48	1		CMX4_PEM8	20	6
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Plug e + Missing Et	EM12	5000	1500	0		MET15_PEM20	50	15
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Di-Gamma/Z-notrack	EM12	5000	1500	0		TWO_EM_16	17	5
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		TOTAL	12395.8				TOTAL	495

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= not neeeded (yet)

General Rule CDF applies

- High level of automation in the trigger!
- Physicists do not need to know details of how MET, Tower Energy, or PT are actually implemented in L1, L2, or L3
- Trigger Working group meets every week or so to assess current trigger status and to review proposals for new triggers.

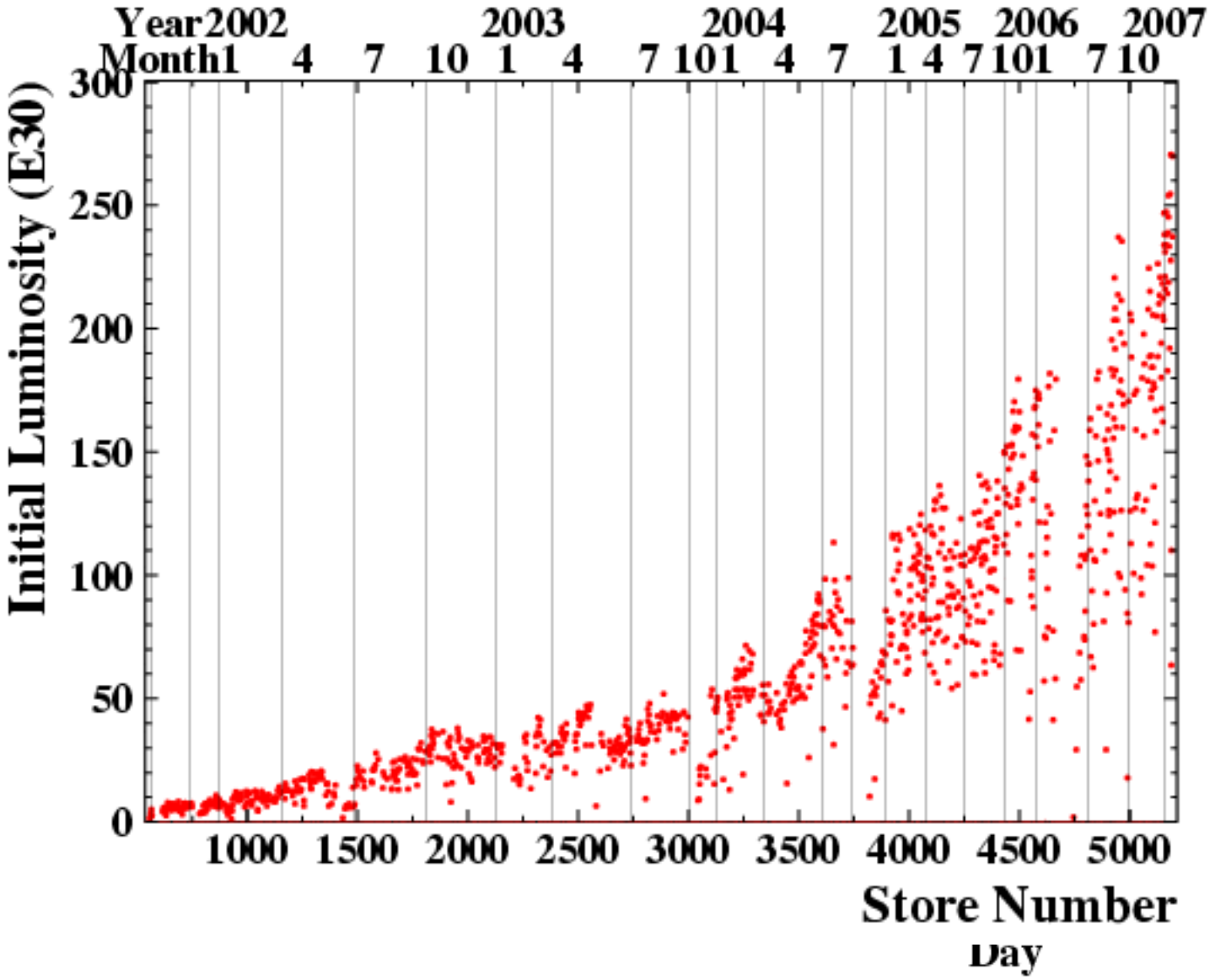
General Rule CDF applies

- Trigger Databases
  - All high level quantities are added to a trigger table along with parameters
  - Possible to add quantities if you need them (like ‘jet’ definition, or ‘muon’ definition)
  - Mostly though, parameters change.
  - The “trigger” is then created or built by collecting together the information and combinations from the database.
    - Lots of clever scripting in Perl (Level 3 anyway)

