
Tevatron Collider Monte Carlo

Version 2.0 (for Run II)

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Outline

- What's going on here?
- Random numbers
- Assumptions
 - *Collider parameters*
 - *Randomizations*
- How does this work?
- What can we learn from this model?
- Web Interface, “beta” version

What's going on here?

- Phenomenological (non-analytic) model of the Tevatron Collider Complex
 - *Began during Run I, with Vinod, GPJ & others helping*
 - *McGinnis's ordered me to revive it now.*
- Incorporate randomness
 - *Downtime*
 - *For the Tevatron, stacking and the PBar Source*
 - *Variations in all realistic parameters*
 - *E.g., transmissions during a shot, lifetimes, uncertainty in exactly how many pbars we extract, shot setup time, downtime, etc....*
- Develop intuition for controlling stores
 - *Based on these assumptions and randomizations*
 - *Many already have this intuition, but not all....*

Current Features

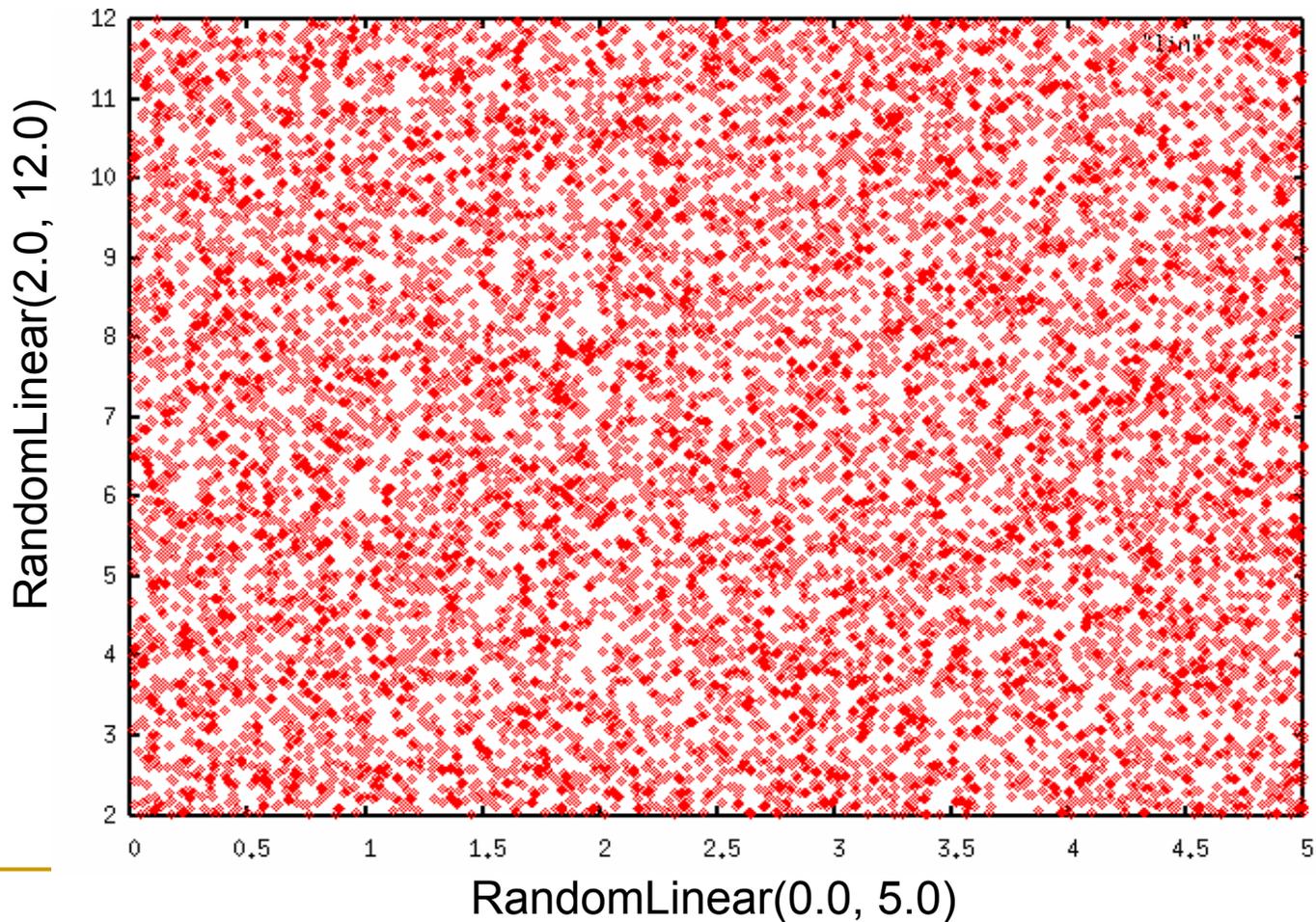
- Represents Run II performance, today.
 - *Easy to change to reflect “tomorrow’s” performance*
- Many algorithms for ending stores
- Linux, C++
 - *Pretty good random number generator: drand48()*
 - *Can simulate 10,000 weeks in about 23 seconds*
 - *Command-line arguments: scan a parameter*
 - *Easily adaptable, through recompilation*

Limitations

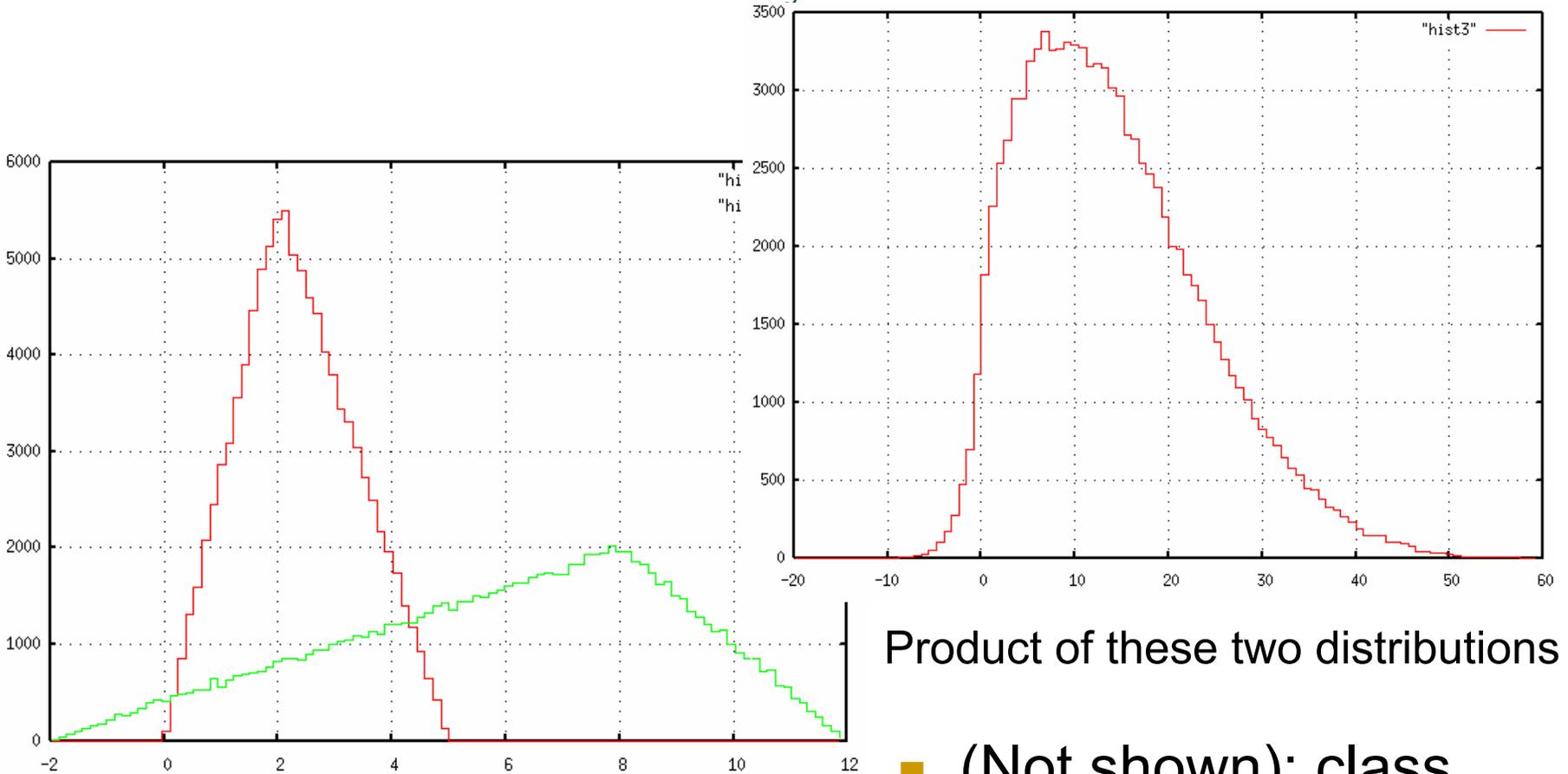
- This is a phenomenological model!
 - $\mathcal{L}(t=0) = K \times N_p(0) \times N_{pbar}(0) / (\varepsilon_p(0) + \varepsilon_{pbar}(0))$
 - $K = (1.331 \pm 10\%) \times \beta \gamma / \beta^* [\text{cm}]$
- Downtime over 24 hours is not considered.
 - *Extended shutdowns are irrelevant.*
- Performance in the model does not improve.
 - *Just random fluctuations around specified performance.*

Random Numbers

- Unix's drand48(); class RandomLinear



Class RandomLikely



(0, 5, 2) and (-2, 12, 8)

Product of these two distributions

■ (Not shown): class RandomBoolean

Assumptions

- Collider Parameters
- Randomizations

Collider Parameter Assumptions

ProtonEmittance	20
ProtonERange	5
ProtonIntensity	27
ProtonIRange	5
PBarEmittance	15
EmitVsStack	0.02
PBarEmitRange	3
MaxPBarEmit	30
EmitGrowthRange	0.05
ExtractPerStack	0.0011
ExtractRange	0.08
ExtractEfficRange	0.05
ExtractEfficPerStack	0.0003
energy	980
ZeroStackRate	12
ZeroRateStack	300

■ Stacking rate:

- $12 \times (1-S/300)$ [mA/hr]

□ Stacking off:

- $-0.001 \times S$ [mA/hr]

■ Luminosity Lifetime

- $\mathcal{L}(t) = \mathcal{L}(0) e^{-t/\tau(t)}$

- $\tau(t) = \tau(0) + C_1 t^{C_2}$

- $C_1 = 1.8 \pm 0.2$

- $C_2 = 0.595 \pm 0.005$

Randomization Assumptions (Tevatron)

Parameter	Desc	Class	Values			Units
coinFlip		RandomBoolean	0.5			
varySetupTime	Length of shot setup	RandomLikely	* 1.2	4	2.2	Hours
Initial Lum Variation	Accounts for variation in hourglass, betastar and other unaccounted for stuff	RandomLikely	* Can be changed easily: Command-line argument			
downtimeVary	How long is this Tevatron downtime?	RandomLikely	1	24	10	Hours
experimentsNeedAccess	Do the experiments get an access this time?	RandomBoolean	* 0.1667			
accessTime	How long do the experiments need to access their detectors?	RandomLinear	1	3		Hours
tevatronStudies	Does the Tevatron need study time now?	RandomBoolean	* 0.1667			
studyTiime	How long are Tevatron studies?	RandomLinear	4	12		Hours
initialLifetimeVary	Variation in the initial lifetime	RandomLikely	0.8	1.2	1	Fraction of default lifetime
lifetimeConst1	Lifetime increases as $C1*t^{**}C2$	RandomLikely	1.6	2	1.8	
lifetimeConst2	This is C2	RandomLikely	0.59	0.6	0.6	
upTime	Tevatron uptime	RandomBoolean	* 0.96			per hour

