RHIC/AGS Annual Users Meeting

June 9-12, 2015

Run 15 Report

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U.S. DEPARTMENT OF ENERGY | Office of Science

Beam use request & physics program

STAR detector & upgrades

Run 15 operation & data set

Outlook

Beam Use Request for Run 15

Based on 22 cryo weeks for in 2015 → 17 weeks for physics

System	Energy	Duration	Polarization	Priority	Sequence
$p+Au$	$\sqrt{s_{NN}} = 200$ GeV	5 weeks	Transverse	①	❸
$p+p$	$\sqrt{s} = 200$ GeV	6 weeks	Transverse	②	❷
		6 weeks	Longitudinal	②	❶

❶ double longitudinally polarized $p+p$ collisions, $\mathcal{L} = 50\ \mathrm{pb}^{-1}, P = 60\%$

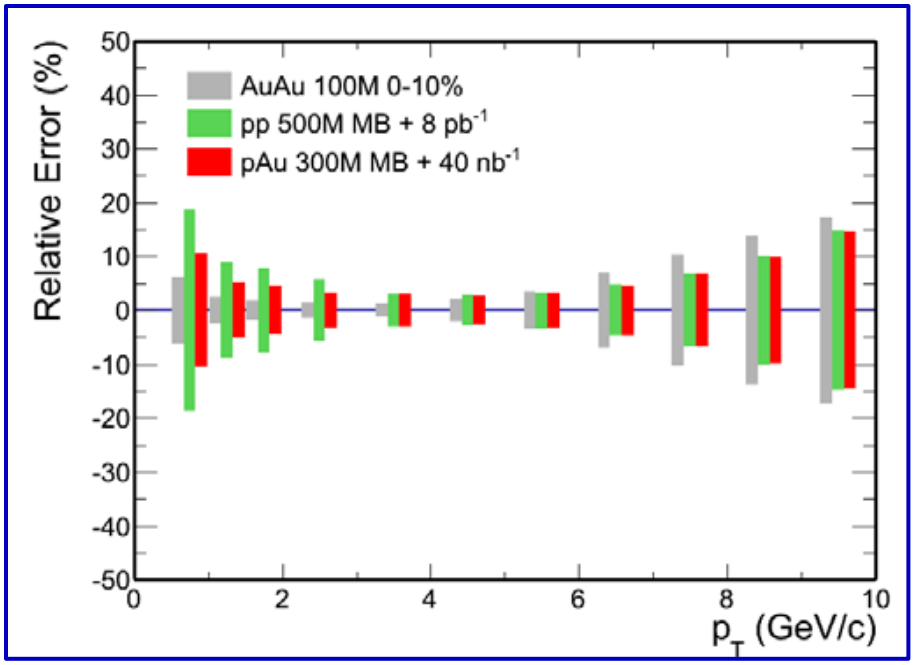
❷ single transversely polarized $p+p$ collisions, $\mathcal{L} = 40\ \mathrm{pb}^{-1}, P = 60\%$

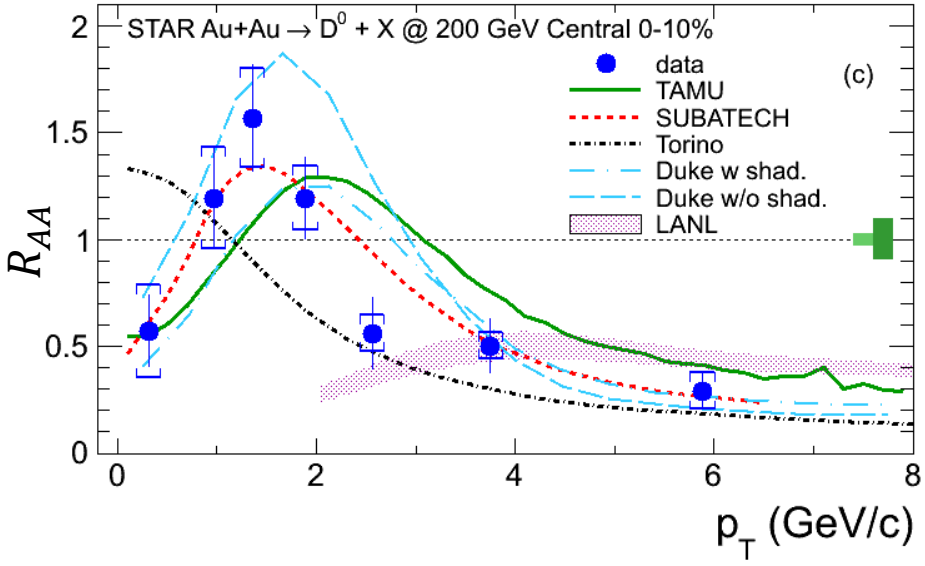
❸ single transversely polarized $p+Au$ collisions, $\mathcal{L} = 300\ \mathrm{nb}^{-1}, P = 60\%$

❶❷❸ also unpolarized for $Au+Au$ reference

1 Hot & Dense Medium Effects

- Precision measurement: R_{AA}
- D^0 mesons with tight z-vertex
  - $|z_{vtx}| < 5$ cm
- Heavy Flavor Tracker
  - Commissioned in Run 14



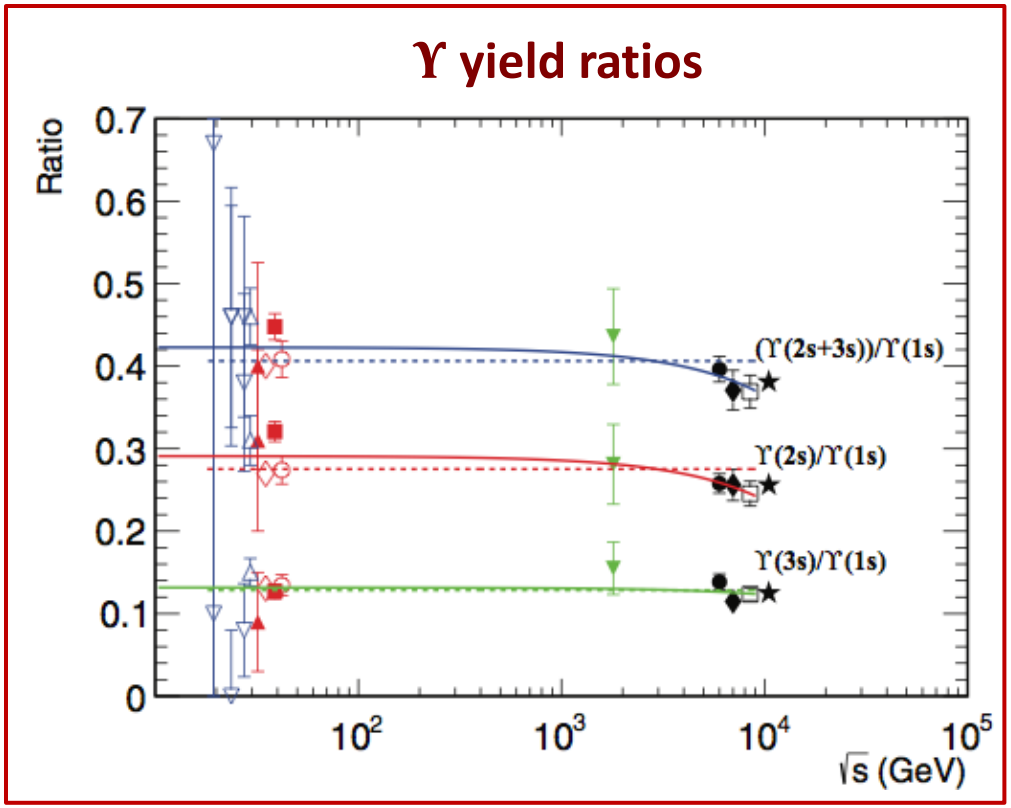


Run 15:

- $p + p$ reference $\sqrt{s} = 200$ GeV
- Combination of
  - minimum bias low-p_T
  - triggered high-p_T

1 Heavy Quarkonia

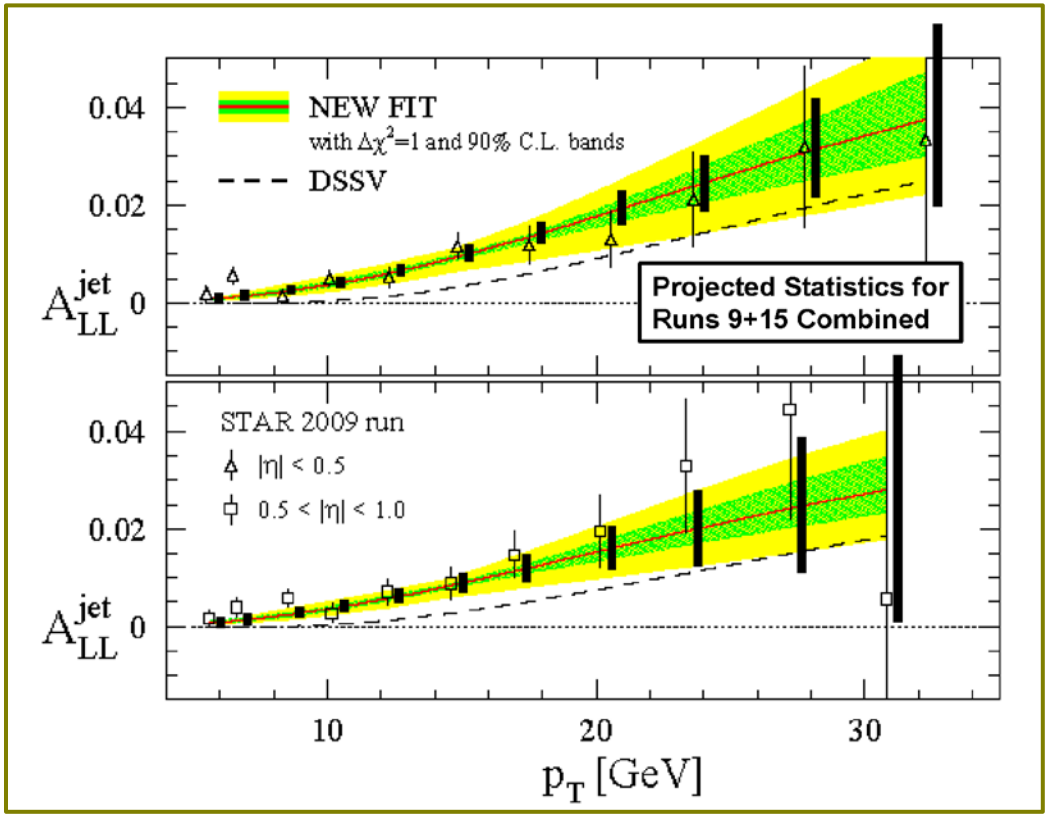
- In-medium dissociation in thermal QCD system
  - Evidence of color screening and free quarks in medium
- Ratio of different $\Upsilon(1s)/\Upsilon(2s)/\Upsilon(3s)$-states: $\Upsilon \to \mu^+ + \mu^-$

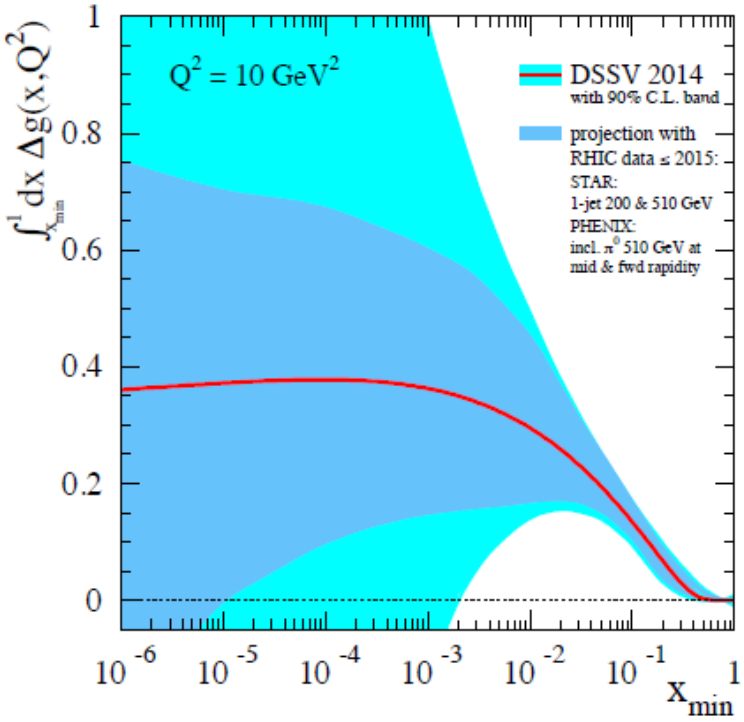


- Compare suppression $Au + Au, p + Au, p + p$ of J/ψ
- Muon Telescope Detector
  - Commissioned in Run 14