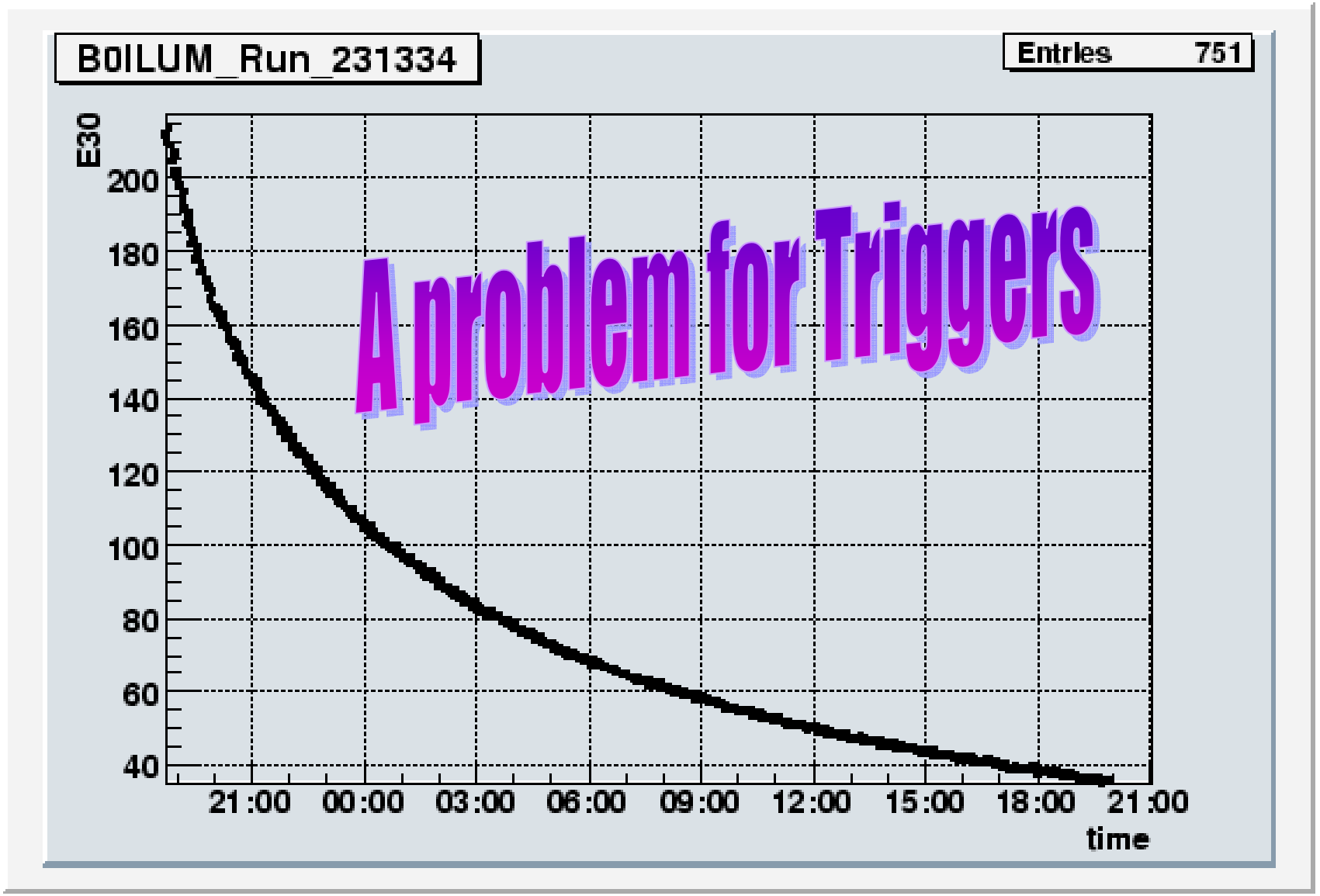
Tevatron Running conditions

Integrated Lum.
To tape for all of
Run II

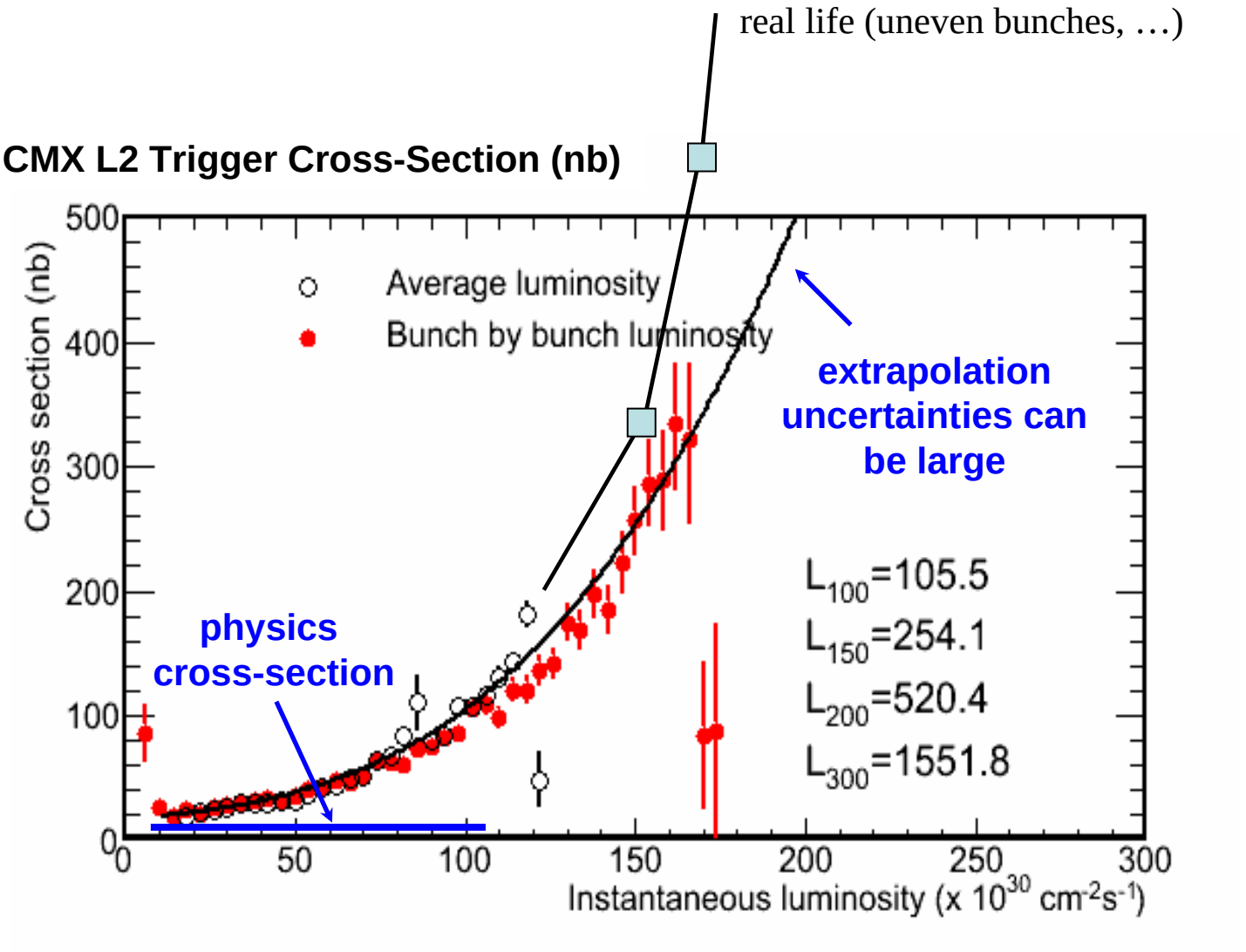
Peak Lum.
For each store.