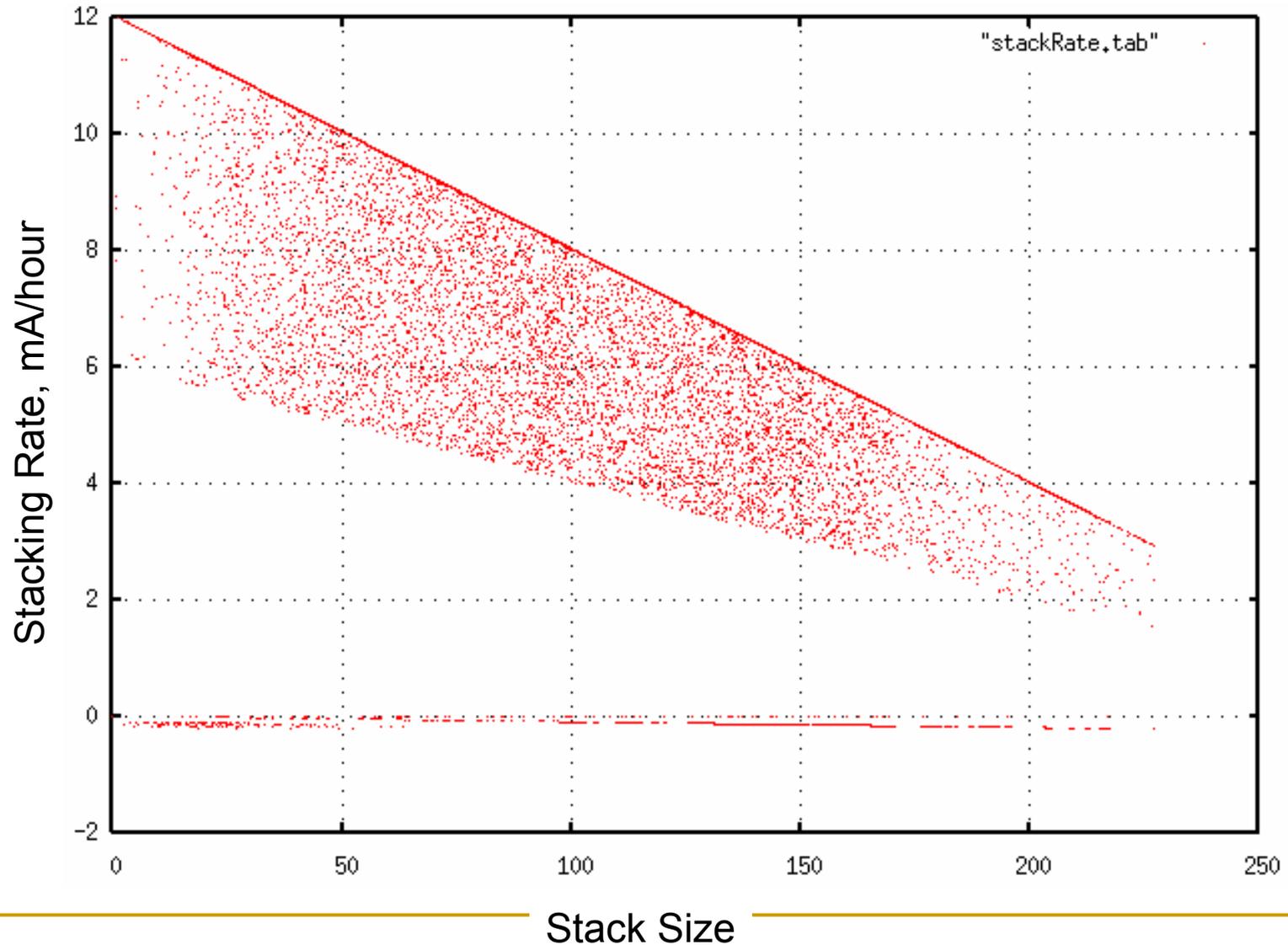
Randomization Assumptions (PBar & Shot)

Parameter	Desc	Class	Values	Units
removeVary	What fraction of the stack do we actually remove?	RandomLikely	0.6 0.99 0.9	Fraction of stack
offTime	How long is a stacking downtime?	RandomLikely	0 2 0.1	Hours
badDowntime	When we have a downtime, probability that it is a really bad one	RandomBoolean	0.1	
stackingSucks	Probability that the stacking rate is reduced	RandomBoolean	0.3	per time step
badRate	How badly does stacking suck	RandomLinear	0.5 1	fraction of full rate
isDown	Probability that stacking is off	RandomBoolean	* 0.97	per day
isDropped	Probability that a stacking down time is actually a dropped stack	RandomBoolean	* 0.5	
extraction	What is the efficiency of unstacking, i.e., fraction retained from stack to extraction line	RandomLikely	0.7 0.95 0.92	
transmissions	12 steps of efficiencies from Accumulator to Tevatron	RandomLikely	0.98 0.99 1	

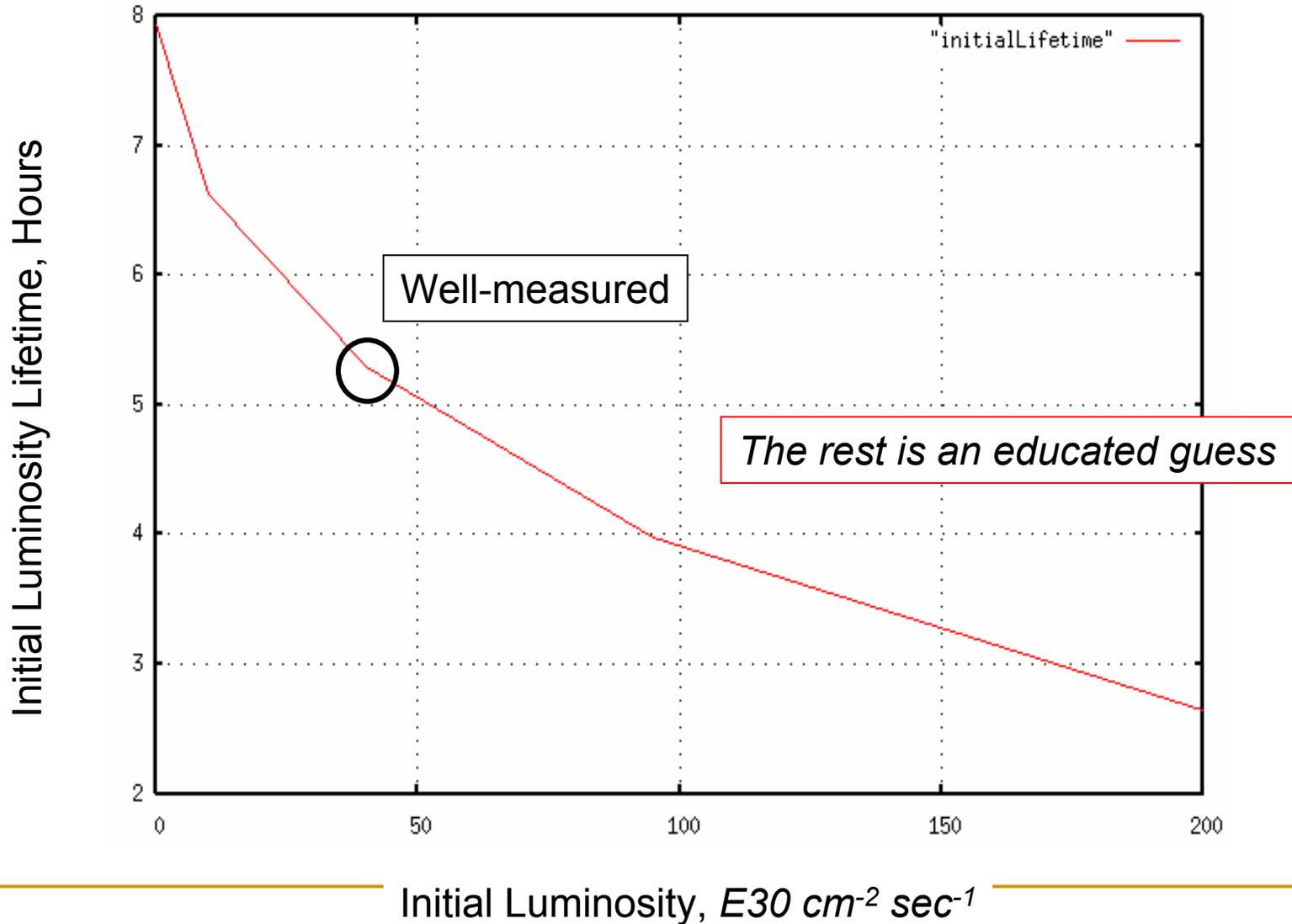
How does this work?

- Step size = 0.1 hours
 - *Diminish the luminosity*
 - *Stack*
 - *See if anything has failed*
 - *Stacking stops*
 - For a RandomLikely down time
 - *Stacking slows down*
 - For this step, by up to 50% (RandomLinear)
 - *Lose a store*
 - Plus a RandomLikely recovery time.
 - *Lose a stack*
 - Plus a RandomLikely recovery time.
- If stack or store is lost, will stack to a reasonable stack size and shoot
 - *Reasonable = 100 mA*
 - *If a stack is lost, we keep the store in for a long time!*
- Otherwise, when we reach the “Target Stack Size” we start shot setup.
 - *Shot setup time varies from 1.2 to 4 hours*
- Repeat for N weeks, dumping all sorts of relevant data.