1 Gluon Polarization in the Proton

- With recent RHIC data: $\int_{0.05}^{1} \Delta g(x)dx = 0.2^{+0.06}_{-0.07}$
- Improve statistics at high-p_T for jet measurements
  - Low-p_T systematics limited

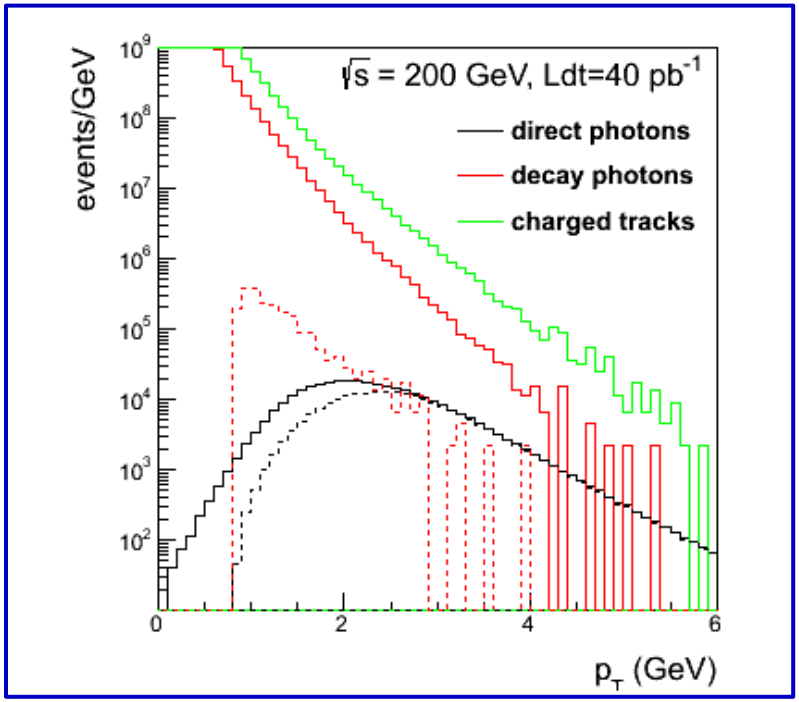


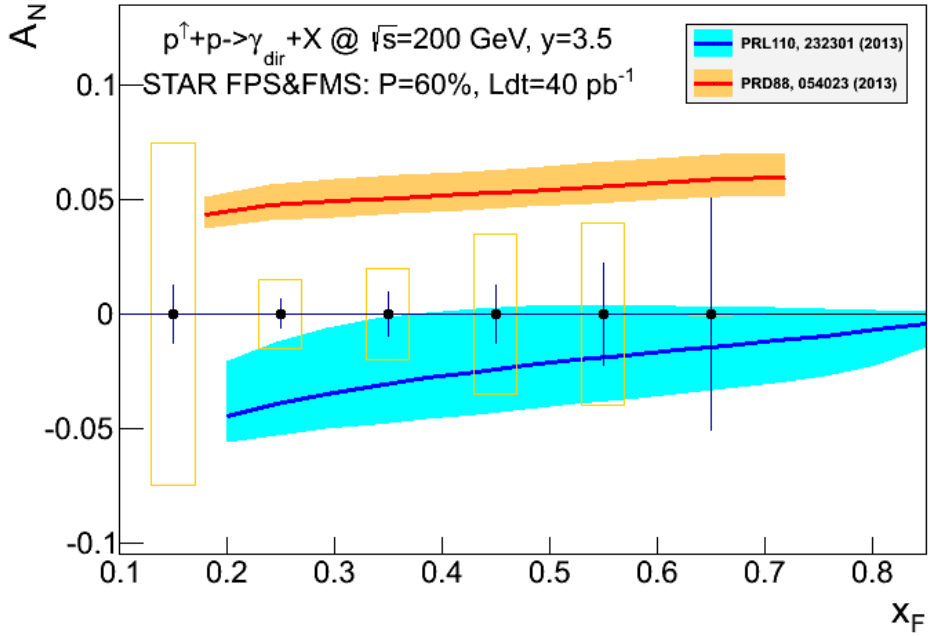


RHIC Spin white paper arxiv:1501.01220

2 Universality in QCD

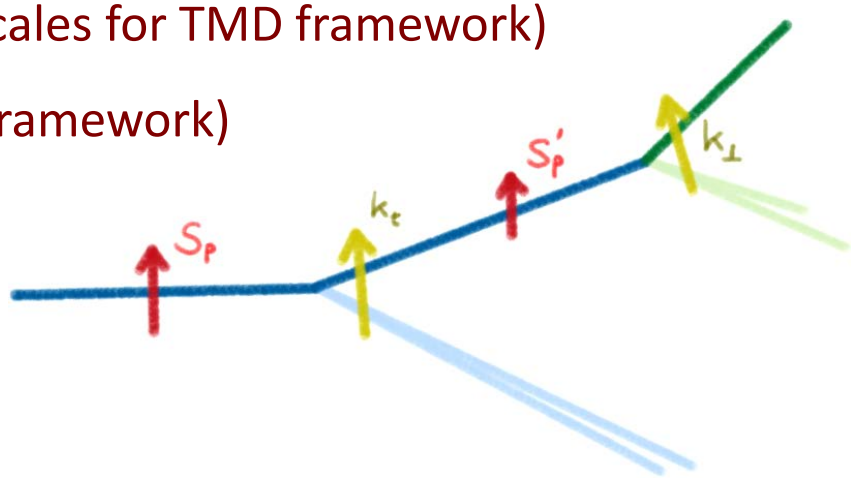
- Process dependence of spin-orbit correlations in nucleons
  - Sign-change in TMD *Sivers* function: SIDIS vs. Drell-Yan
  - Equivalent description in twist-3: $gT_{q,F}(x,x) = \int d^2k_\perp \frac{|k_\perp|^2}{M} f_{1T}^{\perp q}(x,k_\perp^2)$
  - $q + g \to q + \gamma$ at forward rapidities ($3 \lesssim \eta \lesssim 4$)

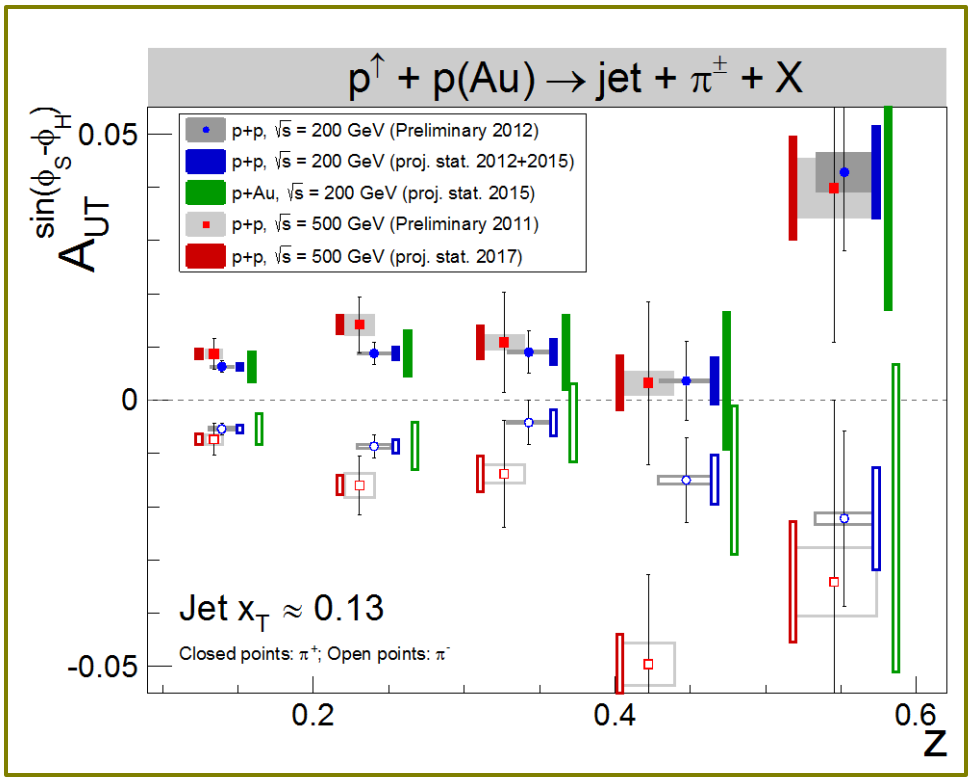


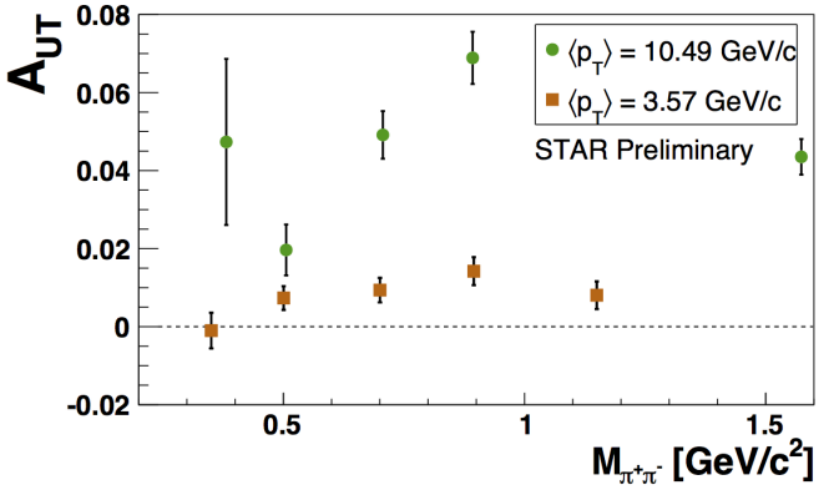


2 Spin Dependent Fragmentation

- Use spin dependent fragmentation as analyzer for transversity
  - $\pi^{\pm}$-jet correlations (provides two scales for TMD framework)
  - dihadron fragmentation (collinear framework)

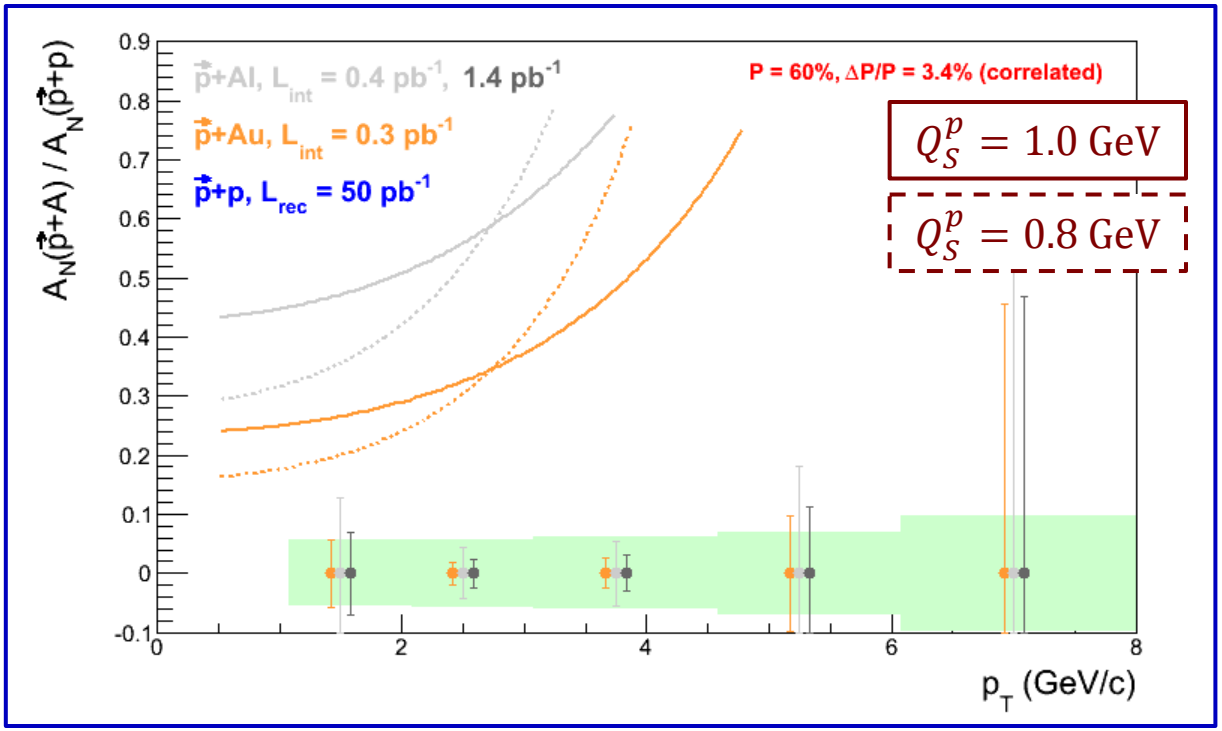


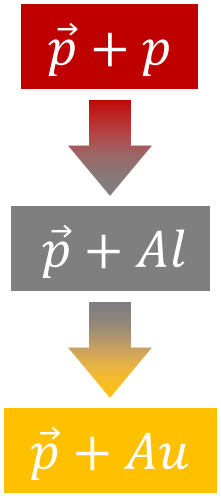




3 Saturation in Cold Nuclear Matter

- Gluon saturation signature in transverse single spin asymmetries A_N
  - Color Glass Condensate calculations Phys. Rev. D84, 034019 (2011)
    → A_N suppression depends on saturation scale Q_S^p
  - Saturation is enhanced in nuclei: $Q_S^A = A^{1/3} \cdot Q_S^p$