Tevatron Run Conditions



Compounding The Problem

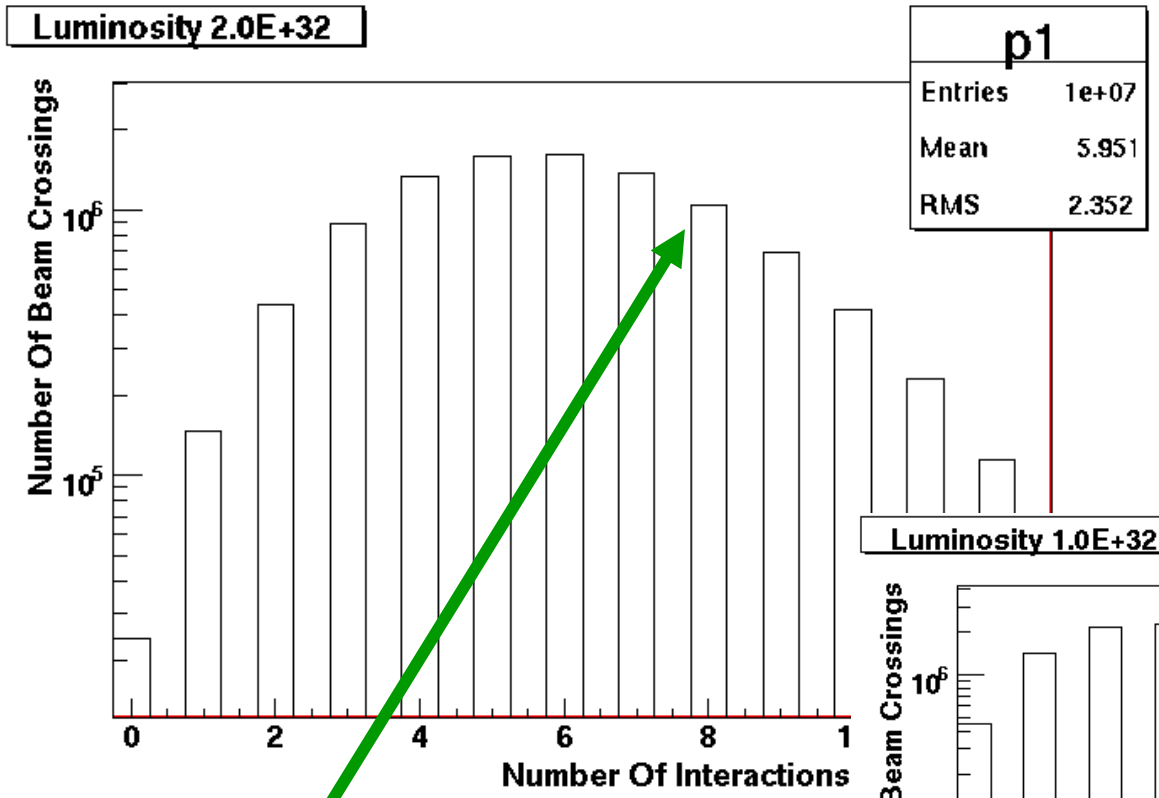


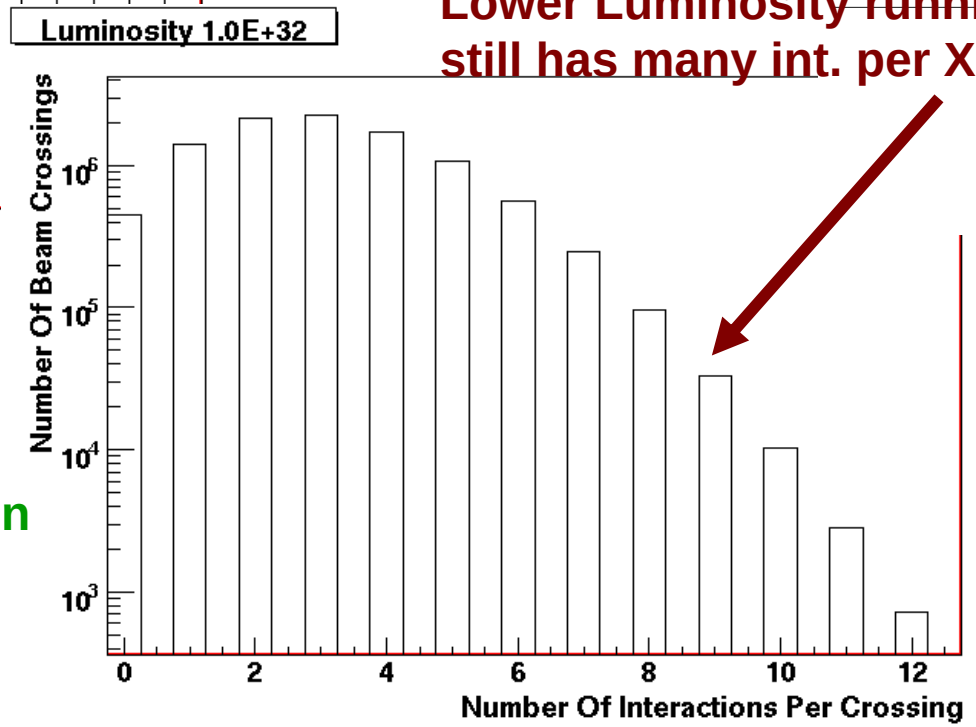
Predicting Trigger Rates

- Problem→ Difficult to predict X-section performance as Luminosity increases.
  - Remember that earlier trigger with the quadratic dependence?

- Use the Poisson distribution of the number of events per crossing to our advantage.
- Look at the trigger cross section as a function of Number of Interactions per crossing.
- Then Scale up to higher Luminosity

Predicting Trigger X-sections





This technique is quite mature on CDF.

Gets within factor of two despite bunch intensity variations

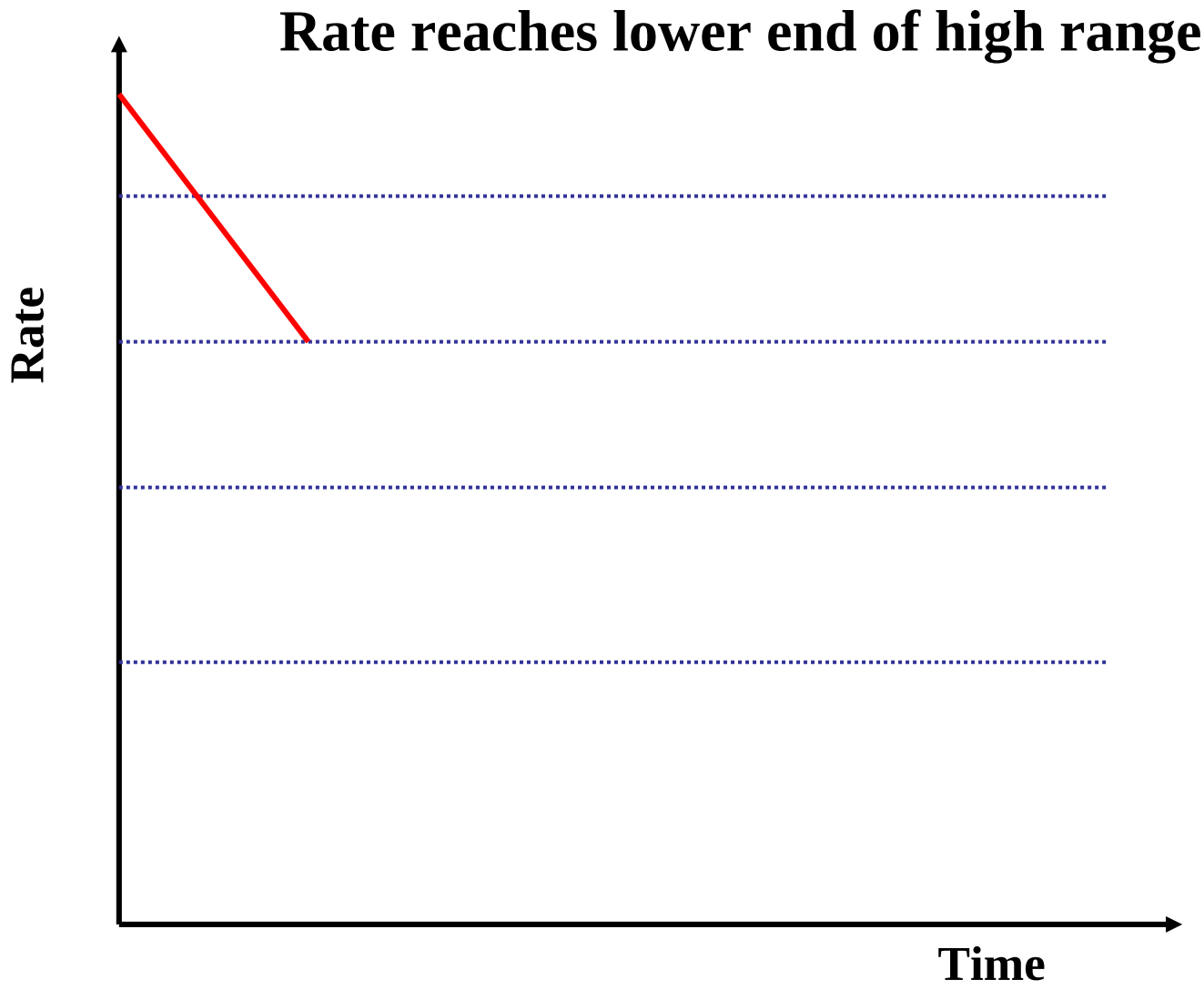
Lower Luminosity ~~running~~ still has many int. per Xing

Use the events with large No. of Crossings to predict what will happen to the triggers at higher Luminosity.

Dealing with the Beam: Dynamic Prescaling

- Change prescale automatically during the course of a run
- Three key values
  - Maximum prescale
    - Initial value at start of run
  - Default prescale
  - Minimum prescale
- A Scaler Monitor looks at rates and uses these parameters to adjust prescales