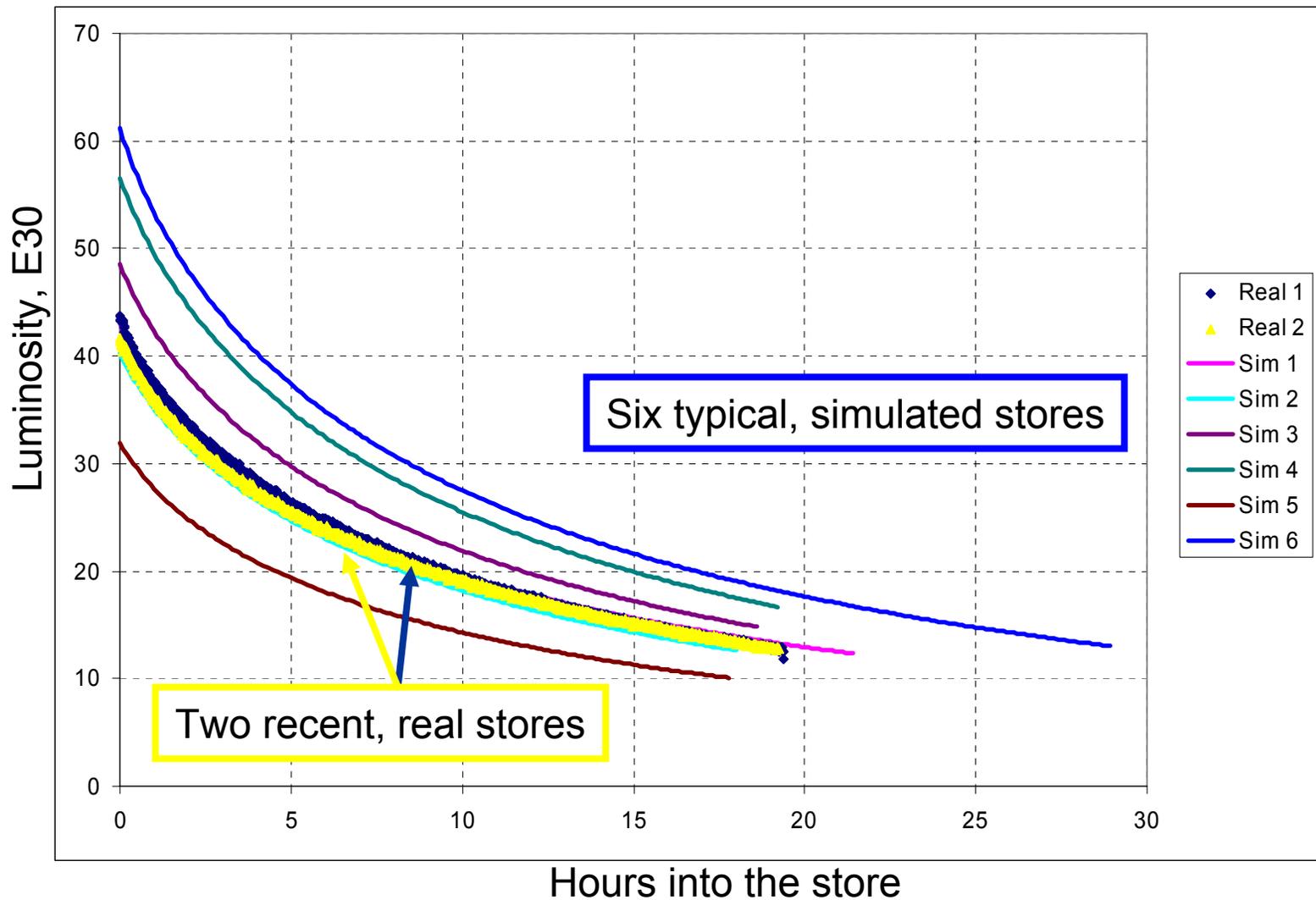
Stacking Rate in the Simulation



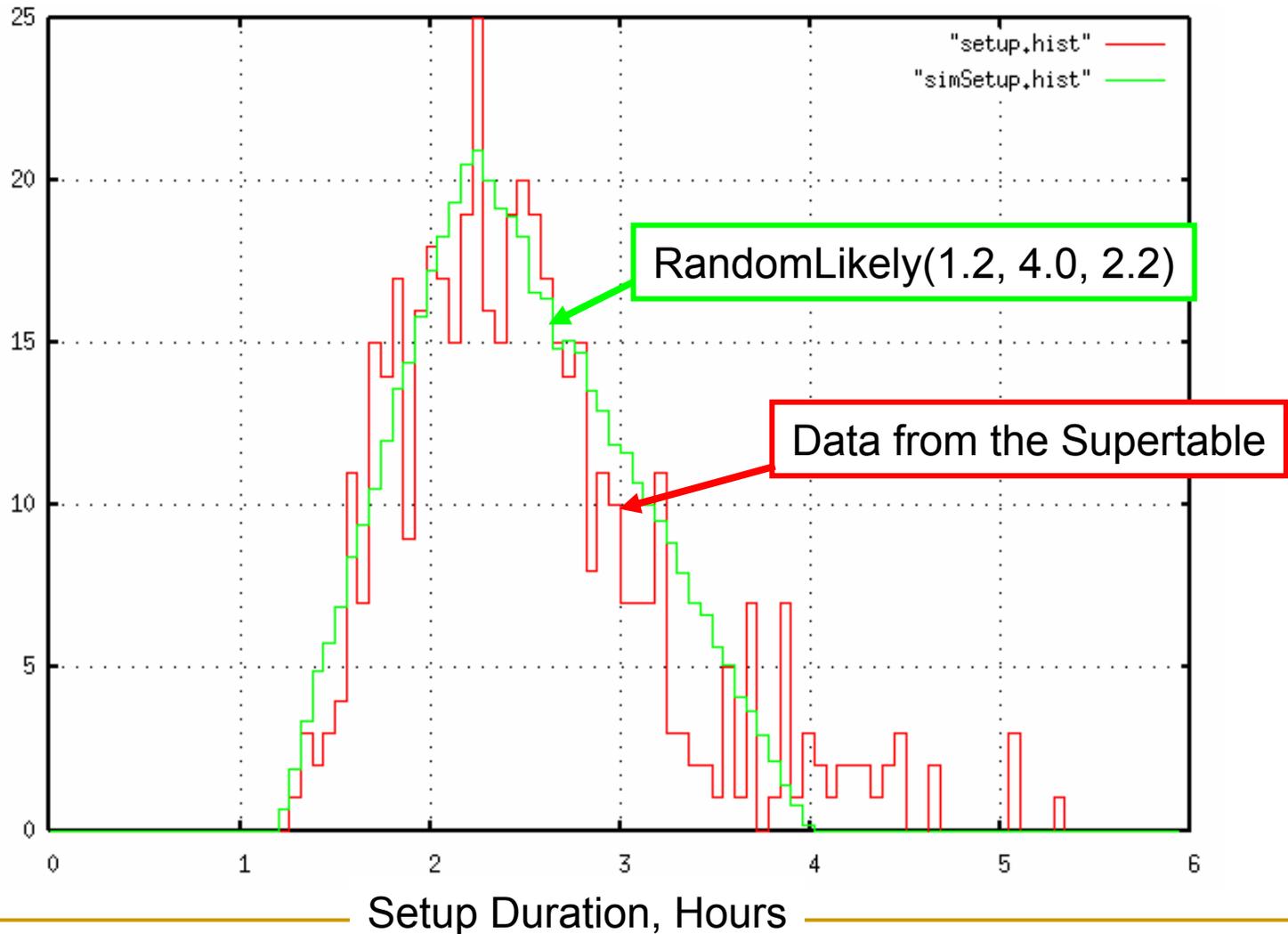
Initial Luminosity Lifetime Assumption



Lifetime: Real vs. Sim



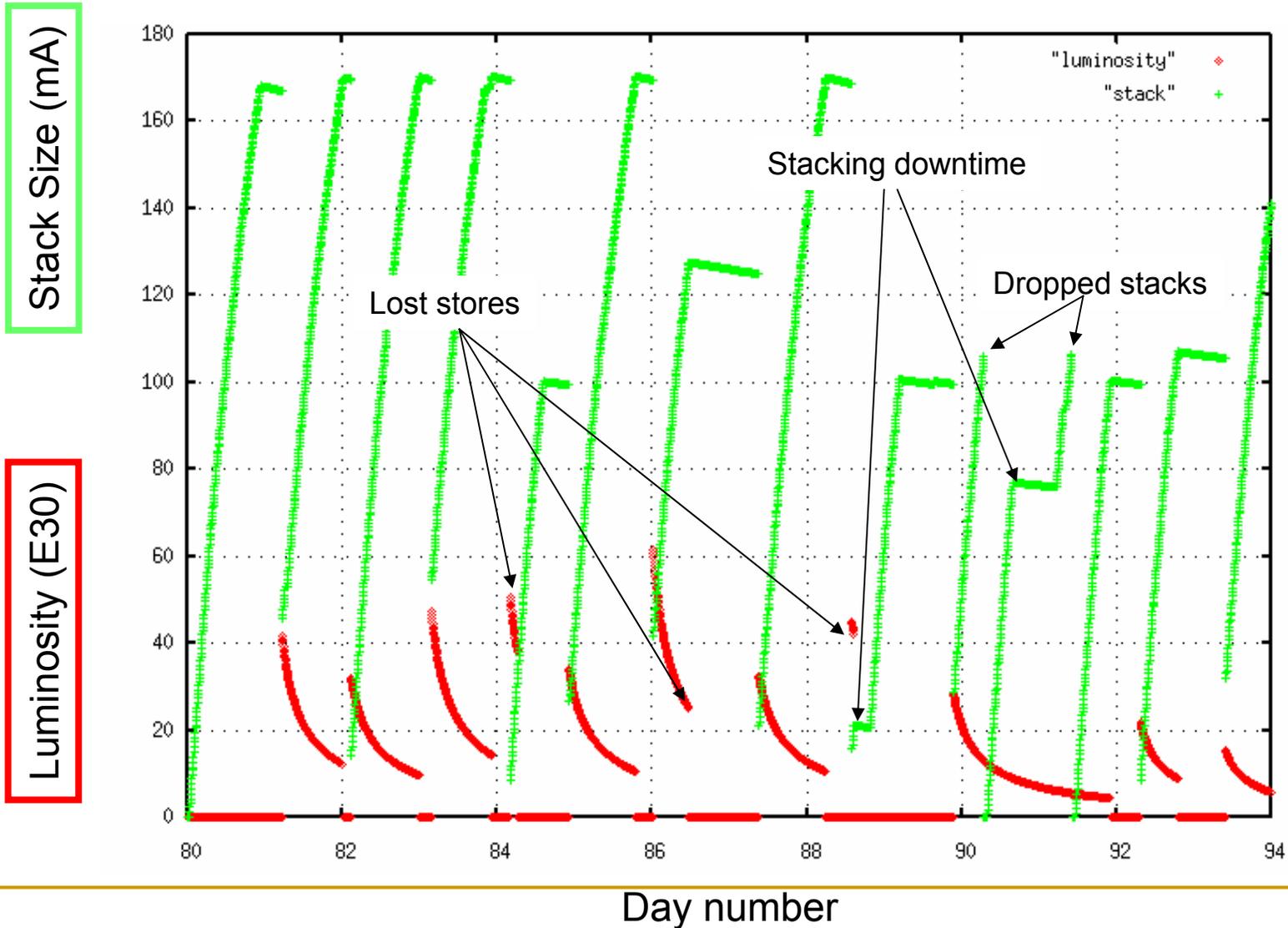
Shot Setup Duration, Real vs. Sim



What Can We Learn from this Model?