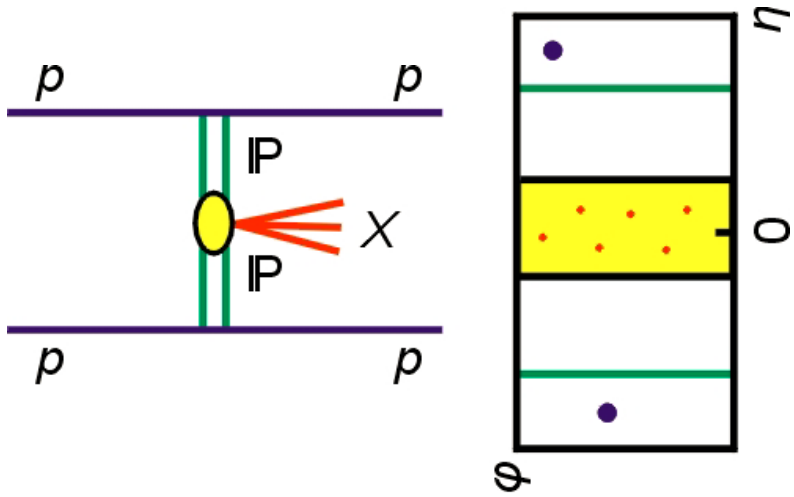


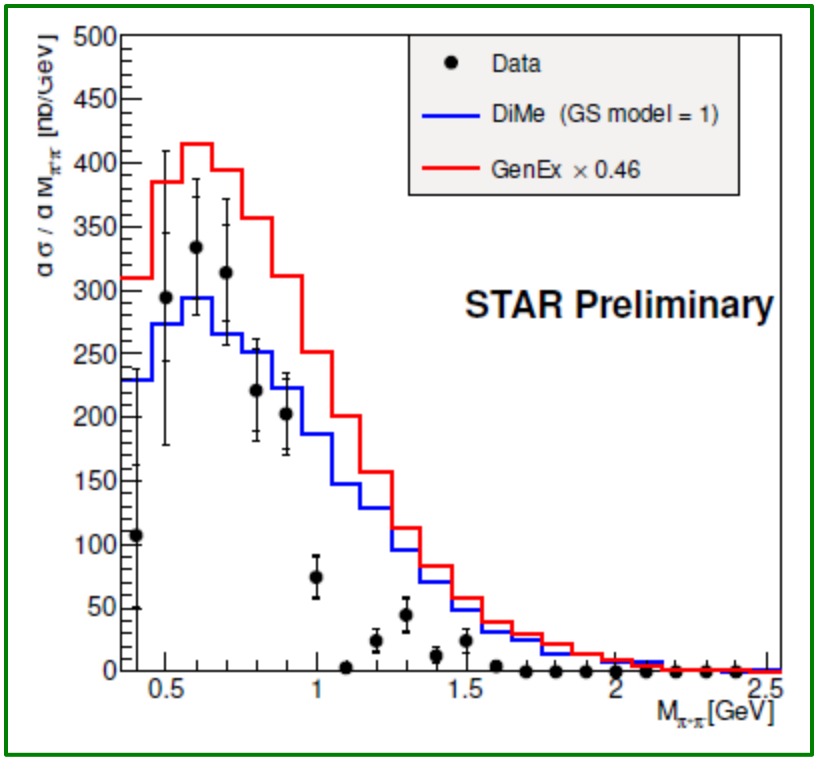


Can we see the onset of saturation?

1 Diffractive Processes

- Pomeron exchange
  - color singlet combination of gluons
  - central exclusive production for glue ball search at low missing p_T



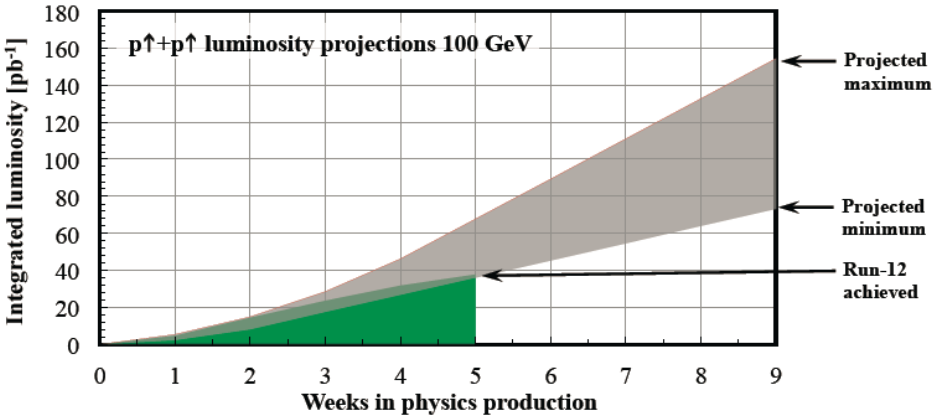


- Origin of transverse single spin asymmetries
- Single diffractive dissociation / elastic scattering with increased statistics and extended t-range

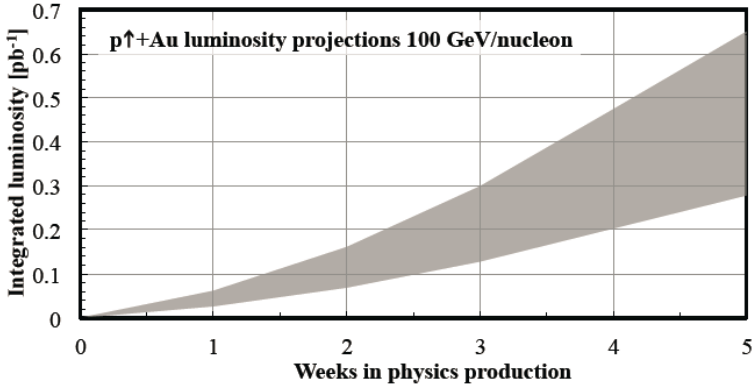
Run 15 Timeline

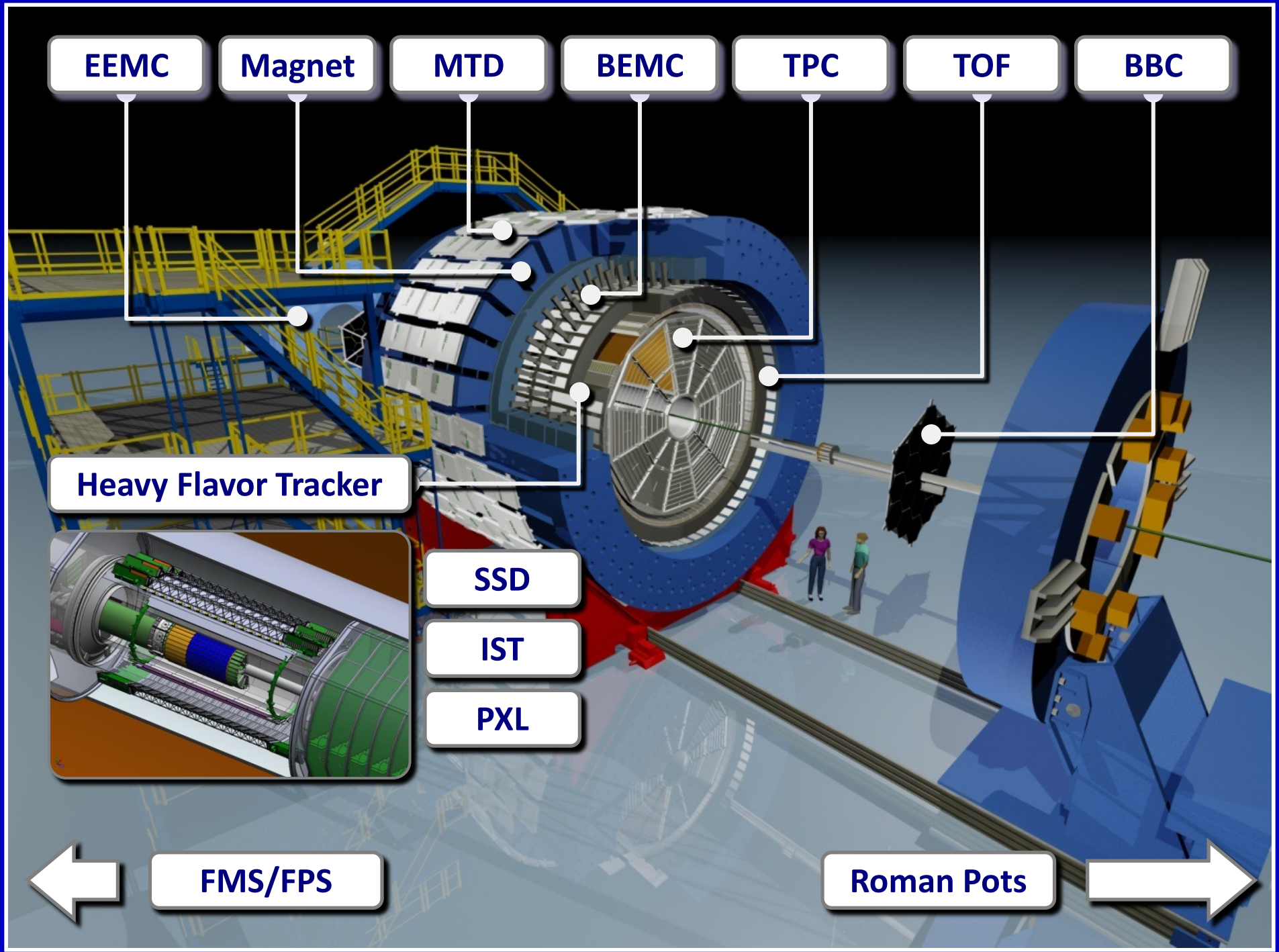
PAC recommendations:

- 9 weeks of $\vec{p} + \vec{p}$, $\sqrt{s} = 200$ GeV
- 5 weeks of $\vec{p} + Au$
- 2 weeks of $\vec{p} + Si$



2014/12/03	West pole tip closed
2015/01/20	Cool down to 4 K, watch shifts ready
2015/02/03	First collisions at $\sqrt{s} = 200$ GeV, full shift crews
2015/02/10	Start of physics program in $\vec{p} + \vec{p}$
	FMS/FPS commissioning (gain iterations, trigger ready)
2015/03/10	Changing to transverse polarization
2015/04/02	Back to longitudinal polarization
2015/04/27	End of $\vec{p} + \vec{p}$
2015/05/04	Start of physics program in $\vec{p} + Au$
2015/06/08	Changing to $\vec{p} + Al$
2015/06/22	Begin cryo warm-up




EEMC
Magnet
MTD
BEMC
TPC
TOF
BBC
Heavy Flavor Tracker
SSD
IST
PXL
FMS/FPS
Roman Pots