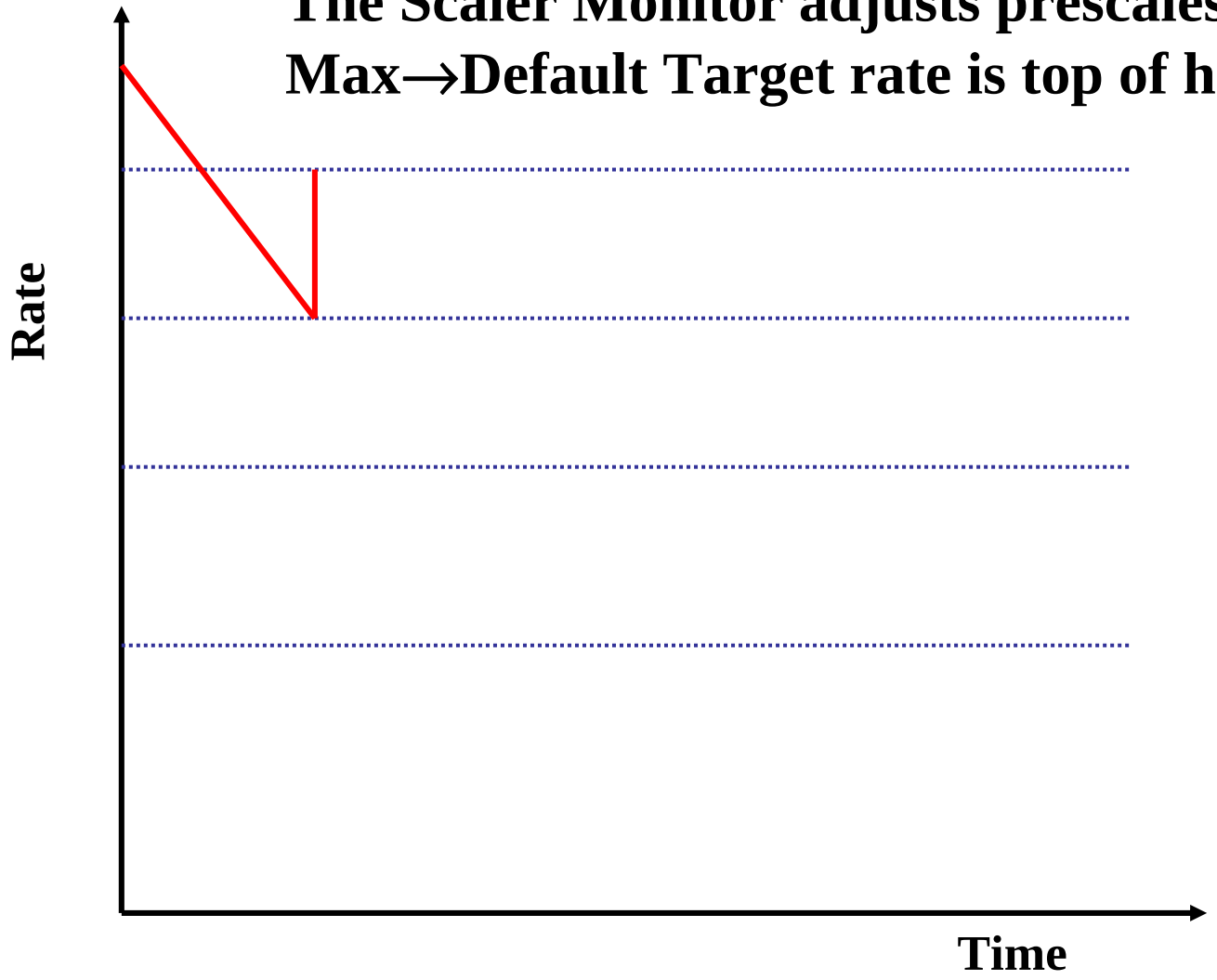
Dynamic Prescaling



Dynamic Prescaling

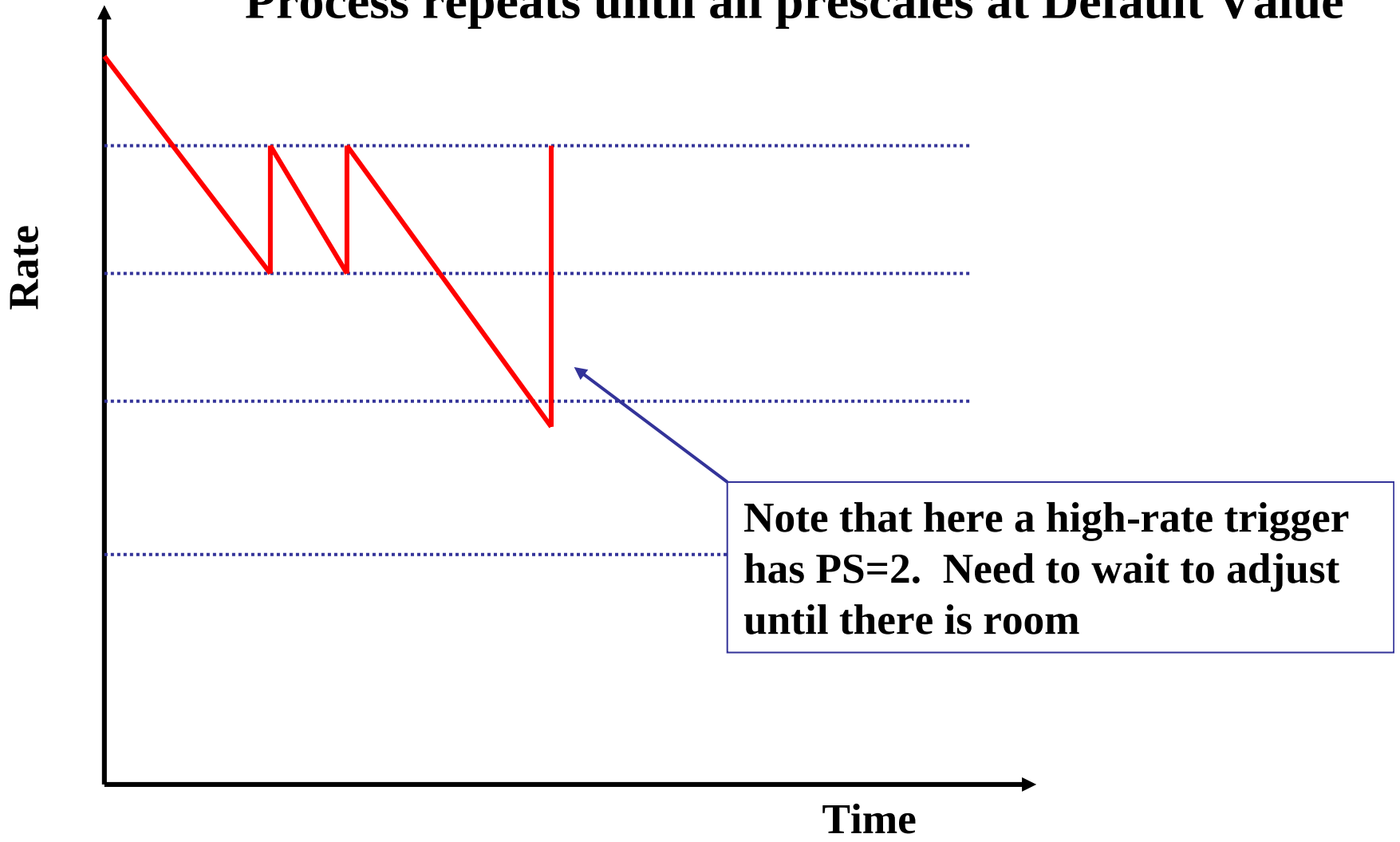
The Scaler Monitor adjusts prescales:

Max→Default Target rate is top of high range



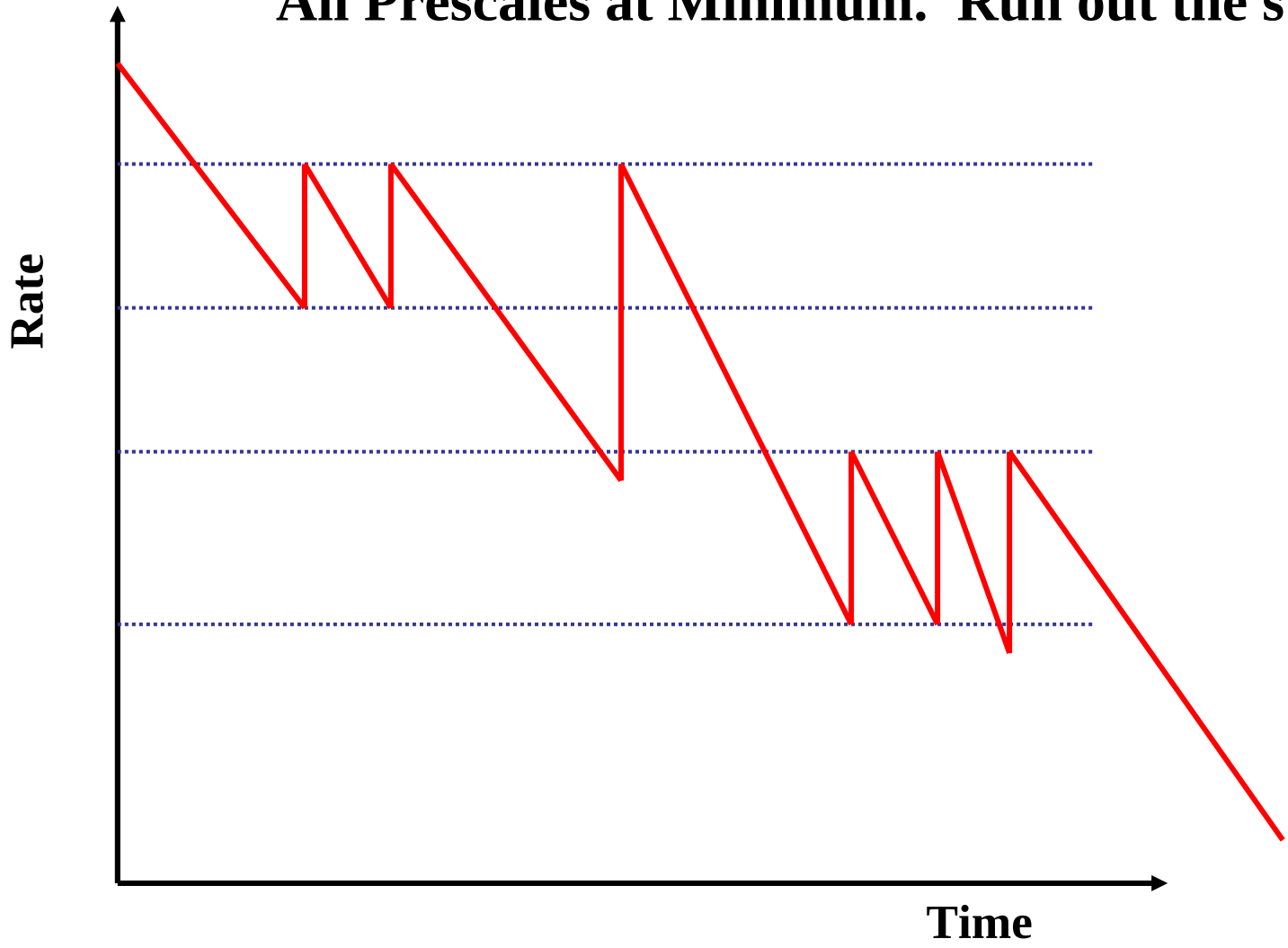
Dynamic Prescaling

Process repeats until all prescales at Default Value



Dynamic Prescaling

All Prescales at Minimum. Run out the store.

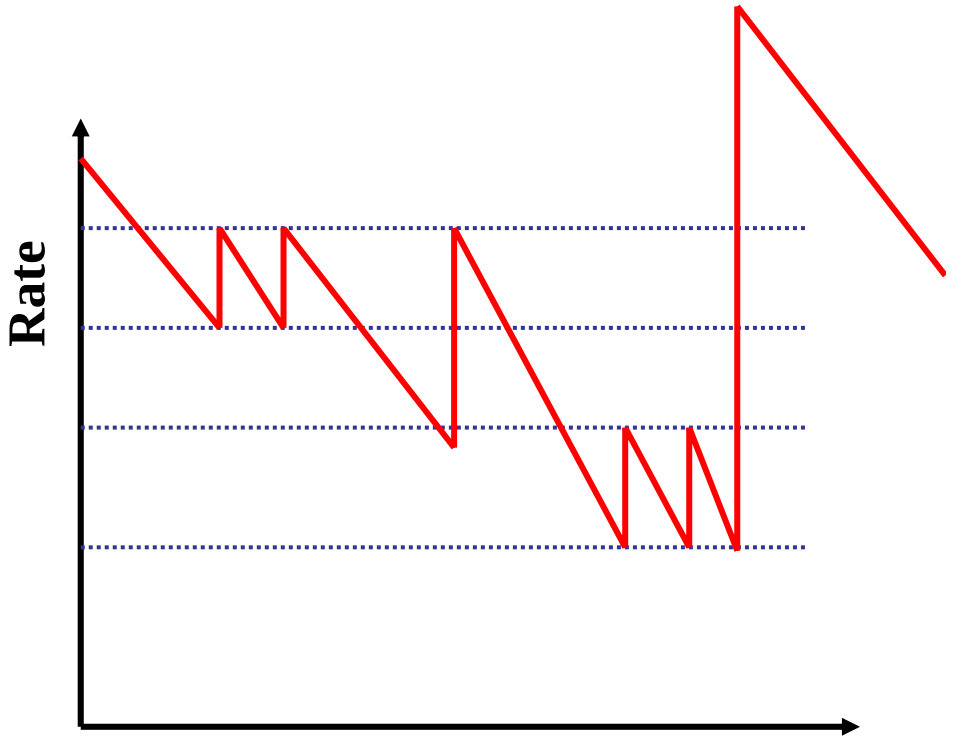


Über Prescale

- Prescaling on the μs timescale
- Accept L1 trigger only if 3 or 4 buffers are free
  - Excess capacity because of fluctuations in interval between accepts
  - Allows a high-rate trigger to fill in gaps in lower rate sample
  - Total L1 accept rate will exceed that allowed in normal running with minimal deadtime contribution
- Maybe Useful on ATLAS at some point??

UPS Delivers!

- Able to take high rate of lower purity triggers at low luminosity
- Considerations
  - Only <u>one</u> UPS trigger allowed
  - Enabled when all prescales are at minimum
    - Don’t get fancy!
  - Once enabled, Scaler stops adjusting prescales in response to trigger rates