- Replicating typical performance, today
 - *Typical store data, typical weeks.*
- How should we end stores?
 - *When we have a choice.*
- Tevatron up-time
- Where do we integrate luminosity?
- The impact of future improvements

Typical 2-week period, Stacking to 170 mA



Typical Store Data

Store #	Stack Size	Initial Lum	Final Lum	Integrated Lum	Duration	Clock	Why?
6789	186.91	40.578	14.086	1318.19	16.2	1262.7	Intentional
6792	141.34	36.669	9.479	1332.17	21.4	1286.5	Intentional
6794	168.7	58.482	33.921	827.79	5.3	1300.2	Failure
6797	100.16	29.528	9.112	1032.7	18.7	1349.7	Intentional
6799	153.46	33.62	15.086	793.01	10.2	1366.8	Failure
6801	111.52	19.754	7.196	625.56	15.4	1415.7	Failure
6803	166.59	27.062	8.249	876.16	17.5	1442.1	Intentional
6805	169.58	38.654	34.464	104.82	0.8	1446.1	Failure
6806	99.18	18.965	6.236	576.33	15.6	1493.9	Intentional
6807	138.38	32.879	27.346	150.22	1.4	1501.5	Failure
6809	100.11	22.234	5.89	798.03	21.1	1542.2	Intentional
6812	164.15	42.239	25.991	512.99	4.4	1552.3	Failure
6815	165	53.977	15.453	1718.22	17.7	1589.8	Intentional
6816	150.76	23.946	7.236	780.89	17.7	1613.9	Intentional
6817	164.2	33.594	10.141	1148.03	18.8	1638	Intentional
6820	167.25	54.836	31.071	896.3	6.2	1649.2	Failure
6823	99.79	29.128	14.305	646.35	9.1	1685.5	Failure
6824	99.86	28.45	8.07	1011.5	20	1730.5	Intentional
6826	169.89	43.565	17.375	1060.54	11.3	1744.4	Failure
6829	215.37	42.929	12.854	1348.99	17.2	1791.5	Intentional
6830	153.06	46.881	15.343	1541.38	17	1815.6	Intentional
6833	153.88	33.597	25.292	249.48	2.4	1822.4	Failure
6835	99.76	24.706	17.054	247.13	3.4	1834.6	Failure

Typical Weeks

Week #	Integrate d Lum	TeV Store hours	Pbars stacked	Pbar stacking hours	Setup Hours	Num Setups	TeV Down Hours	Stacking Down Hours	Lost Stores	Lost Stacks
0	4222.201	65.6	728.153	101.2	36.8	5	27.12	3.4	2	0
1	8088.165	96.3	728.575	95.6	52	6	19.99	0.2	1	0
2	4946.258	79	704.611	92.4	39.2	6	47.32	0.3	3	0
3	7608.557	103.7	927.933	116.2	27.3	8	27.75	15.4	3	2
4	6170.989	87.2	856.513	121.2	39.6	7	37.02	0.6	4	0
5	7949.223	108.1	928.515	131.2	49.2	5	8.35	6.6	1	1
6	4663.606	69.7	616.147	79.1	38.7	6	30.24	1.5	3	0
7	6870.132	87.2	899.05	116.2	43.1	7	32.44	2.1	4	1
8	3356.024	66.6	624.699	82	50.2	6	27.13	4.4	3	0
9	6182.532	89.5	837.154	112	44.2	7	26.17	1.1	3	0
10	5814.4	76.8	775.204	108.5	27.5	6	49.3	0.9	3	0
11	3726.808	45.5	795.002	114.1	47.4	7	69.07	9	6	0
12	4618.187	79.7	744.56	92.9	45.6	6	29.61	7.3	5	0
13	4038.567	81.8	647.667	82.5	37.9	6	41.72	2.4	3	0
14	7302.312	78.4	930.969	129.8	44.4	7	33.79	0	3	0
15	7100.883	89.9	741.377	101.4	38.2	6	37.57	2.4	3	0
16	6602.829	85.8	819.159	117.3	41.9	6	39.76	3	3	0
17	4016.671	63	739.529	95.5	48.5	6	27.56	1.3	2	1
18	6094.109	70.1	762.499	111	43.6	6	34.67	2.1	4	0
19	6624.905	89.7	816.277	108.2	46.2	7	20.6	4.1	2	0
20	3637.59	44.6	807.115	106.3	52.3	6	58.39	0.5	5	0
21	6381.156	84.4	804.172	104.7	35	7	46.64	1.4	4	0

Algorithms for Ending a Store

1. When one of these crosses the target:
 - *Stack Size*
 - *Store Duration*
 - *Integrated luminosity of the store*
 - *Instantaneous luminosity falls too low.*
2. When 2 or more of these are satisfied
3. Compare “Expected Luminosity” vs. luminosity now
 - *Ratio*
 - *Difference*
4. “Figure of Merit”
 - *No good ...*

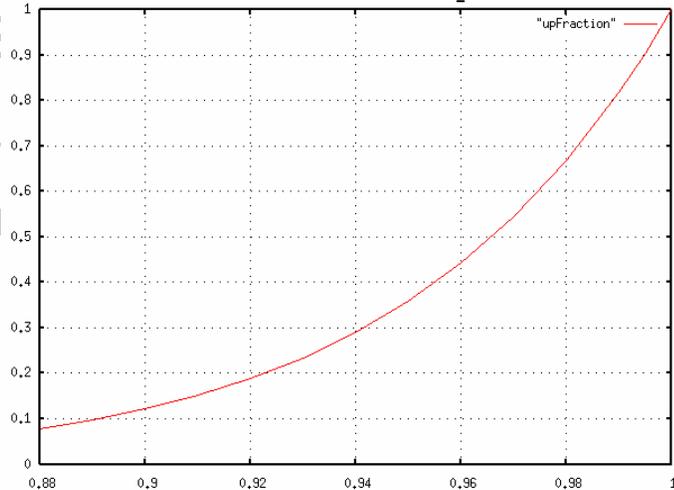
Explore the Search for the Best Target Stack Size

■ Tevatron up time varies

- *94% per hour to 99% per hour*

- *E.g., the probability a stack is up*

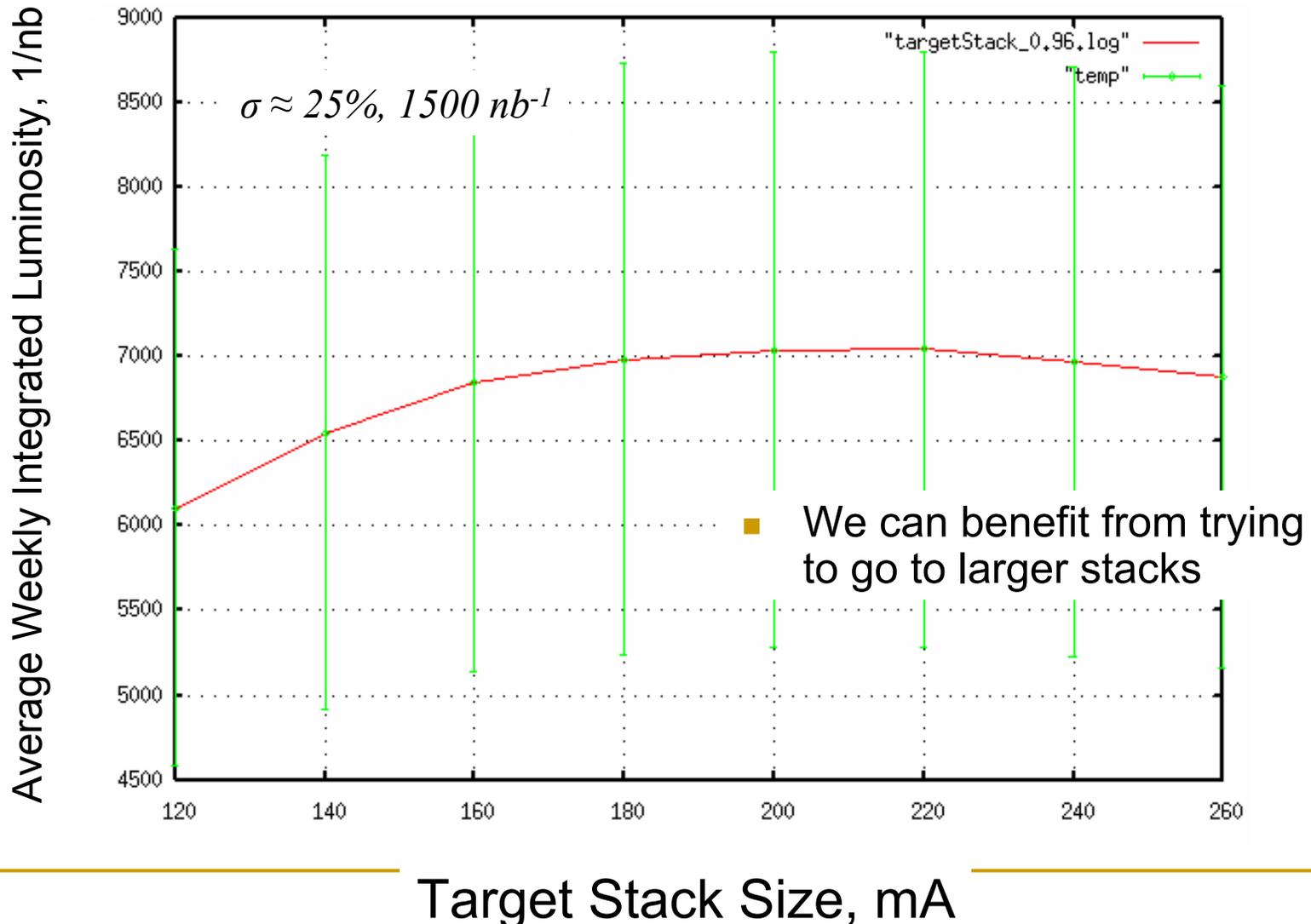
- $(0.94)^{20} = 0.290$
- $(0.96)^{20} = 0.442$
- $(0.99)^{20} = 0.818$



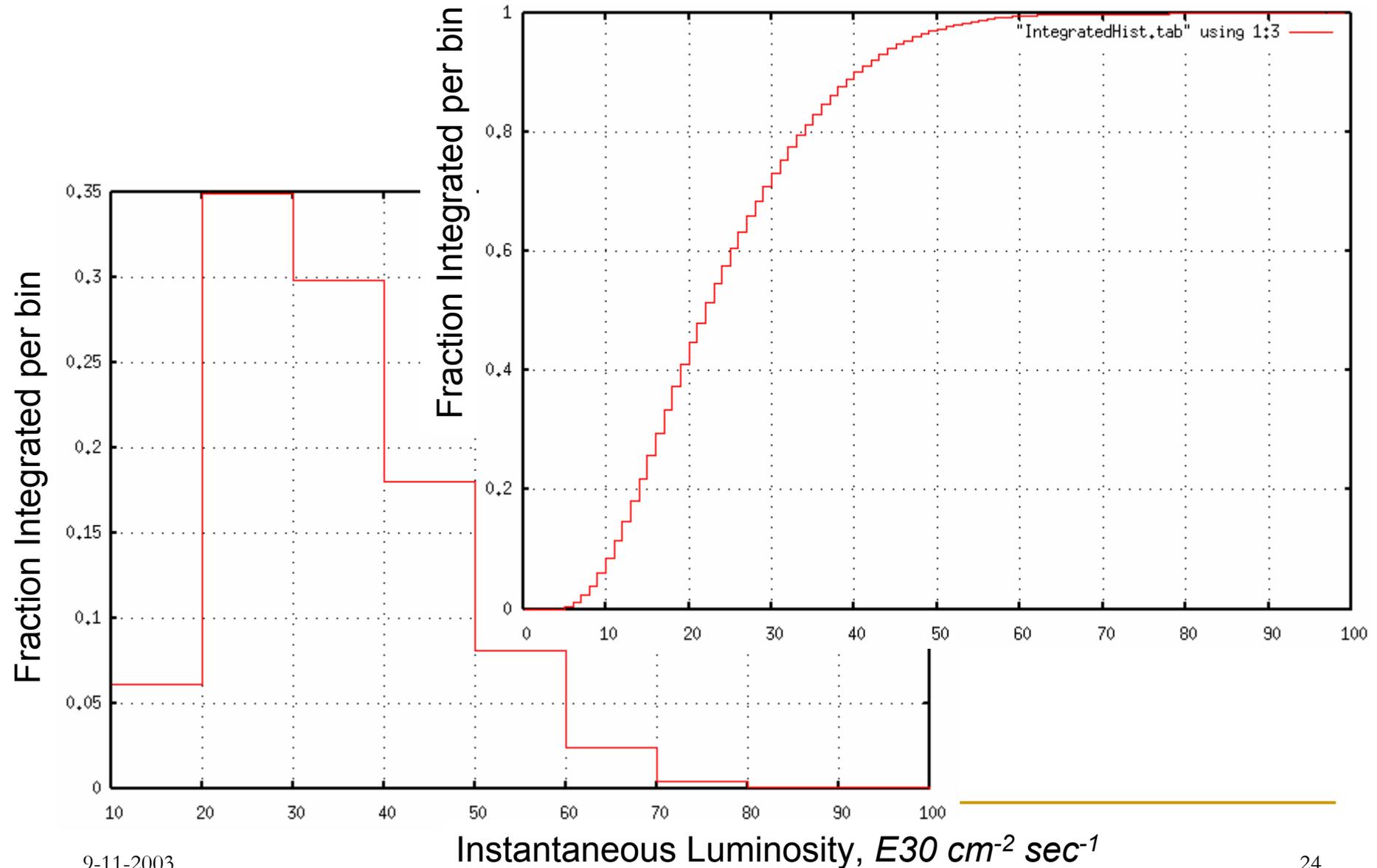
■ Charts and tables ...