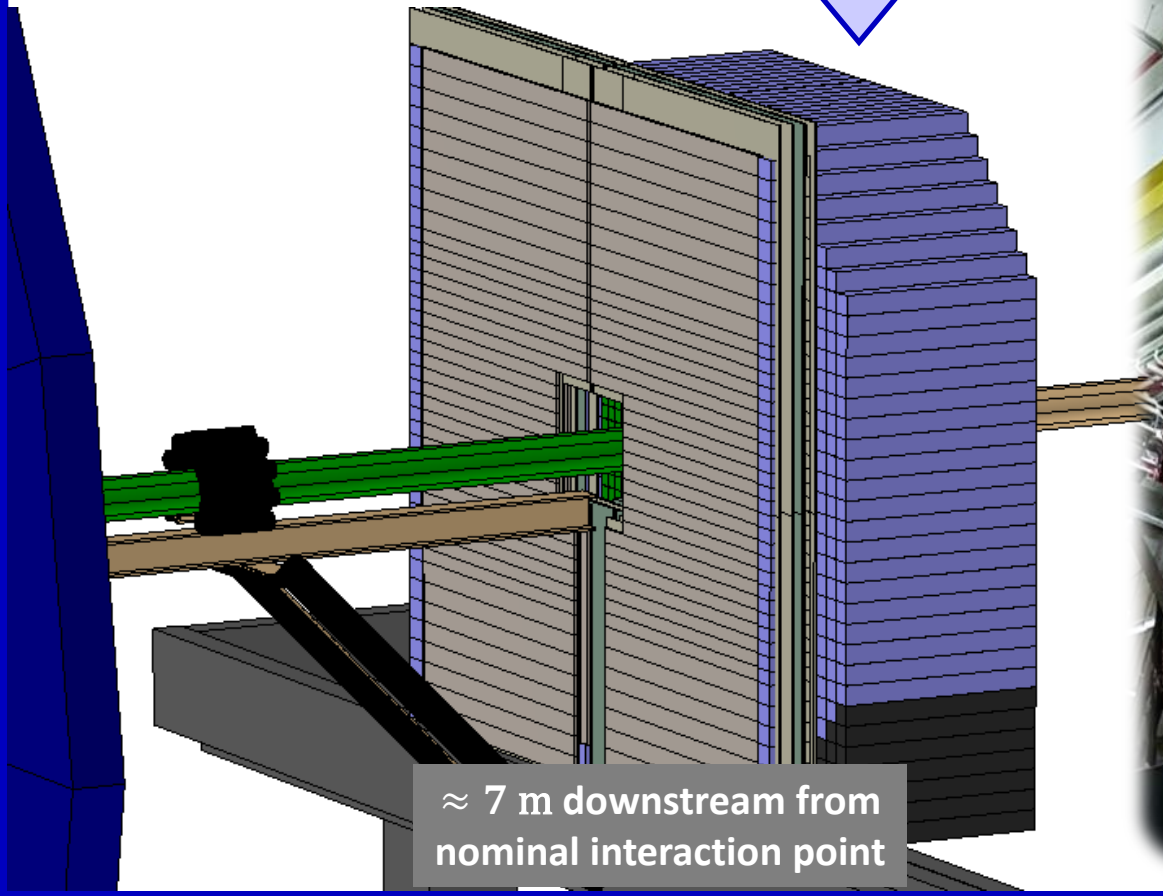
Preshower at Forward Rapidities

Preshower

scintillator hodoscope

Forward Meson Spectrometer

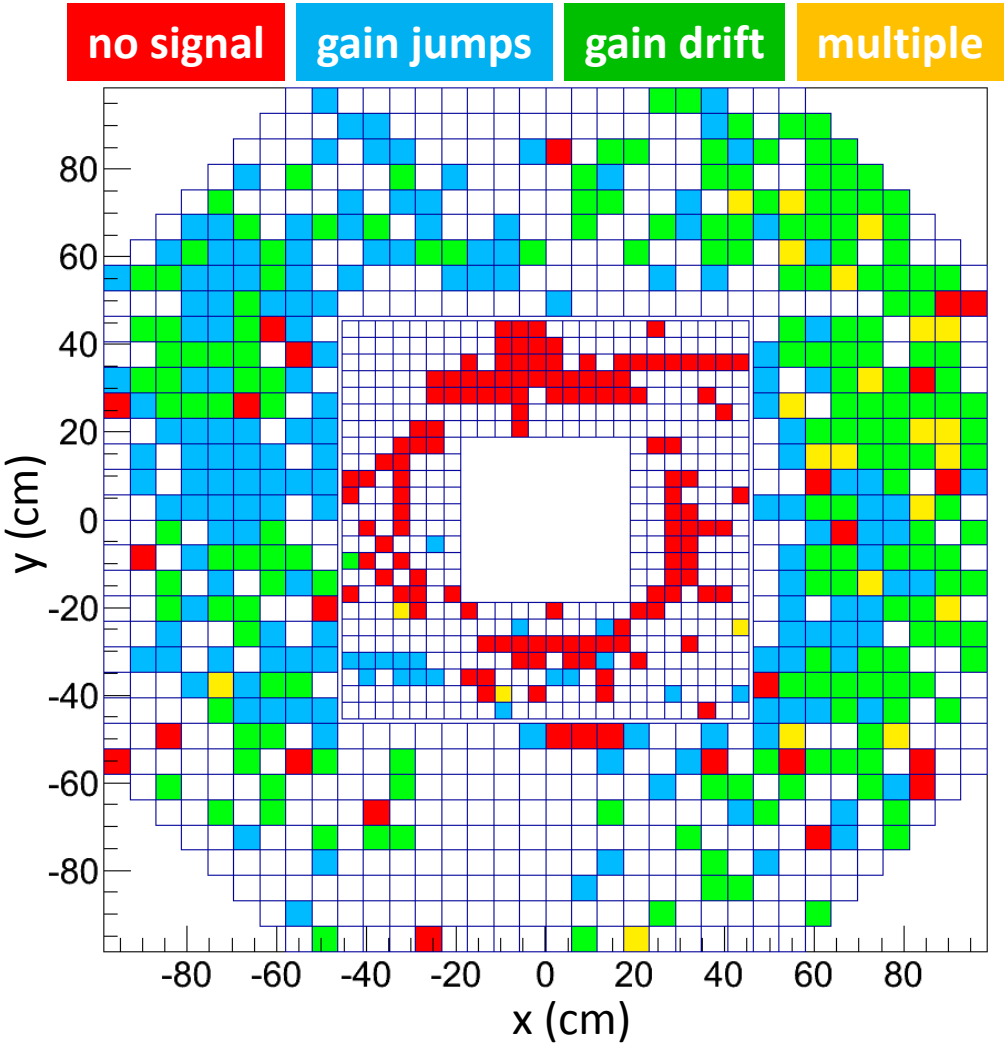
476+788 PbGl towers

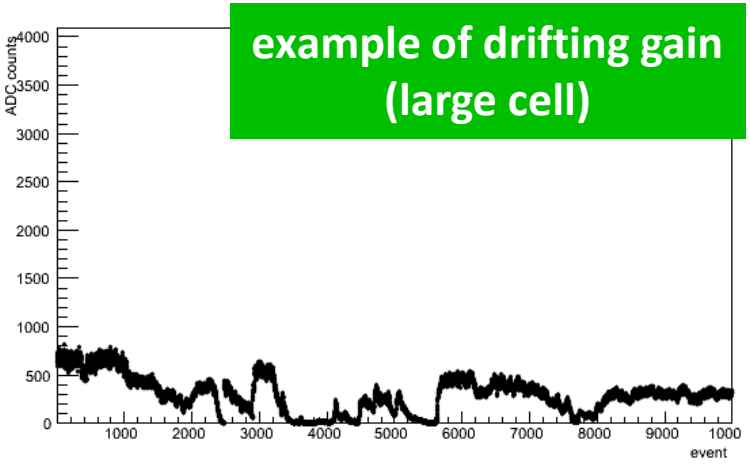


≈ 7 m downstream from nominal interaction point

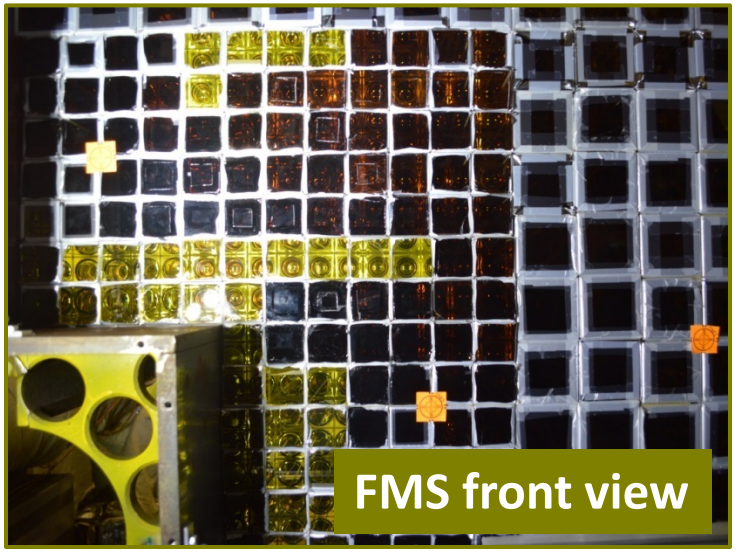
Forward Meson Spectrometer

- FMS Status at the end of Run 13



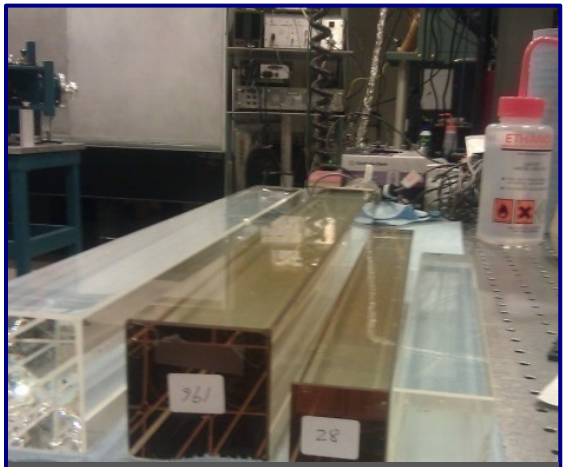


Radiation damage:
discoloration of PbGl



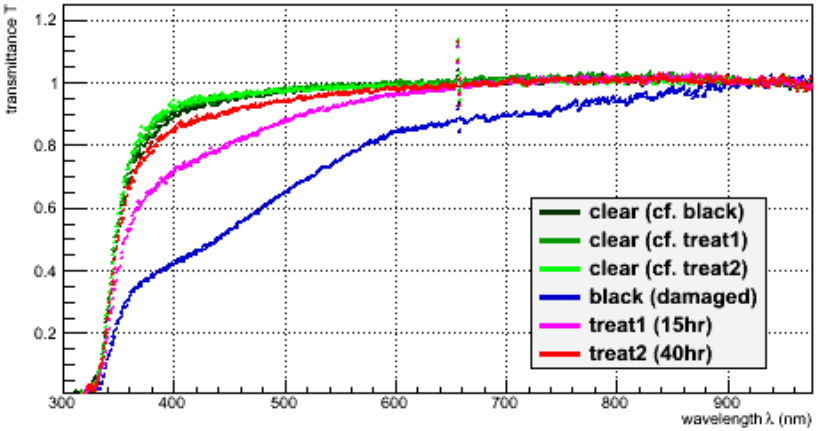
FMS Refurbishing in 2014

Replacement of PMT and bases



Curing of radiation damage

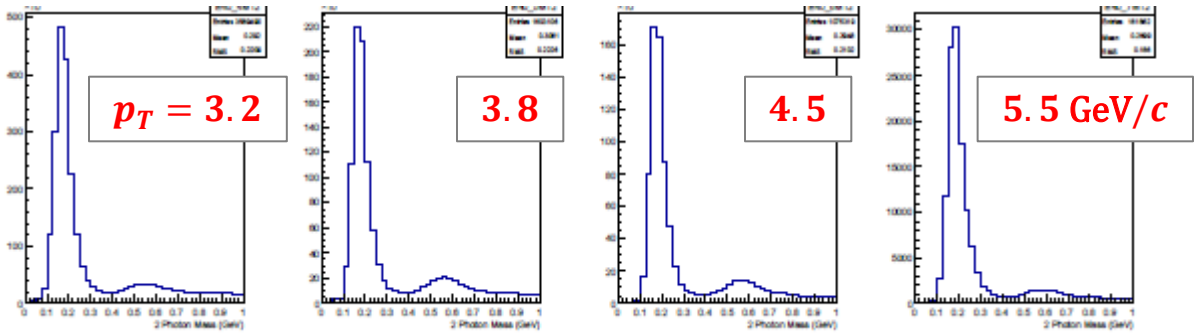
PbGl transparency after UV curing



FMS Performance in Run 15

Invariant mass distributions in $p + Au$

$\langle E_{\gamma\gamma} \rangle = 40\ \mathrm{GeV}/c^2$

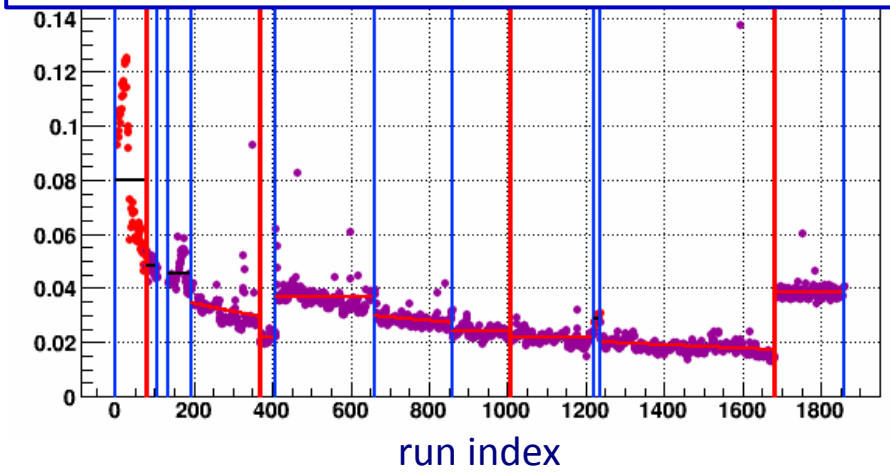


invariant mass ($0 \rightarrow 1\ \mathrm{GeV}/c^2$)