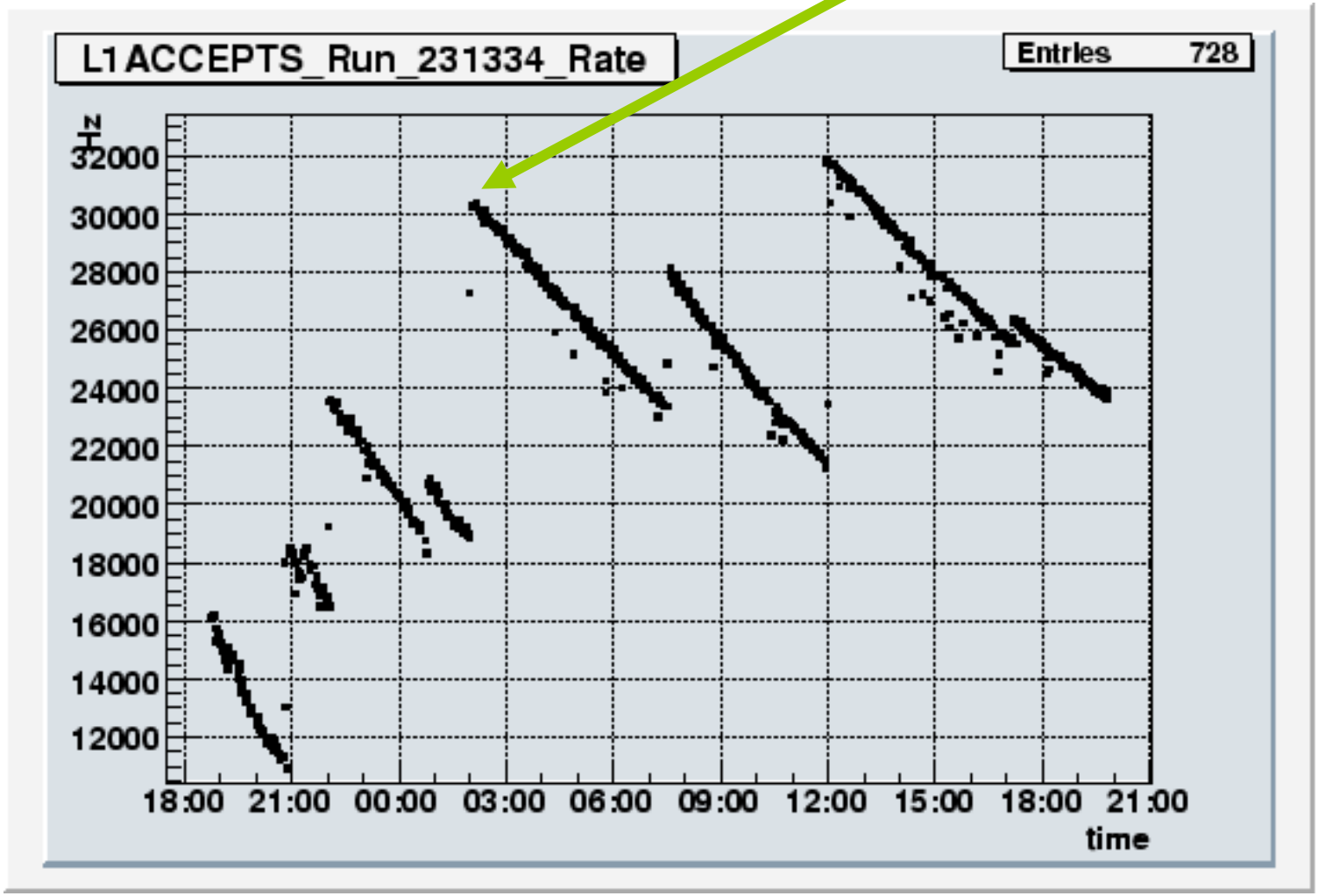


–To improve benefit, need to relax limit on L1A rate

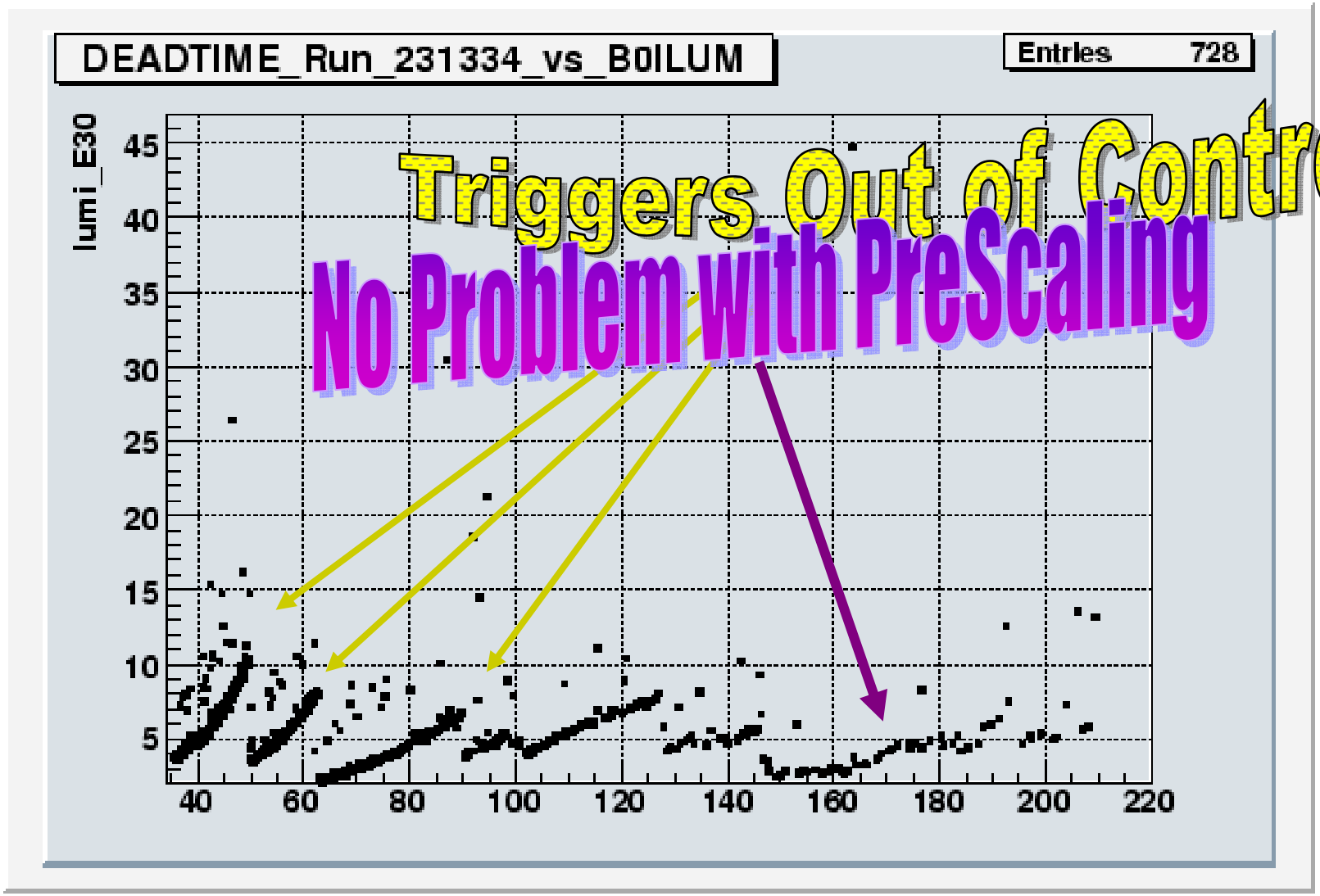
Current Trigger Performance

Level 1 accept rate in Hz

Uber Pre-Scale kicks in.



Current Trigger Performance



Instantaneous Luminosity, E+30

Other tools: Just be Clever!

- Beam Counters (CLC) are capable, through timing their signals, of finding crossings with large number of interactions.
  - Use this as a veto for triggers that do not work well at high instantaneous Lum. At Level 1.
    - Diffractive Physics, Some B physics
- Be smarter about online reconstruction
  - stereo XFT for tracking, the L2 Cal upgrade that is coming for calorimetry, better matching between trigger objects like CMX and tracking...

Other tools: Just be Clever!

- Being smarter about signatures.
  - For example if you have to give up inclusive muons, then design a set of lower rate multi-object triggers which get you ~75% of the physics at a lower overall cost in bandwidth.
    - Muon+jet
    - Muon+ high impact parameter track > 2 GeV/c
- This work never stops.
  - Powerful incentive when your physics channel is threatened with high scaling factors.
- No Cook-book solutions.