- *Optimization, downtime, Run Coordinator tables and charts, etc.*

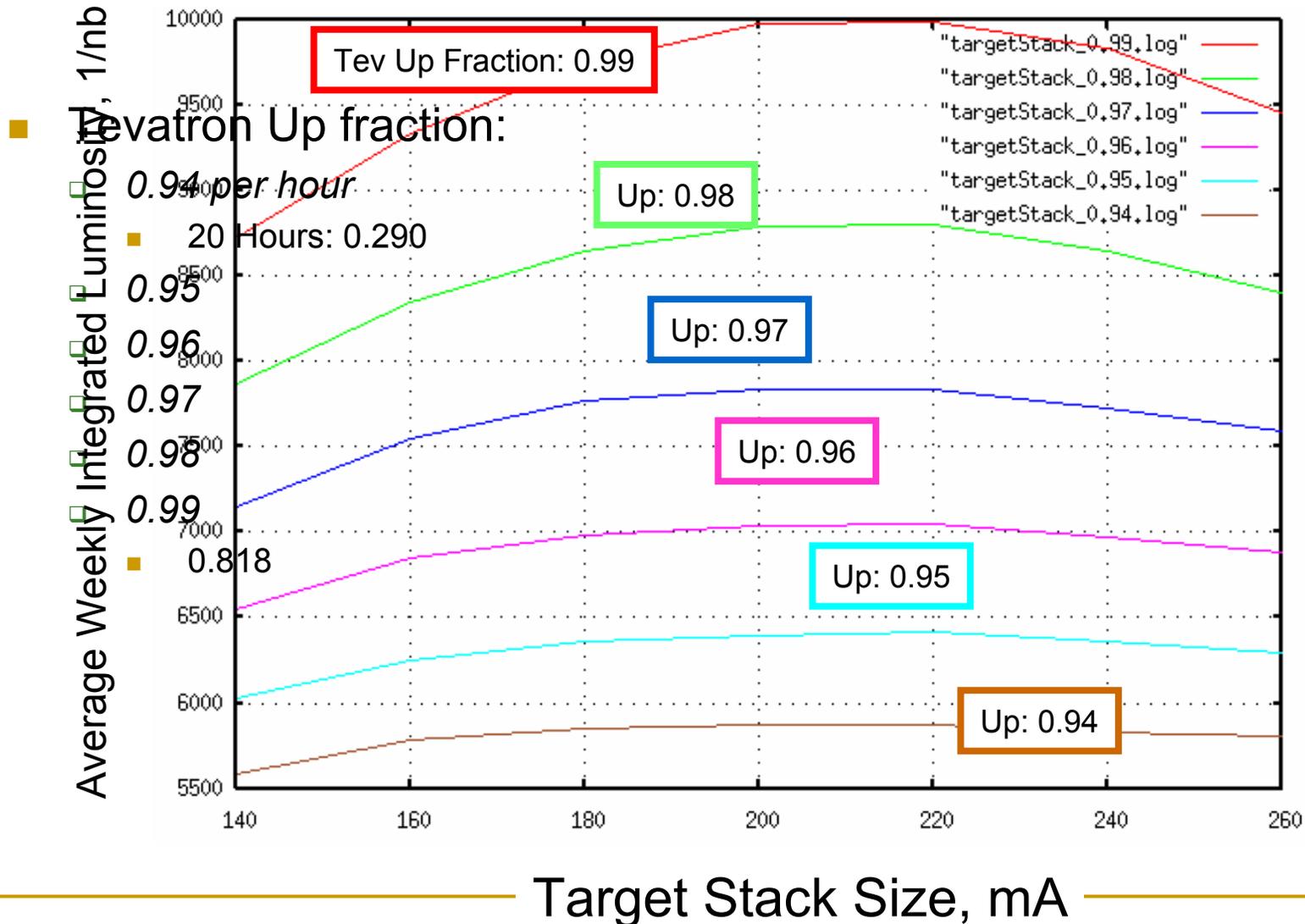
Run eight simulations of a 5000-week period, each with a different value for the Target Stack Size



Where do we Integrate Luminosity?

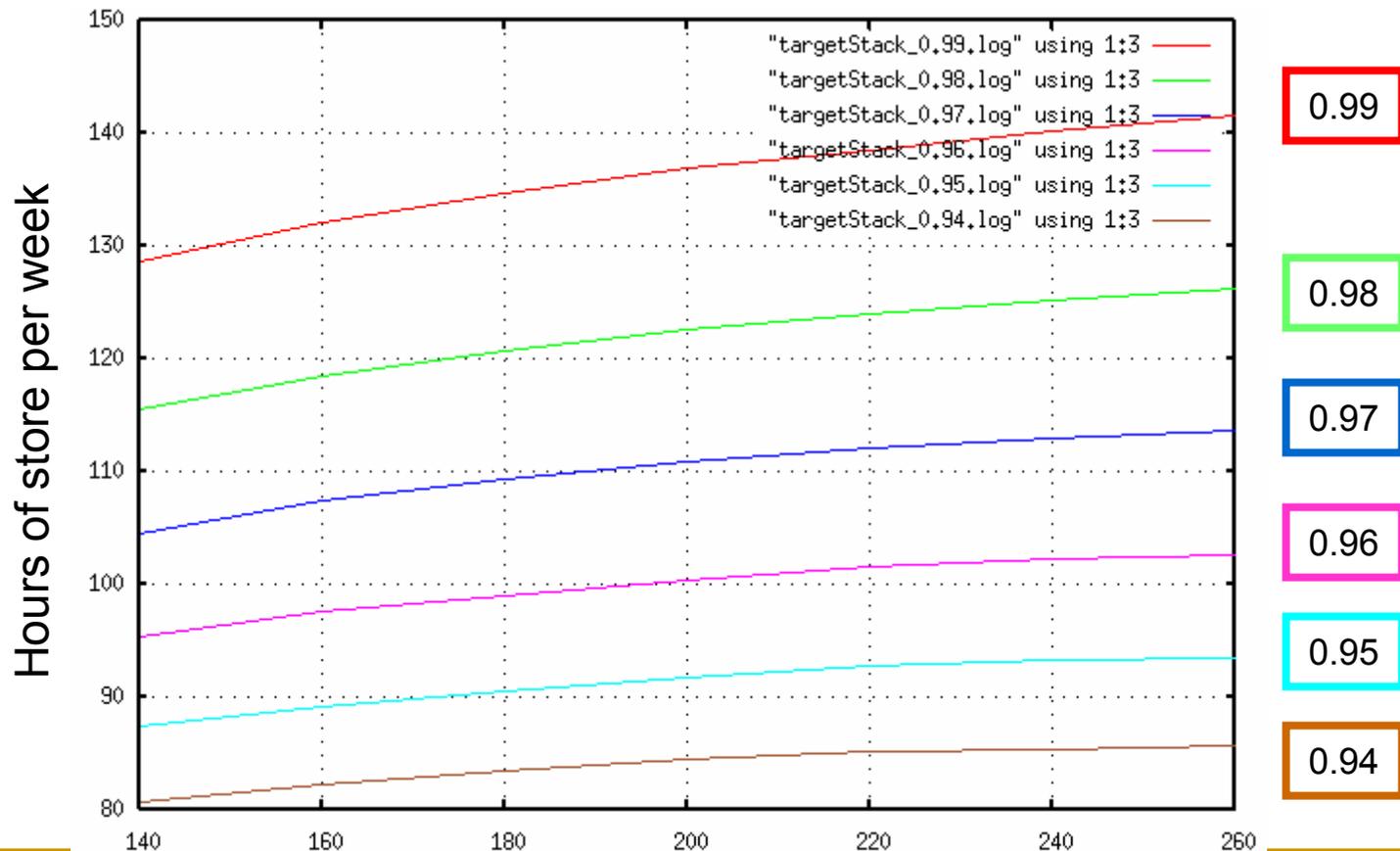


Run for 5000 Weeks, using “Target Stack Size”



Tevatron up-time per week vs. Target Stack Size

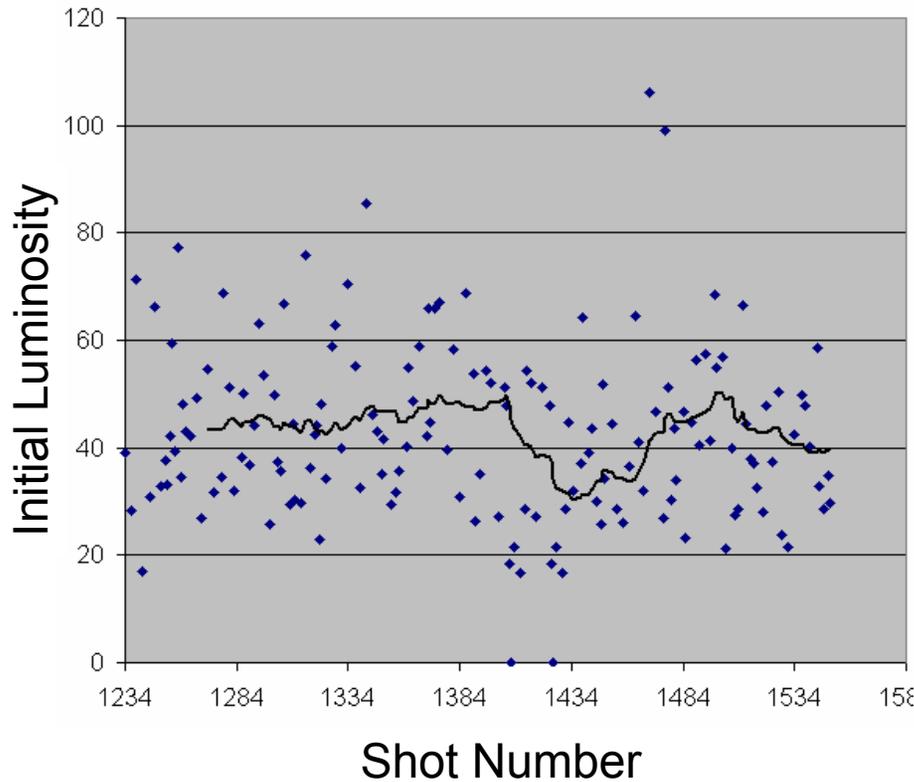
- Recovery time after lost store: RandomLikely(1, 24, 10)