Similar or better in $p + p$ collisions

Trigger performance

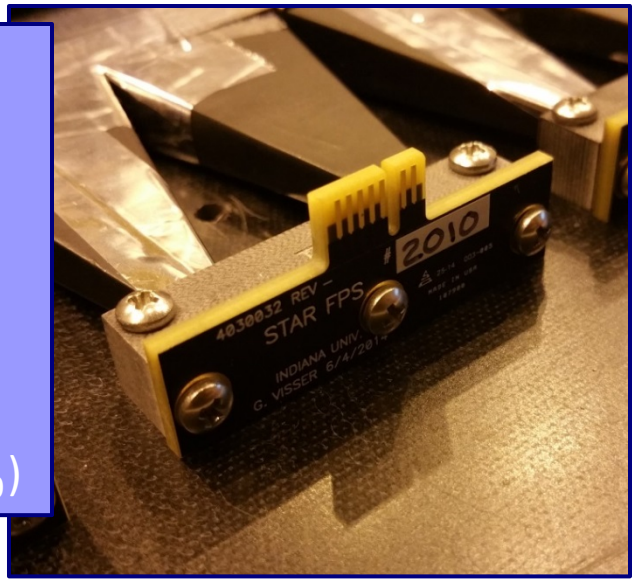
jet patch 2 (high-p_T)

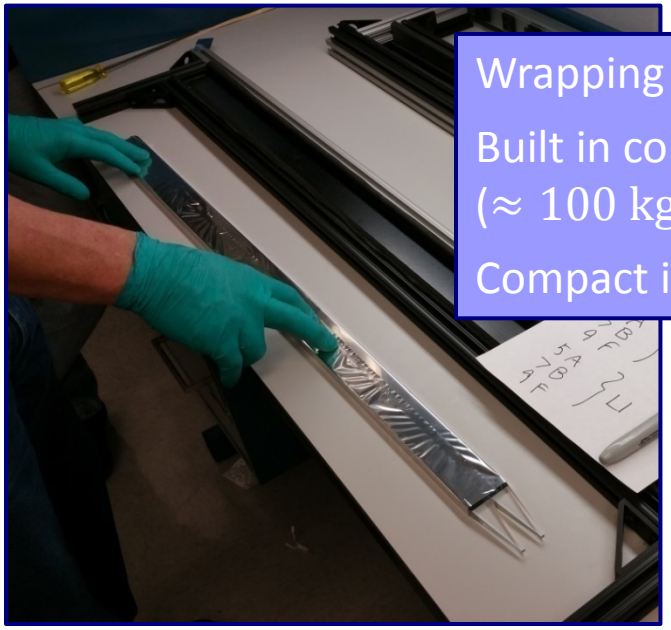


- The FMS is in its best shape ever!
- Gains balanced for p_T-triggering
- Signs of radiation damage (not unexpected)

Forward Preshower Construction

- Double pyramid light guide
- SiPM readout
- Three layers for 2d hit reconstruction
- 3×84 channels
- Pb converter ($\mathrm{d} = 1\ X_0$)

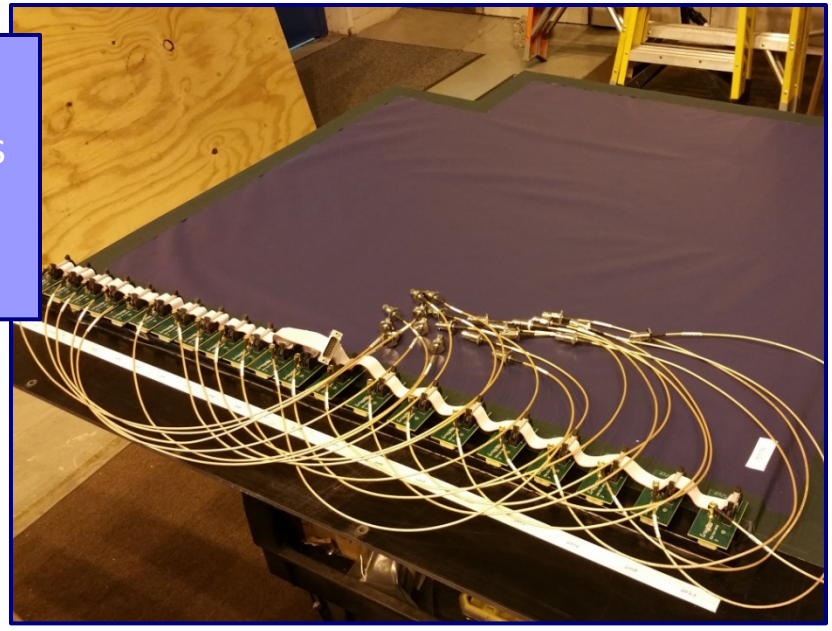




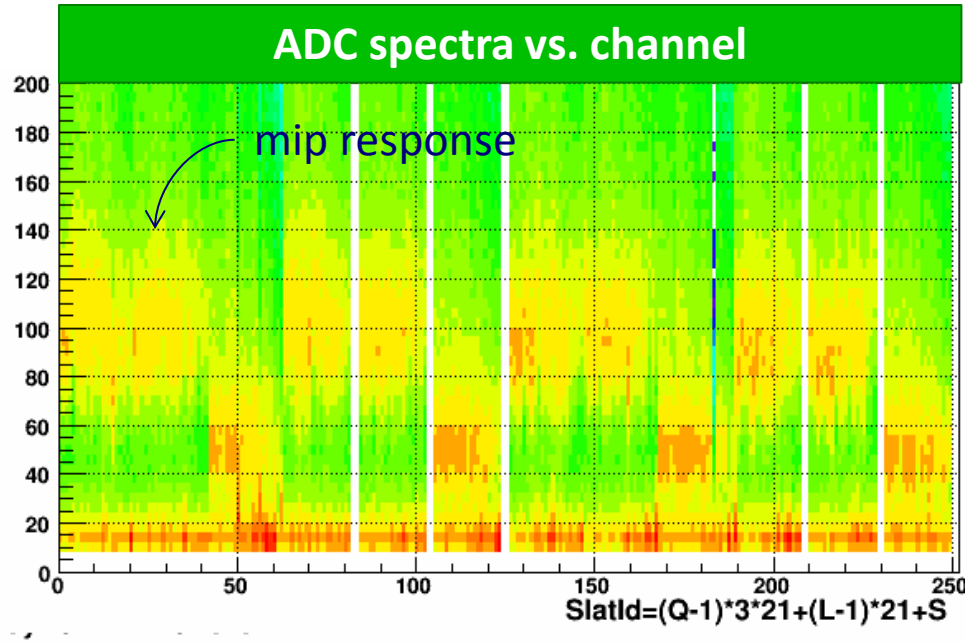
Wrapping at BNL

Built in complete quadrants (≈ 100 kg)

Compact installation



Preshower Performance in Run 15

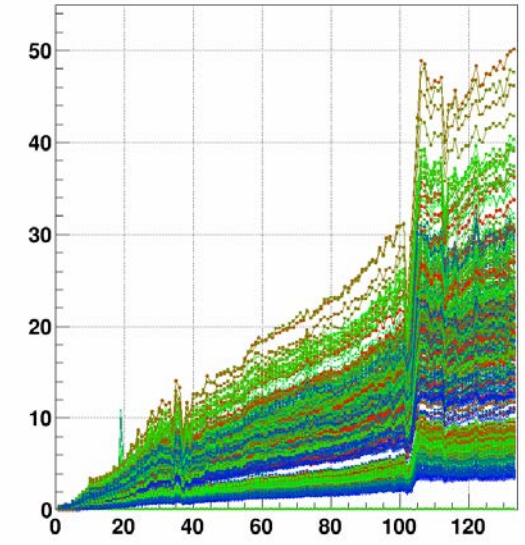


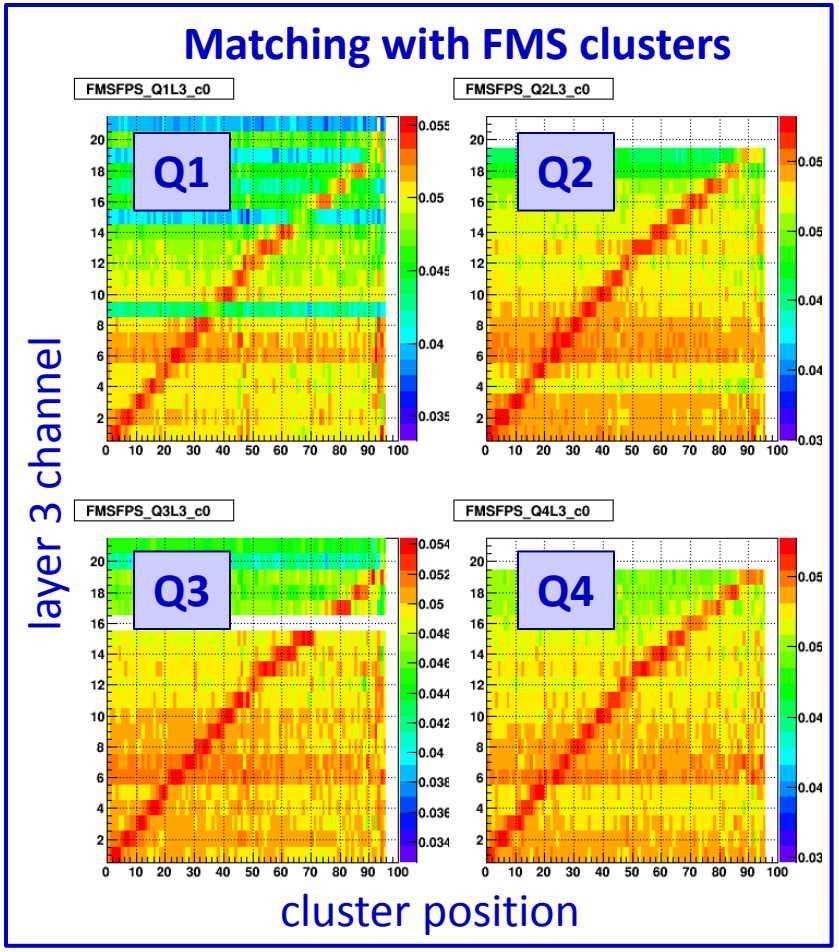
Radiation damage:

Monitoring of dark current in SiPM

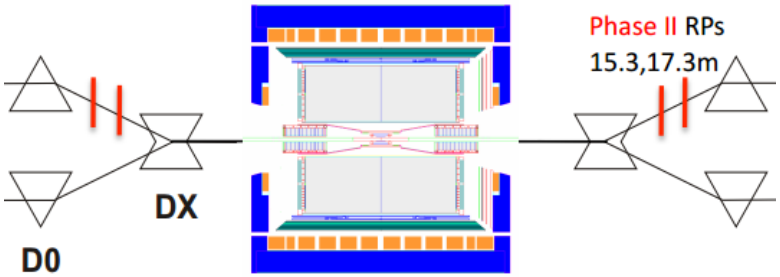
Collision related

Very susceptible to background



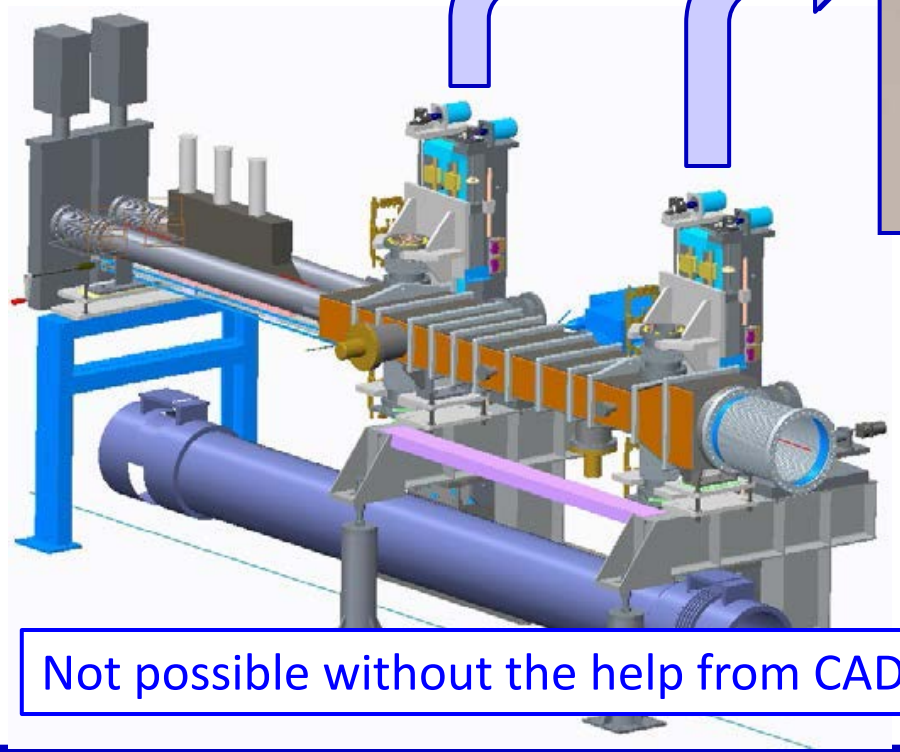


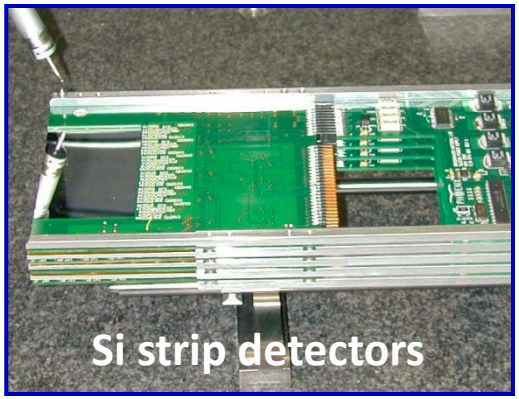
Roman Pot Detectors

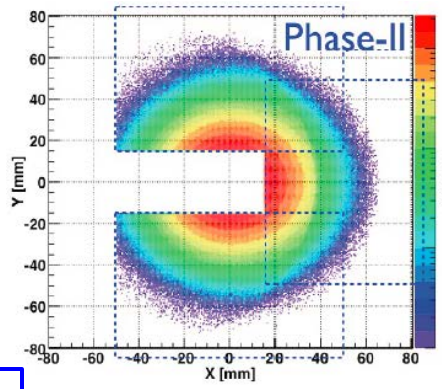


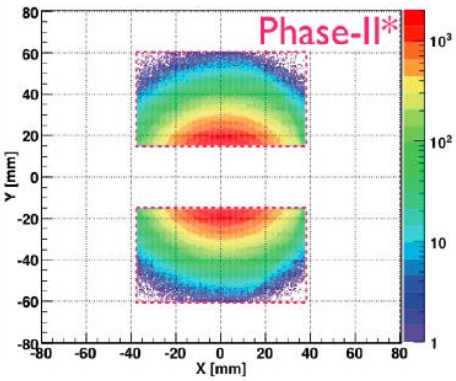
- pp2pp setup from ≈ 55 m $\rightarrow 15$ m
- No special machine settings required

vertical Roman pot vessels





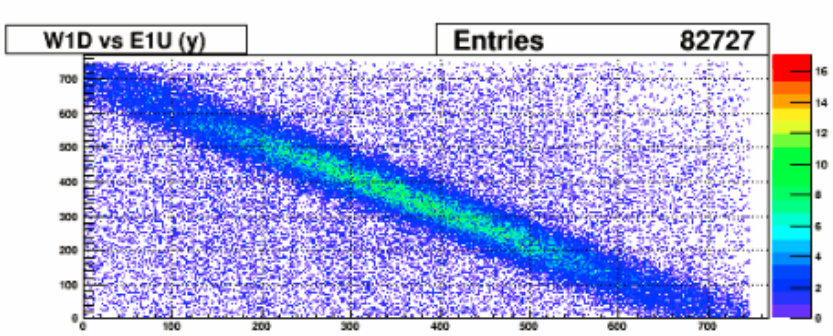




Not possible without the help from CAD!!!

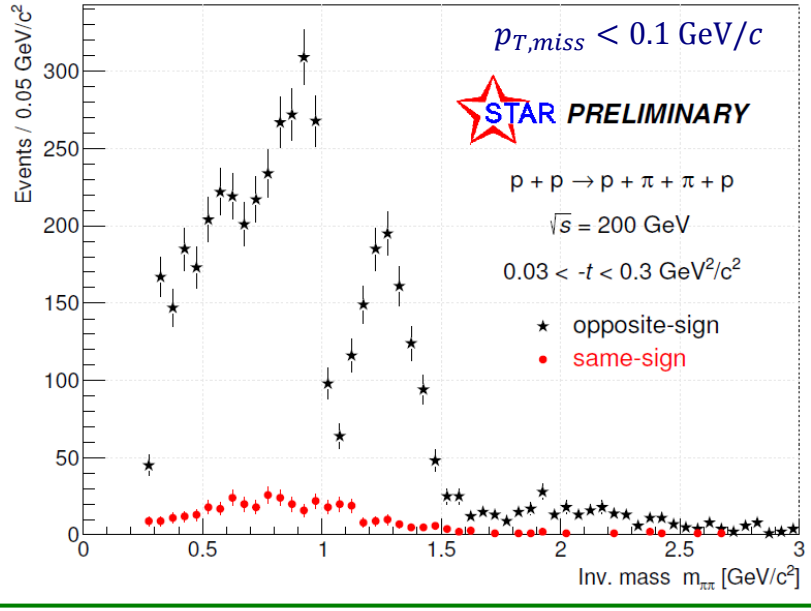
PP2PP Performance in Run 15

Collinearity: elastic $p + p$ scattering

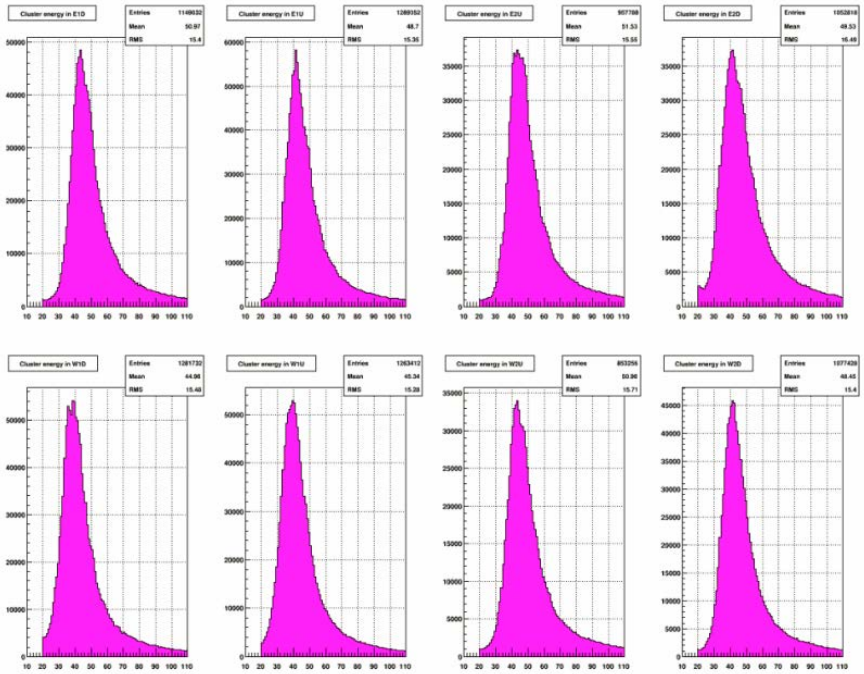


Central exclusive production

no acceptance correction, statistical uncertainties only



dE/dx in all layers

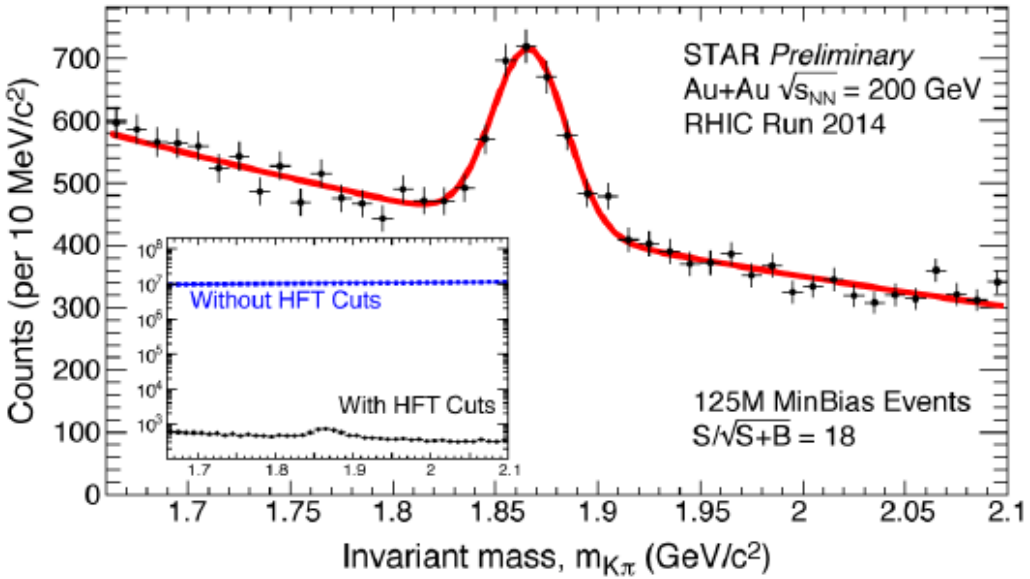


- Very successful operation
  - pp2pp team & shift crew
- Fast-offline alignment studies

HFT Performance in Run 15

- PXL damage in run 14
  - Improved protection against latch-up
  - Refurbished inner ladders (Al)
- Rate limit in SSD
  - Longer internal busy time $1.2\ ms$
  - Reduced common mode noise

PXL	inner layer 4% dead sensors
	outer layer 5% dead sensors
IST	>92% active APV chips
SSD	lost 1 out of 20 ladders
	6% dead wafers
	90% of strips active



- Trigger rates $200\sim800\ Hz$
  - PXL, IST, SSD included at full rate in minimum bias data

⇨ Improved performance in run 15

Data Taking

RUNNING [to RCF]	**16083018**	**production_pp200trans_2015** [PHYSICS]	
In progress...	*Ready for Physics* *Physics ON (436m) [Keep Beam]*		

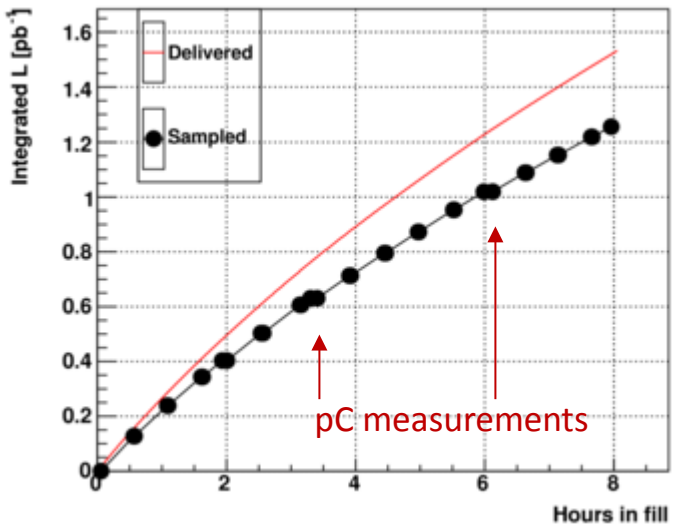
Run started	Tue Mar 24 08:47:57 2015
Duration	0 days, 0 hr, 23 min, 38 s
Blue	100.1 GeV, 19436 ions, Physics Running
Yellow	100.1 GeV, 21048 ions, Physics Running
TCU Clock	9383147.0