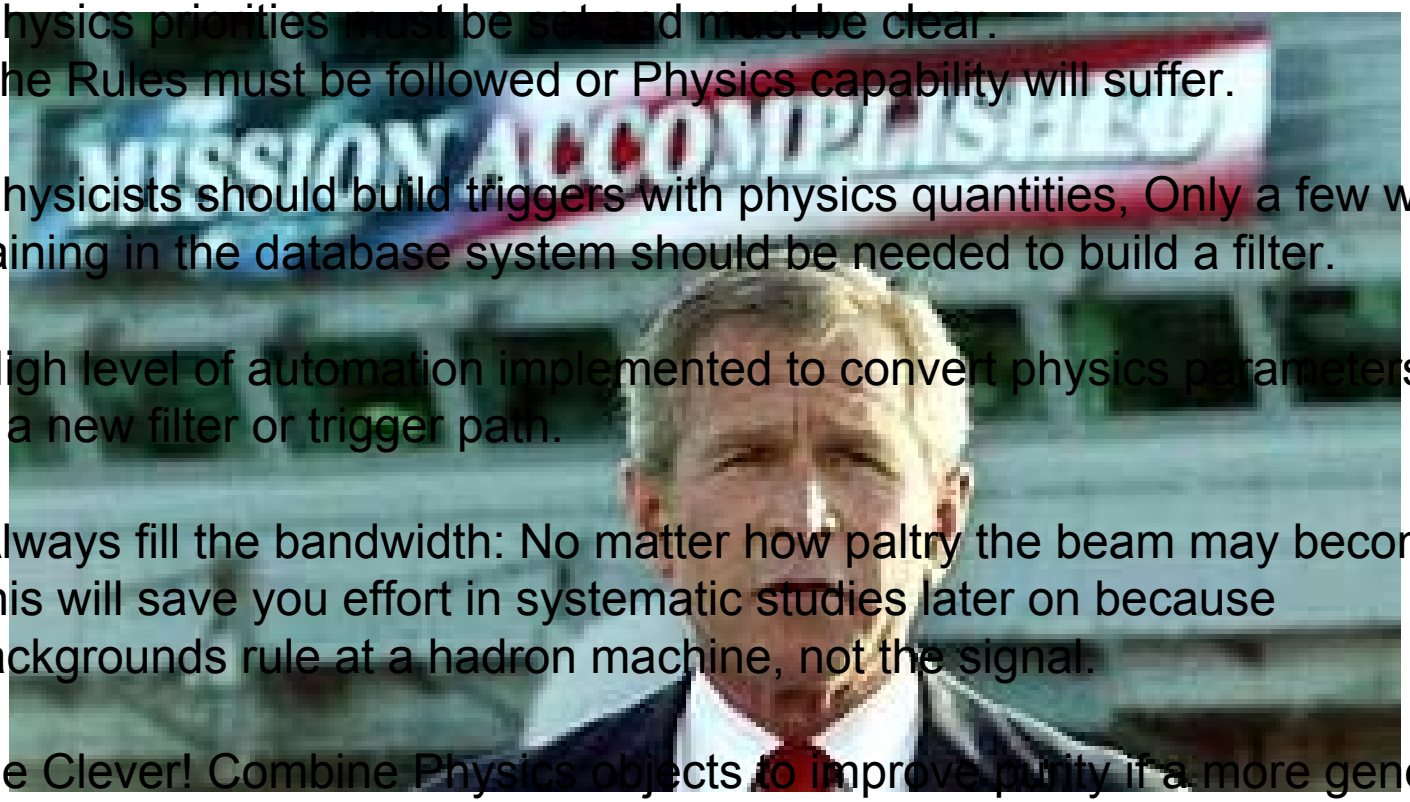
One Thing I Know your Mother never told you about.

- CDF has never managed to get stand-alone silicon tracking into the trigger.
- Only ‘outside in’ tracking has ever worked.

- So far this has not been a problem
- There could, however, be serious gains in purity if this could be implemented.
  - B triggers; muons; even lower energy jets.

Conclusions

•Physics priorities must be set and must be clear.
•The Rules must be followed or Physics capability will suffer.



•Physicists should build triggers with physics quantities, Only a few weeks training in the database system should be needed to build a filter.

•High level of automation implemented to convert physics parameters to a new filter or trigger path.

•Always fill the bandwidth: No matter how paltry the beam may become. This will save you effort in systematic studies later on because backgrounds rule at a hadron machine, not the signal.

•Be Clever! Combine Physics objects to improve purity if a more general trigger rate goes out of control.

•Then try to keep the general trigger, but pre-scaled, anyway.

Backup Slides

The talk is OVER!

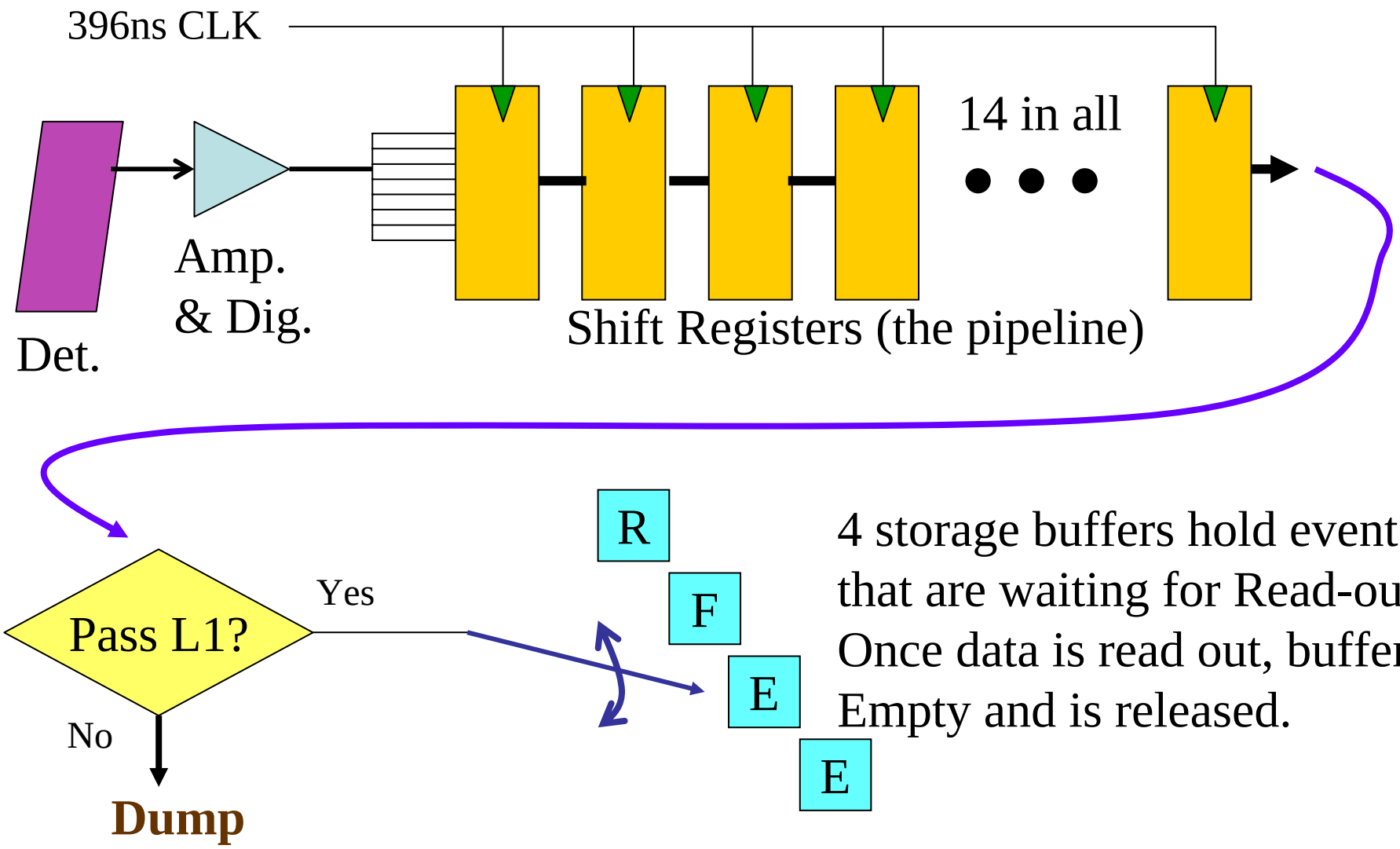
What happened to Regional tracking?

- We cannot run stand-alone silicon in Level 3.
  - Silicon tracking is ‘Outside-in’ only
- Early thoughts were to use previous triggers to define ‘regions of interest’ in which hits would be sought for tracking (or other triggers at L3)
- Instead, full reconstruction was chosen.
  - Effort put into optimising full reconstruction
  - Make it lean and mean as possible.
    - Has worked well so far.