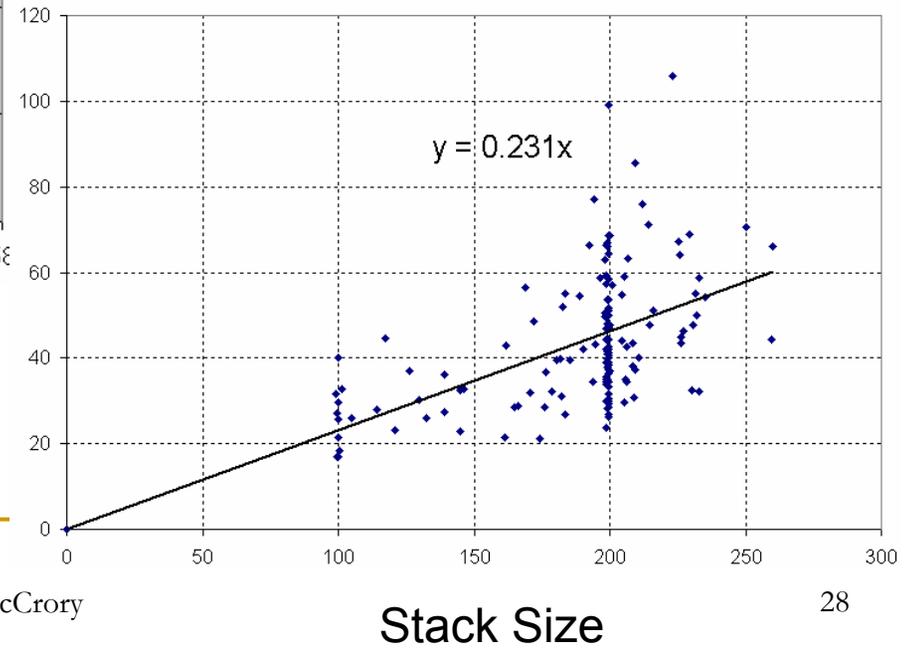
Fraction of Stores Lost vs. Target Stack Size



Run Coordinator Charts

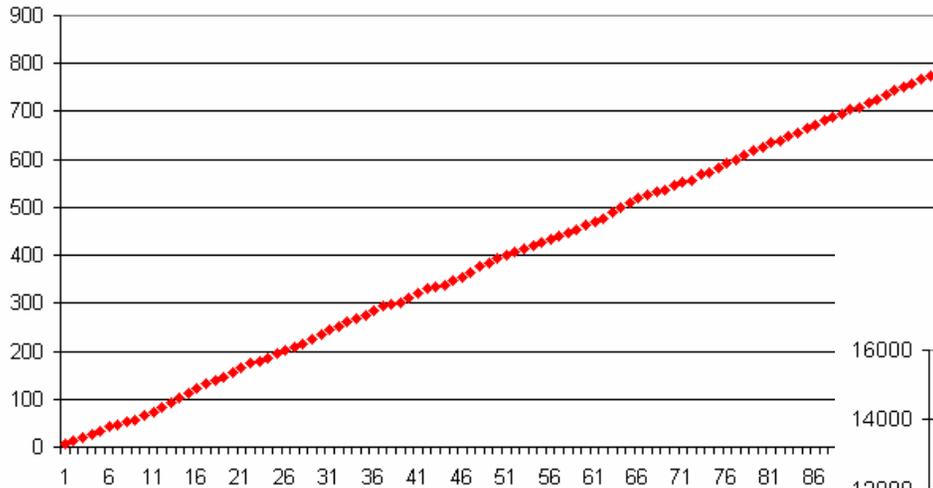


◆ Init Lum
— 20 per. Mov. Avg. (Init Lum)

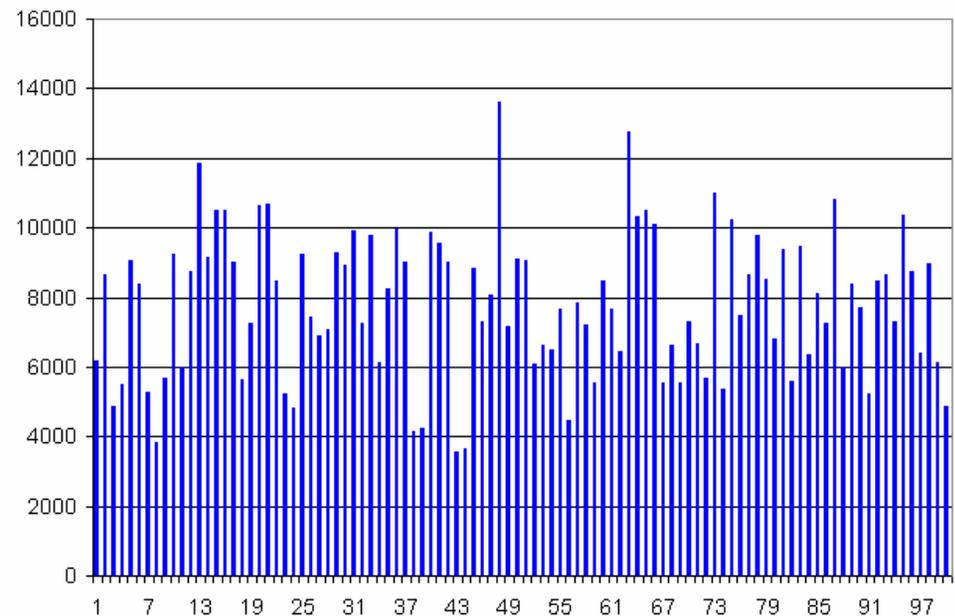


More Run Coordinator Charts

Run Integrated luminosity



Integ Luminosity per week

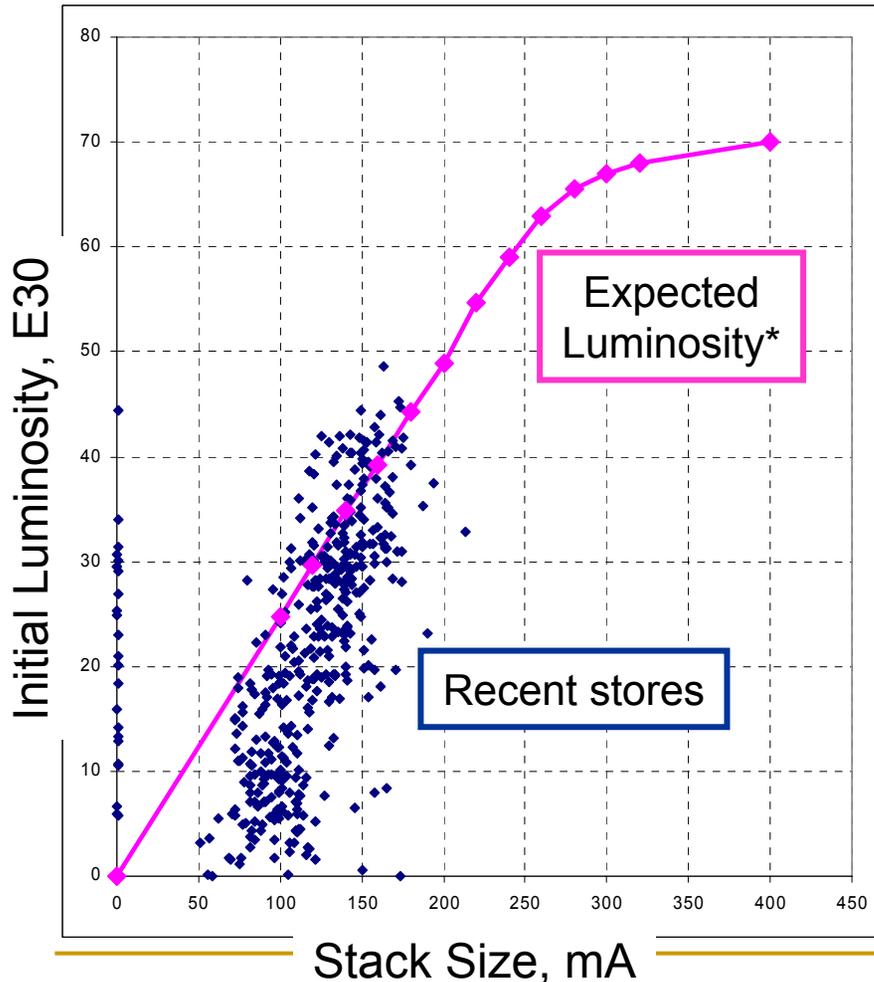


Remember: No shutdowns!

More Esoteric Stuff

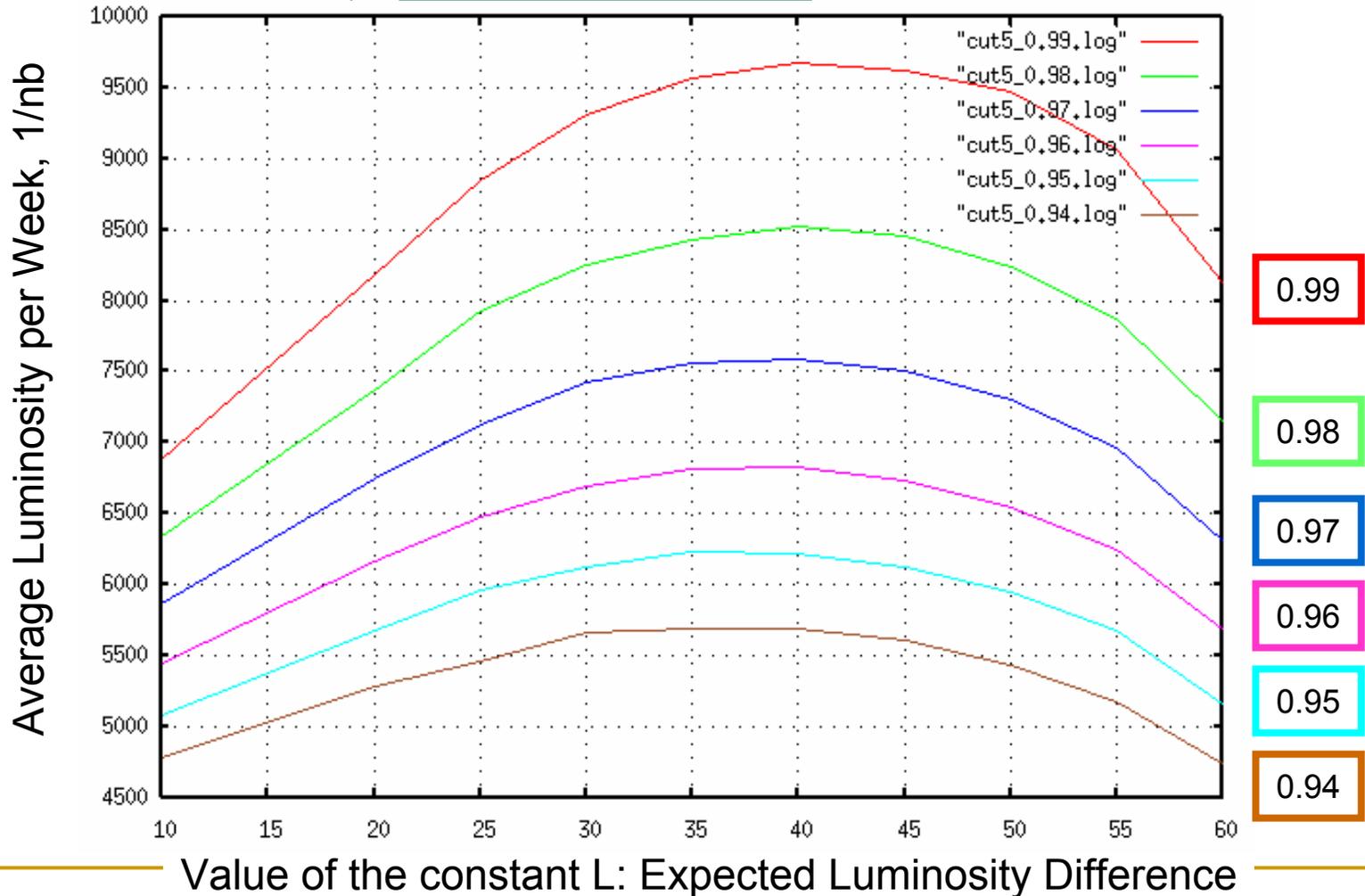
- Different end-of-store algorithms
 - *“Luminosity Potential”*
- Startup after a dropped store
 - *“Reasonable Stack” vs. Target Stack*
 - *“Reasonable Stack” in the context of “Luminosity Potential”*
- Better stacking