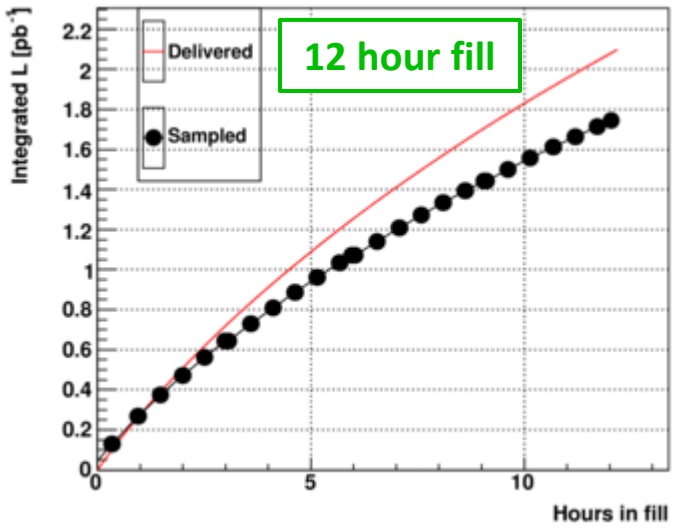
Trigger	DAQ Evts	DAQ Hz	L0 Evts	L0 Hz	Sca Hz	Sca Dead	Built	Trigger	DAQ Evts	DAQ Hz	L0 Evts	L0 Hz	Sca Hz	Sca Dead	Built
RP_SD	8378	7	8379	6	722208.7	22 %	8377	BHT1*VPDMB-30	199662	152	199745	156	184	17 %	199662
RP_SDT	32961	22	32974	24	83066.1	22 %	32960	BHT0*BBCMB	1929	1	1930	1	10159	11 %	1929
RP_RPZMU	5580	3	5584	5	5	0 %	5580	BHT1*BBCMB	1835	1	1836	1	1637	11 %	1835
RP_RPZE	3247	3	3249	3	4	25 %	3247	BHT2*BBCMB	100959	61	100994	64	76	8 %	100959
RP_RP2MU	6046	2	6048	2	7	29 %	6046	singlemuon-5	48794	38	48810	37	411	12 %	48794
RP_RP2E	6221	2	6223	4	8	25 %	6221	emuon-30	35026	23	35043	29	37	11 %	35026
RP_CPT2	313386	222	313509	241	1457	20 %	313383	dimuon	106804	66	106831	62	89	10 %	106803
RP_ET	57505	37	57513	40	154536.1	18 %	57504	bbc-mtdcosmic	11544	8	11548	9	1048	10 %	11544
RP_CP	42167	26	42185	31	174302.2	22 %	42165	FMS-sm-bs1	71966	47	71978	51	3162	8 %	71966
RP_Zerobias	1155	1	1156	1	9383145	22 %	1155	FMS-sm-bs2	193254	127	193276	124	[illegible]	7 %	193253
RP_CPEI	933[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	FMS-sm-bs3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8 %	188594
BHT1*VPDMB-30-nobsmd	221[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8 %	72292
JP2	272591	207	272715	238	256	10 %	272587	FMS-lg-bs2	139761	103	139776	98	[illegible]	8 %	139761
JP2-bsmd	246336	189	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	186	[illegible]	10 %	230211
AJP	4557	4	4559	3	253	[illegible]	4557	[illegible]	[illegible]	[illegible]	[illegible]	96	[illegible]	10 %	125269
EHT0	30433	26	30448	27	32	9 %	30433	FMS-JP2	135072	105	135081	100	105	9 %	135072
JP1	400227	275	400386	303	1790	21 %	400225	FMS-JP1	383609	262	383663	275	711	9 %	383609
JP2*L2JetHigh	272591	207	272715	238	256	10 %	272587	FMS-JP0	76011	56	76021	52	7270	8 %	76010
EHT0*EJP1*L2Egamma	25923	23	25936	24	28	11 %	25923	FMS-DiJP	37273	19	37277	21	32	19 %	37273
BHT2*BJP1*L2Bgamma	87842	49	87874	54	76	14 %	87842	FMS-LED	1242	1	1242	1	1	0 %	1242
VPDMB-5-trgonly	4968	4	4968	3	25675	8 %	4968	VPDMB-novtx	1809	1	1810	1	423078.4	11 %	1808
VPDMB-5-ssd	636837	444	637102	474	25675	56 %	636835	ZDCMB-trgonly	2944	2	2944	2	2939	7 %	2944
BBCMB	1031	1	1031	1	1195761.1	12 %	1030	VPDMB-30	1239	1	1239	1	150921.1	11 %	1238
BHT0*VPDMB-5	24342	20	24350	17	200	8 %	24342	ZEROBIAS	978	2	979	1	9383145	65 %	977
								ALL	*3483182*	*2528*	*3483558*	*2549*	*9383145*	*0 %*	*3482512*

Using a mix of 48 triggers through run 15 to achieve all of our physics goals

Run 15 Performance

typical 8 hour fill

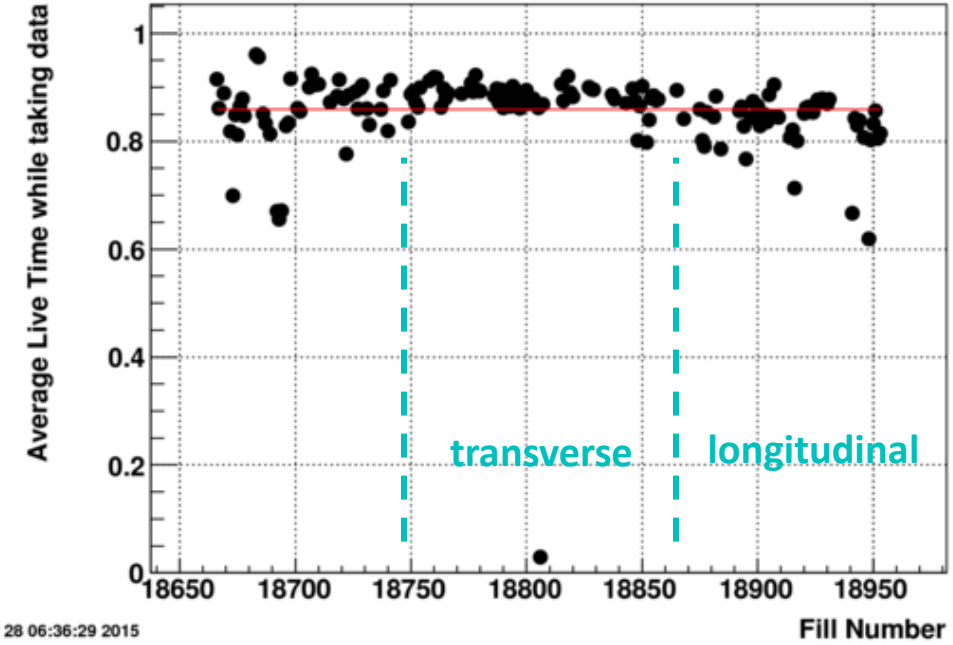




over 80% live

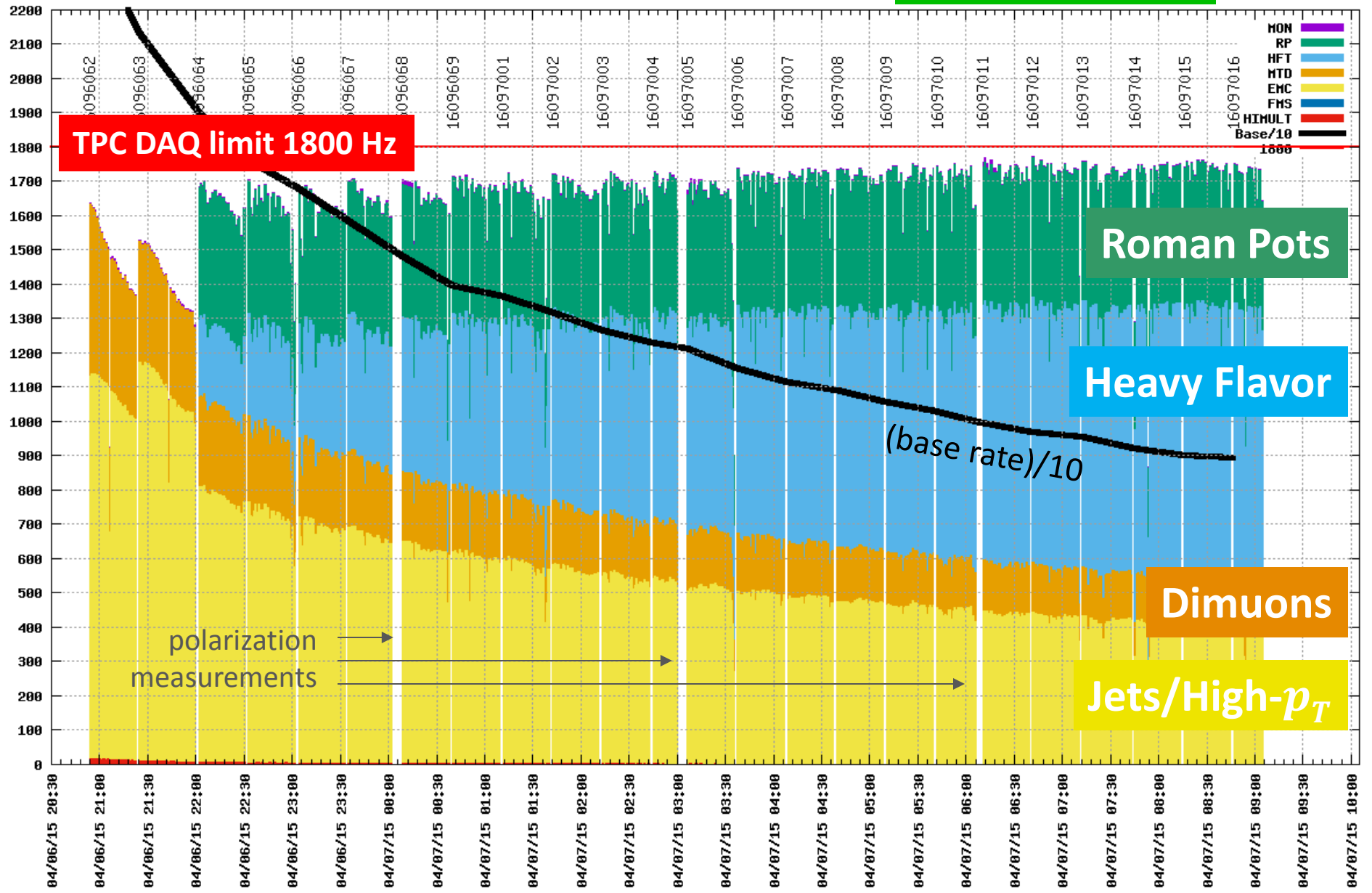
- average DAQ dead time 15%
- take data when PHYSICS ON
- optimized balance of triggers

average live time



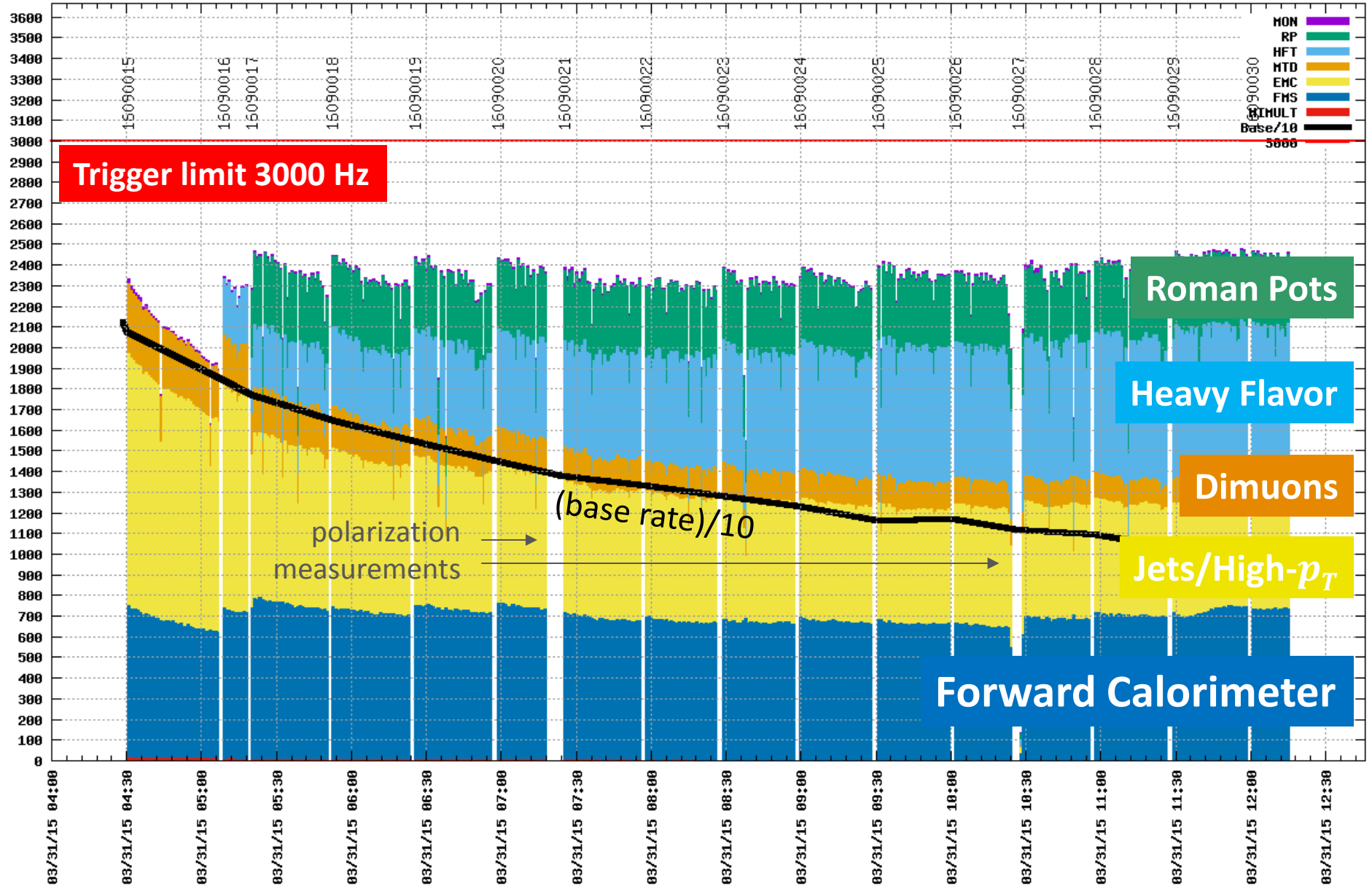
Trigger Bandwidth in $\vec{p} + \vec{p}$