What happened to Regional tracking?

- Defining ‘regions’ was difficult. This took time.
- Defining a limited hit-list to be fed into L3 might have been a better solution than trying to re-find hits within a ‘region’.

Pipelined Trigger And Buffered (deadtimeless)



4 storage buffers hold events that are waiting for Read-out. Once data is read out, buffer is Empty and is released.

Some Data structure Details

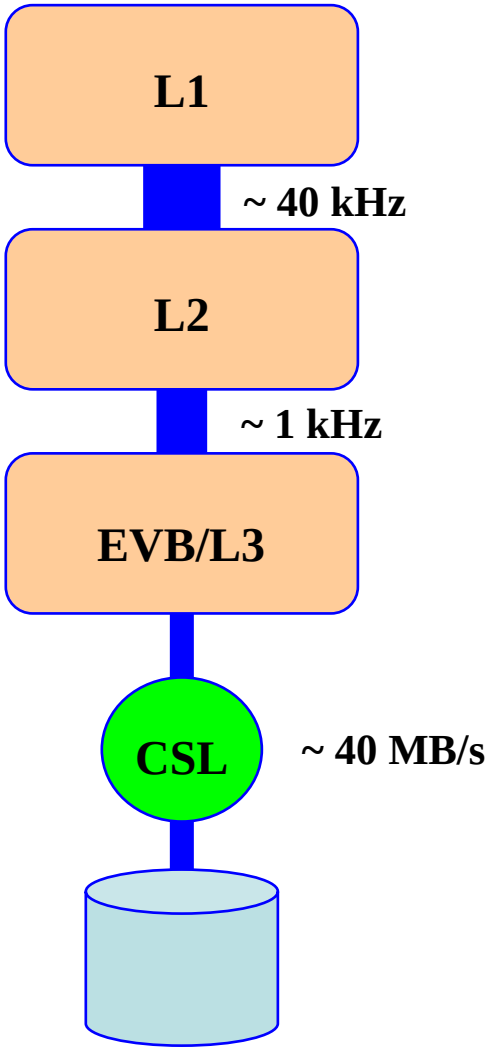
- The Store → from the machine
  - 8 to 24 hours each
- The Run → from CDF operations
  - Corresponds to The Store if everything runs smoothly
    - Meaning not very often.
- The Run Section → A segment of the run.
  - Luminosity and Trigger X-sections updated.

DPS Accounting

- Scalers count triggers before and after prescale
- Prescale efficiency not a simple ratio of totals for run
  - Physics rate is a constant cross section
  - Background grows with increasing luminosity
  - $N = \int (1/P(t))\, L(t)\, \sigma(t)\, dt$
- Do numeric integration over run sections to get effective luminosity:

$$L_{eff} = \sum_i \frac{A_i - A_{i-1}}{B_i - B_{i-1}} \int_{t_{i-1}}^{t_i} L\, dt$$

Recent & Ongoing Upgrades



- L2 Pulsar & SVT : **complete**.

- XFT stereo @ L1 & conf. @ L2 : **complete**.
- 3D tracking & matching @ L2 : **December**

- EVB : ~1kHz @ highest luminosity : **complete**.
- L3 processing $\rightarrow$ 2.4 THz : **complete**.

- CSL : 40-80 MB/s : **31st October**

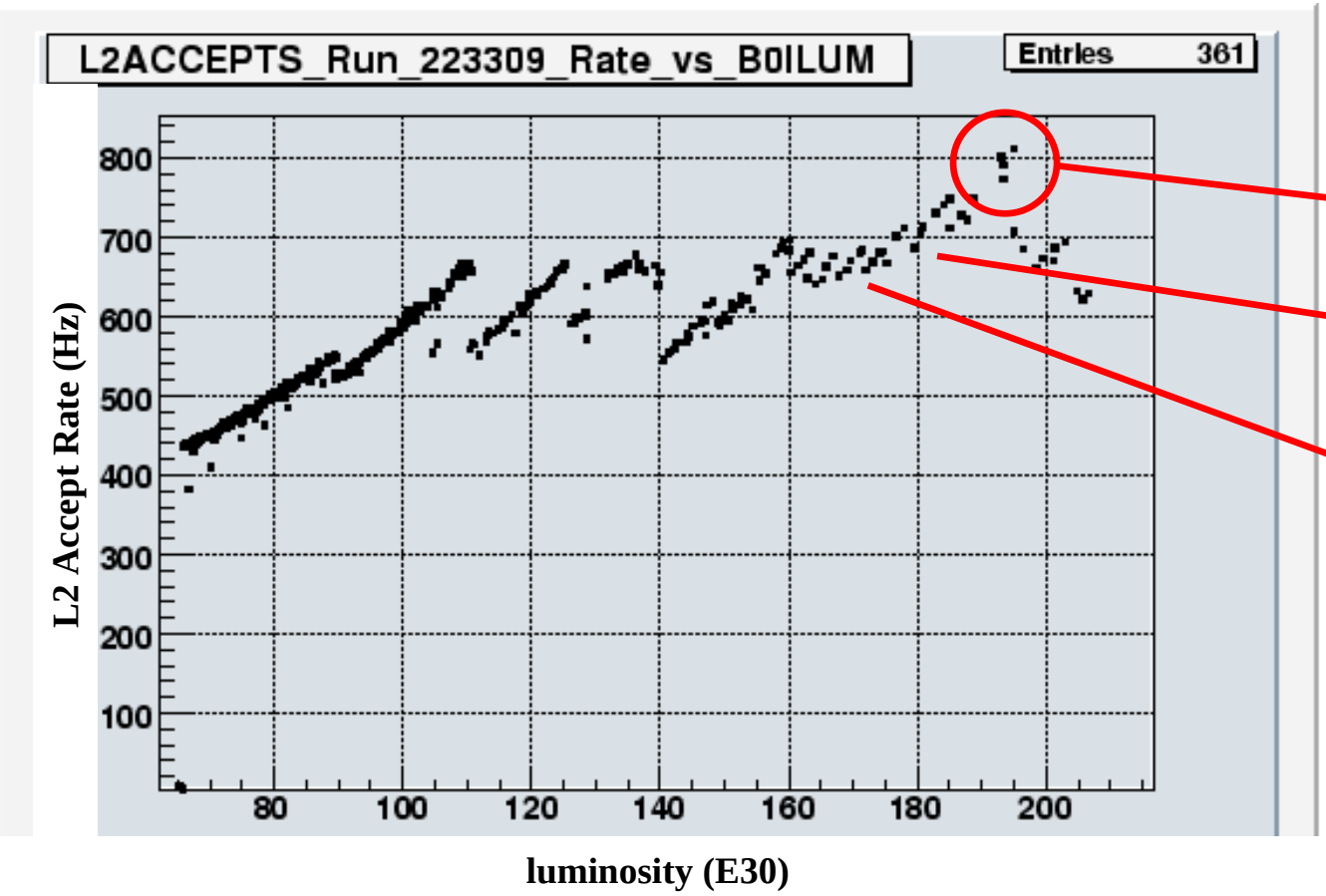
N.B. this is *not* a complete list : TDC's, L3 performance optimisation …

Luminosity Enable

- Enable triggers after luminosity falls
  - Designed for triggers that are not useful with multiple interactions (B-physics) or triggers with very large growth vs. luminosity
  - Under control of The Scalar Monitor
    - No feedback on trigger rate
    - Turn on (or off) only in response to changes in instantaneous luminosity
  - Accounting via normal before and after scalers

PHYSICS_4_00 [7]

- Level2 bandwidth utilization :



CMX triggers on
LUMI 200 enable

MET+2-JET
LUMI 190 enable

HIGGS_HIGH_PT_BJET
LUMI 180 enable

Caution! This is a Different Run!!!

Dynamic Prescaling

Start of Store: All Prescales at Max