Luminosity Difference or Ratio Algorithm

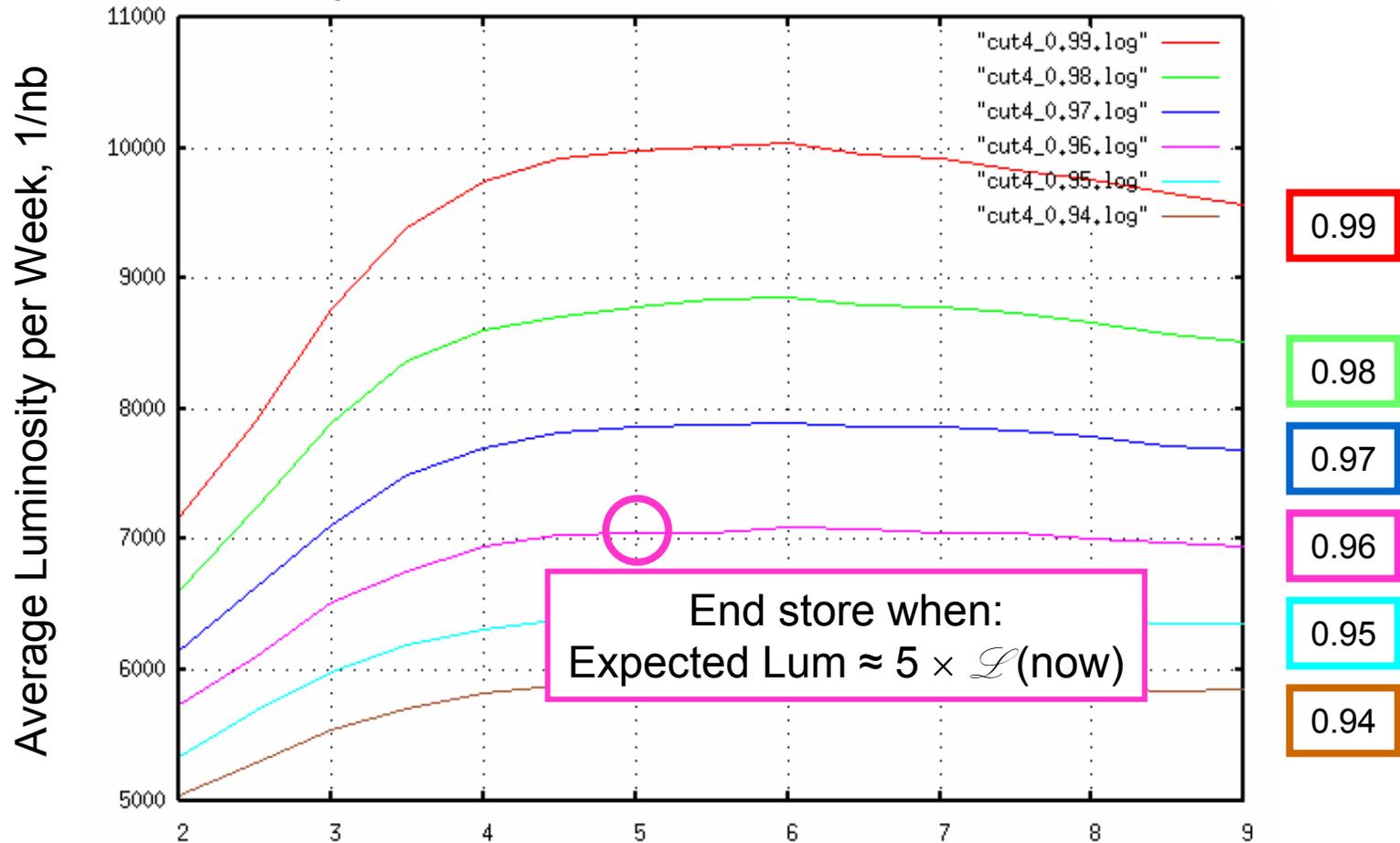


- Use chart, here.
- Two different ways to end stores:
 - When the ratio between the expected luminosity and the current luminosity exceed some constant, V .
 - When the difference exceeds constant, L .
- * Generated by the model; error bars (σ) $\approx 20\%$

Using Algorithm to End Stores on the Luminosity Difference

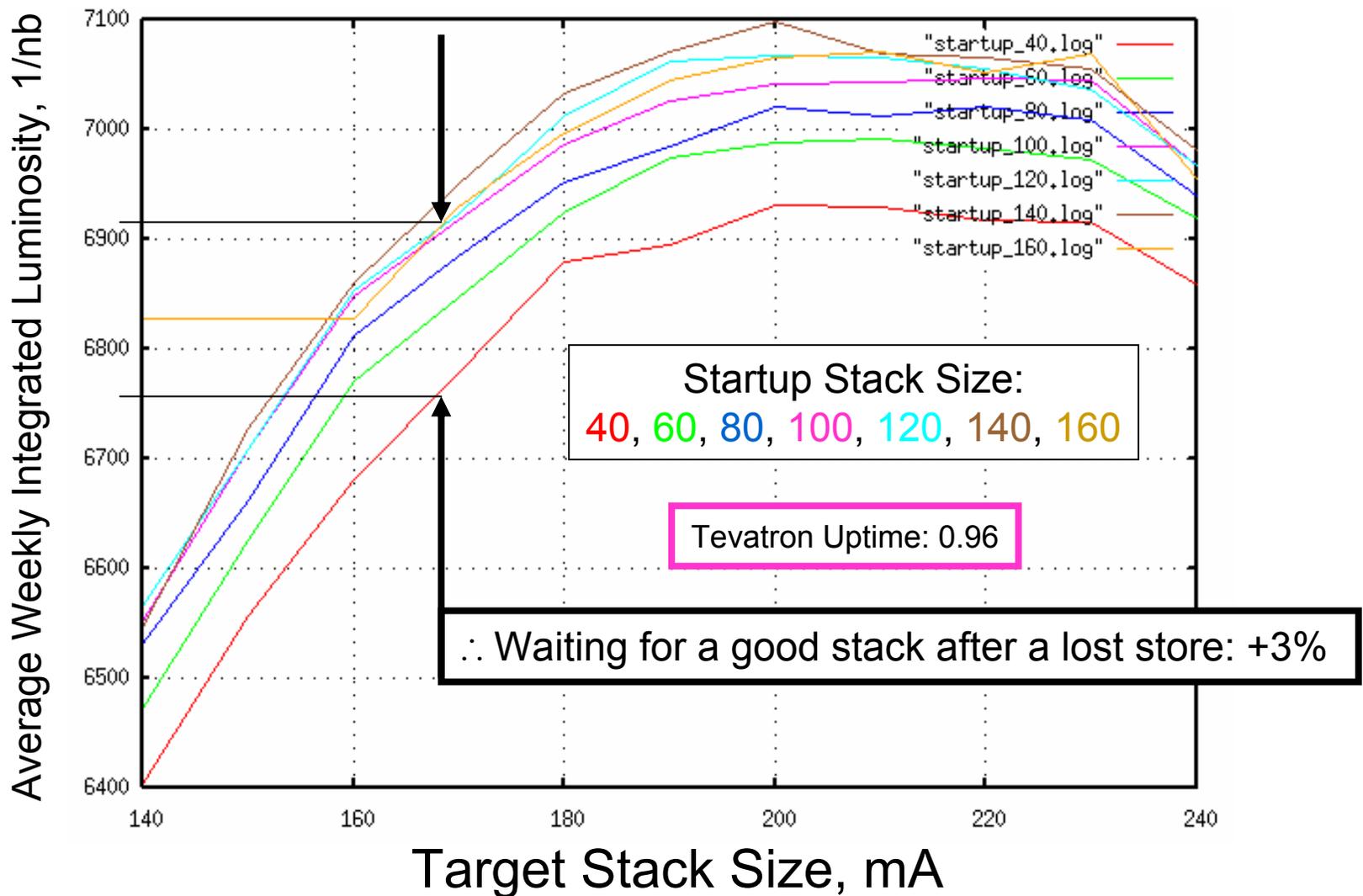


Using Algorithm to End Stores on the Luminosity Ratio

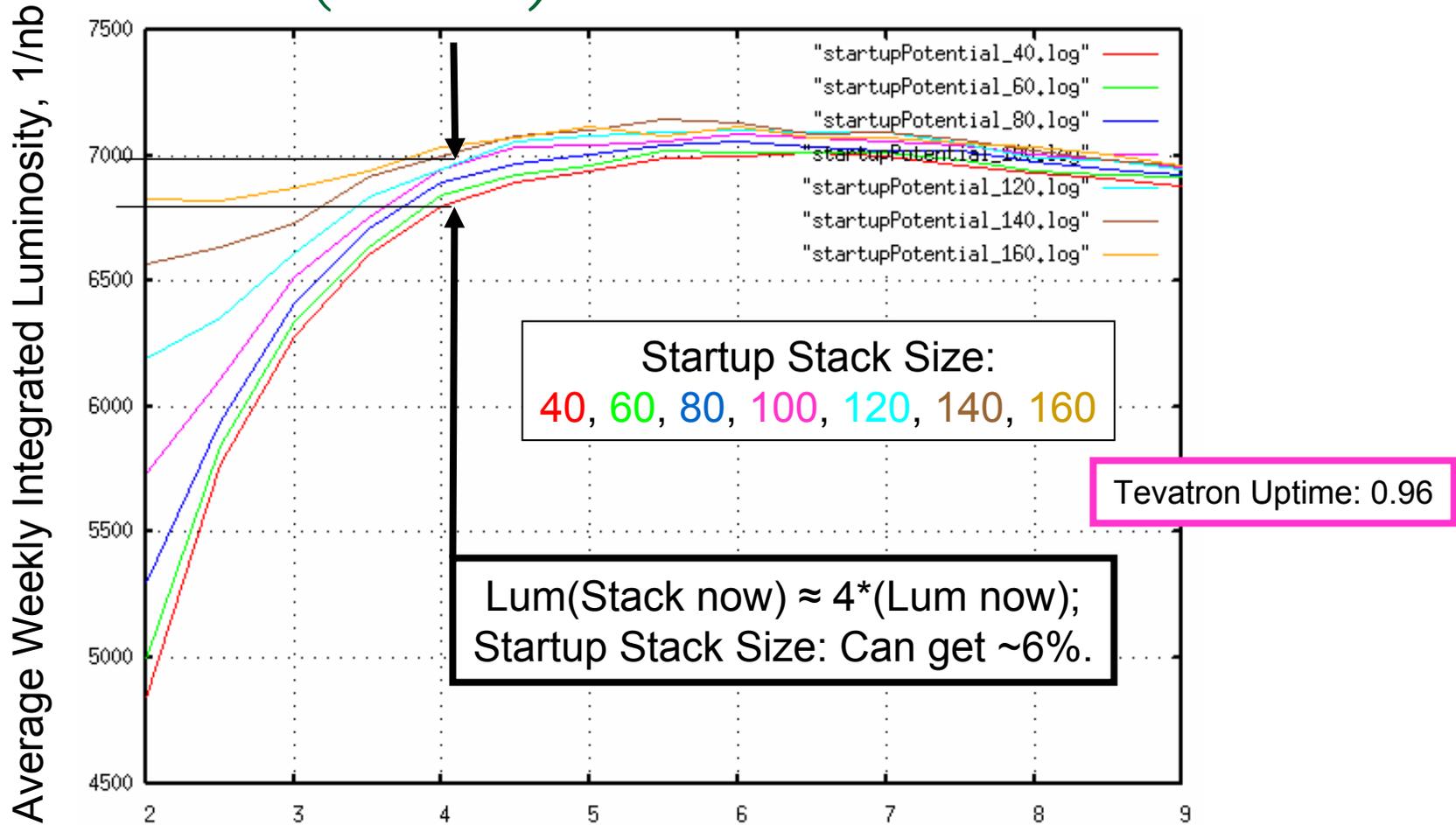


Value of the constant V: Expected Luminosity Ratio

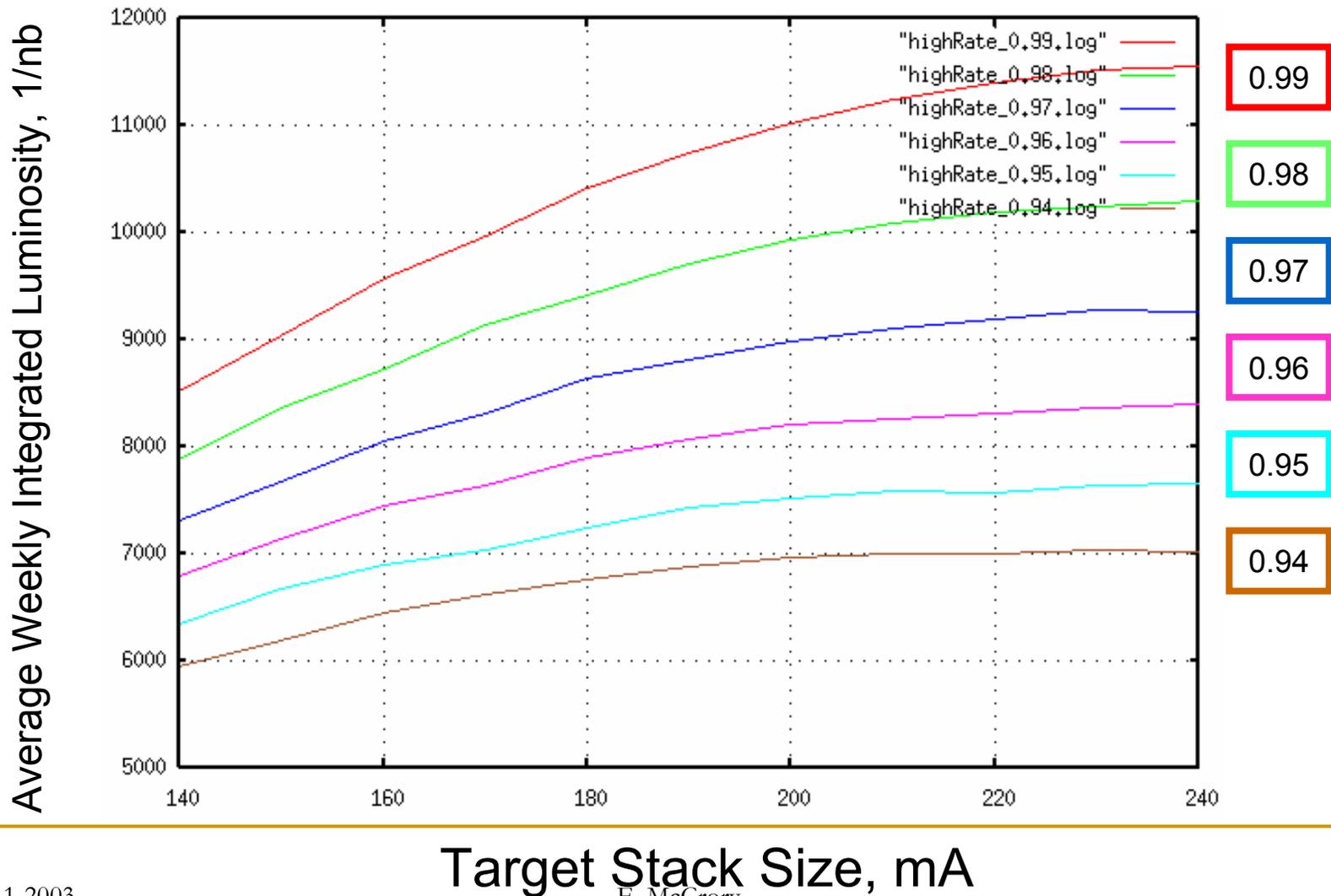
Reasonable Startup Stack Size?



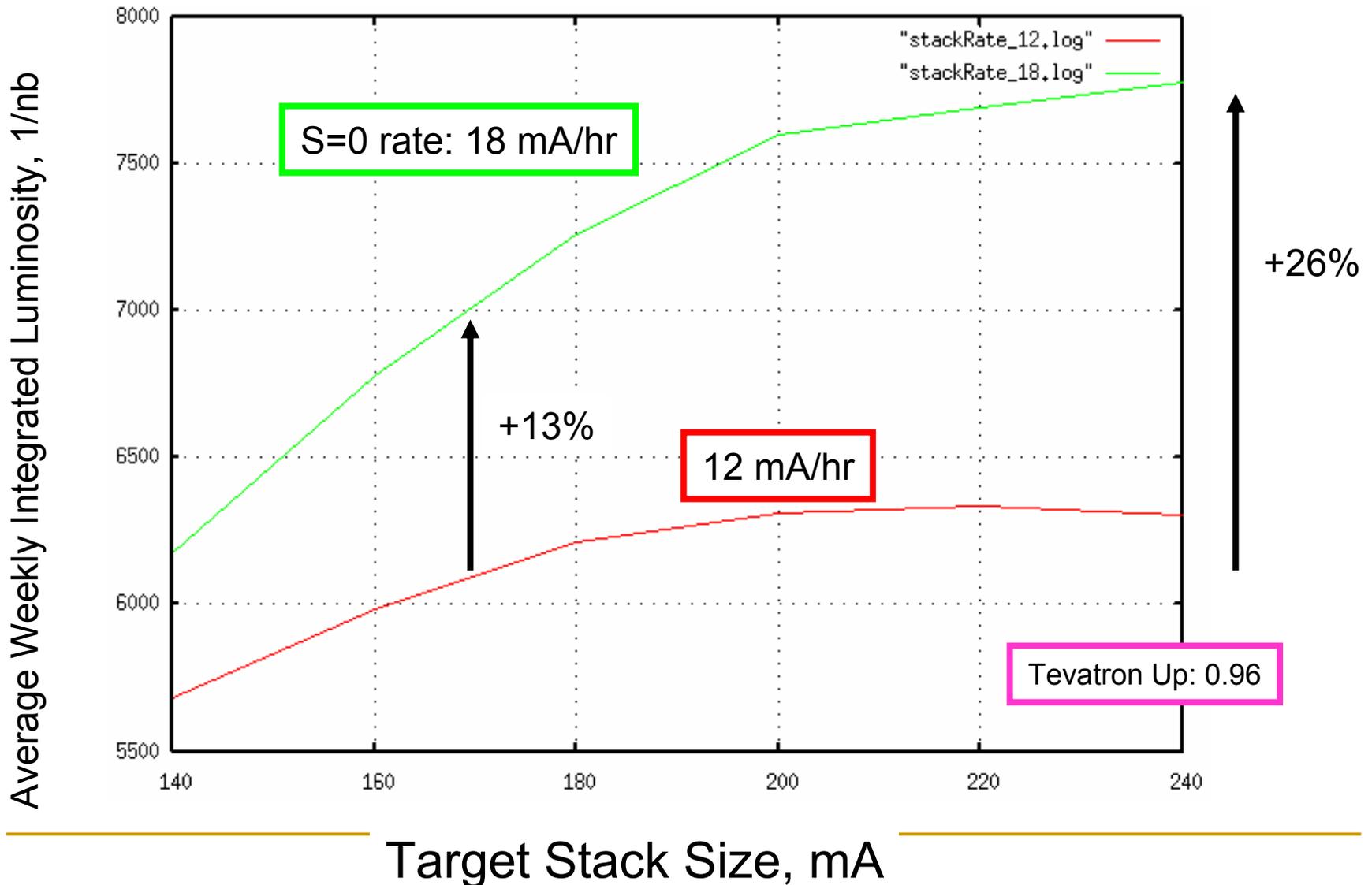
Startup Stack Size and Luminosity Potential (Ratio)



Zero Stack Stacking rate: 18 mA/hr



Compare Different Stacking Rates



Web Interface

- <http://mccrory.fnal.gov/testForm.html>
- Will do one run of N weeks with one set of parameters.
- Probably not fully debugged, yet.

```
mccrory@mccrory:~/collider/simlum
[mccrory@mccrory simlum]$ ./simulate_week -n 17 -T 180 -y 10000 -M 72 -s 100 -z 5,0 -U 0,96 -H
Week_#  Integ_Lum      Store_hrs  Pbars_stacked  stack_hrs  setup_hrs  Setups  Tev_dntime  Pbar_dntime  #drop_stores  #lost_stacks
0      5472,564         81,9      822,769 116,3   18,7   5      27,12   3,00   2      0
1      6657,868         103,6    807,376 119,0   24,6   6      29,00   1,60   2      0
2      5994,598         91,2      890,016 131,9   26,8   7      34,94   0,40   3      0
3      7789,373         121,1    863,483 139,6   17,4   3      8,17    12,30  1      2
4      6394,018         73,4      779,812 129,9   25,6   6      47,34   6,00   5      0
5      6756,364         102,9    898,169 137,8   21,9   6      27,12   6,90   4      1
6      5437,945         78,2      653,814 89,5    24,8   5      41,35   3,90   4      0
7      9272,702         123,2    917,109 126,3   19,3   6      28,87   5,90   4      1
8      6597,741         86,3      816,010 115,8   21,5   5      25,10   0,30   3      1
9      6774,054         93,9      898,532 135,0   19,8   6      48,38   5,50   4      0
10     9704,679         114,0    846,383 122,1   18,4   6      21,82   0,90   1      0
11     5130,057         66,4      882,614 123,9   20,8   7      70,55   1,00   6      0
12     5327,694         78,4      861,512 120,8   20,3   7      47,39   3,20   6      0
13     7806,646         115,1    835,470 113,6   13,2   6      36,90   6,40   3      0
14     6957,667         94,9      847,495 138,7   21,4   5      26,98   1,20   2      0
15     8355,011         83,4      811,496 115,5   22,8   6      42,46   1,50   4      0
16     7265,030         118,3    931,497 142,5   15,2   6      37,94   3,90   3      0
Downtime: stacking = 94,1466 (Total stacking time = 2834)
          Tevatron = 601,459
98 total stores, 57 Stores lost
5 Stacks lost
[mccrory@mccrory simlum]$ █
```

What's Next?

- Use Valary Lebedev's analytical model of the luminosity
 - *To represent more accurately the luminosity lifetime of very large stores.*
- Internal improvements
 - *Exactly match all real numbers*
 - *Especially in the transmission of PBars to low beta.*
- Incorporate Recycler
 - *Study various operational transfer scenarios*