example fill 18882

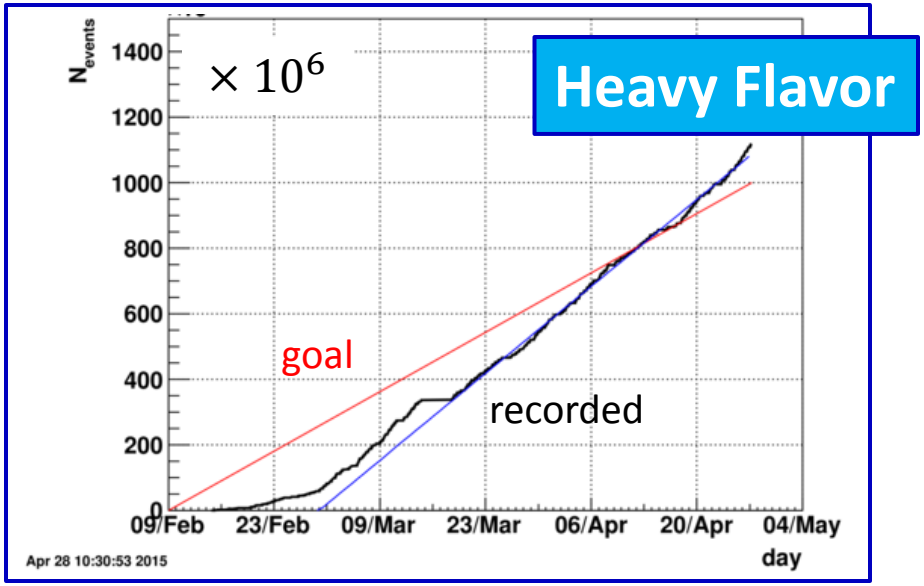


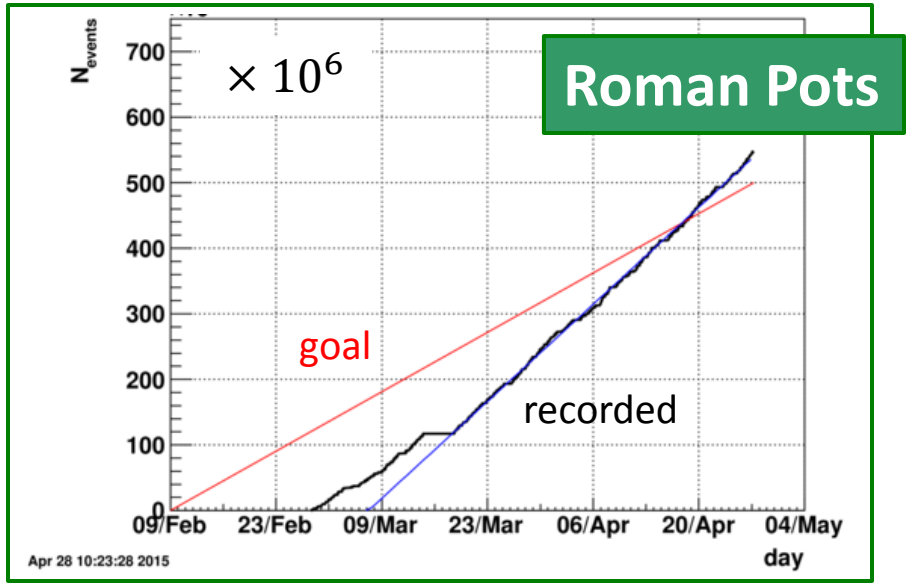
Trigger Bandwidth in $\vec{p} + \vec{p}$

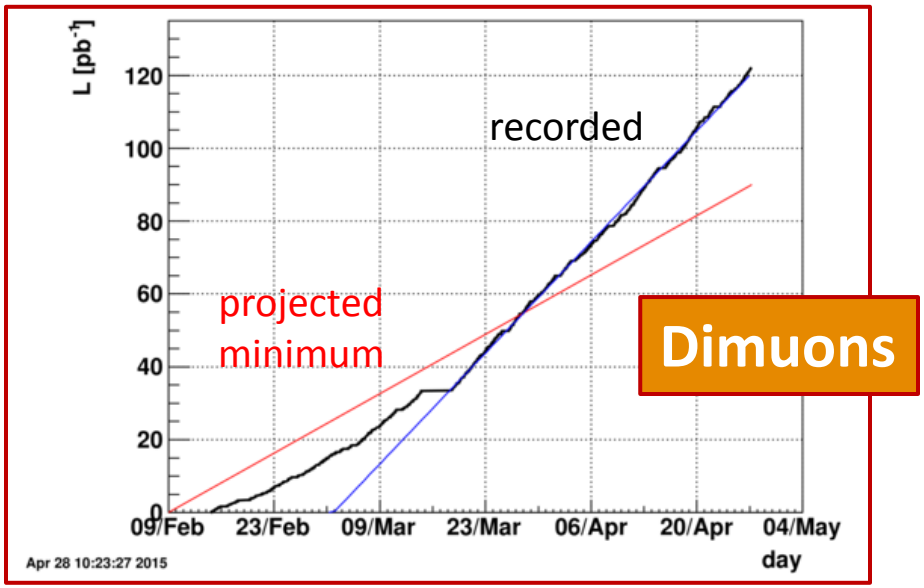
example fill 18847



$p + p$ Reference

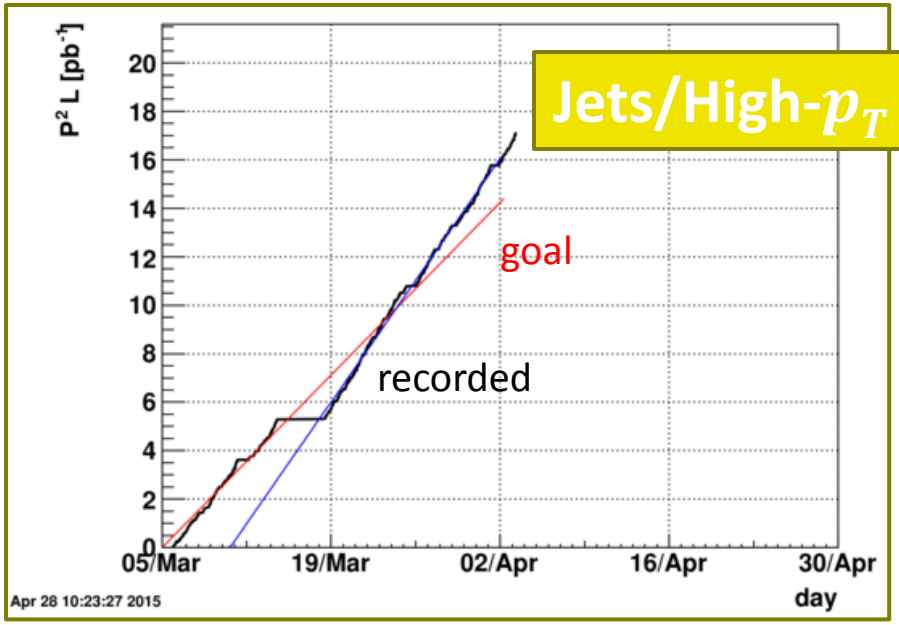






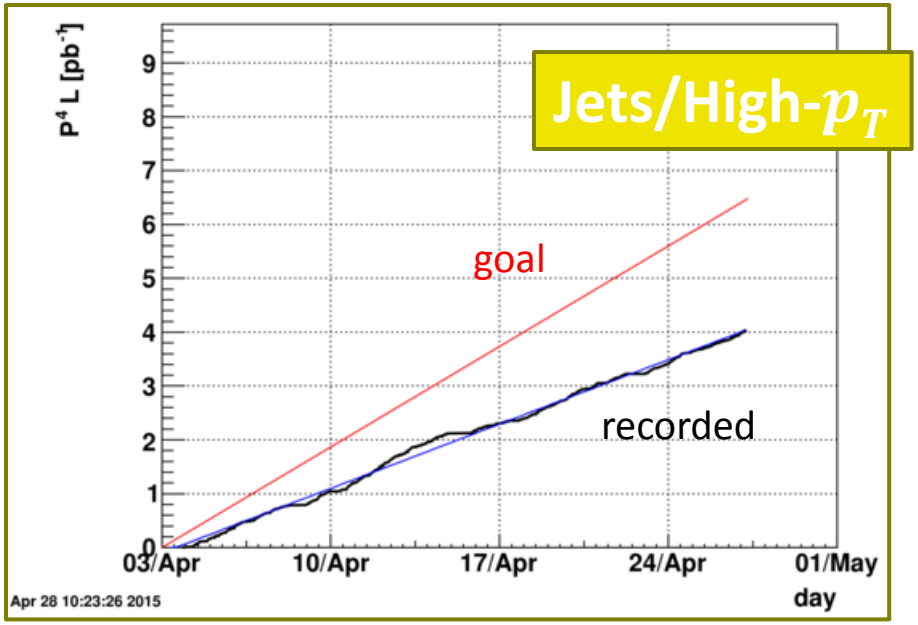
All $p + p$ goals reached or exceeded for heavy ion reference data in 2015!

$\vec{p} + p$ Goals



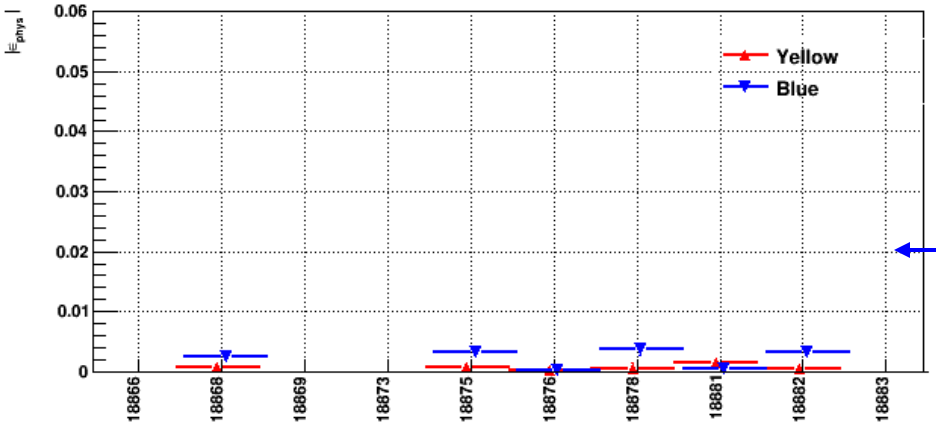
- Transverse polarization
- Single spin asymmetries: figure of merit $\propto P^2 \cdot \mathcal{L}$
- Based on $\mathcal{L} = 40\ \mathrm{pb}^{-1}, P = 60\%$
- *The incident*: loss of four days due to power dip
- Achieved original projections from BUR in four weeks!

$\vec{p} + \vec{p}$ Goals



- Longitudinal polarization
- Figure of Merit $\propto P^4 \cdot \mathcal{L}$
- Based on
  - $\mathcal{L} = 50\ \mathrm{pb}^{-1}$
  - $P = 60\%$
- Spin Rotator Efficiency
  - Transverse component $\mathrm{P}_\perp/\mathrm{P} < 10\%$
  - Polarization decay $\delta P/(P \cdot \delta t) \approx 2\%/\mathrm{h}$
- Falling short of originally projected goals for high-p_T

Transverse asymmetries from ZDC scalers

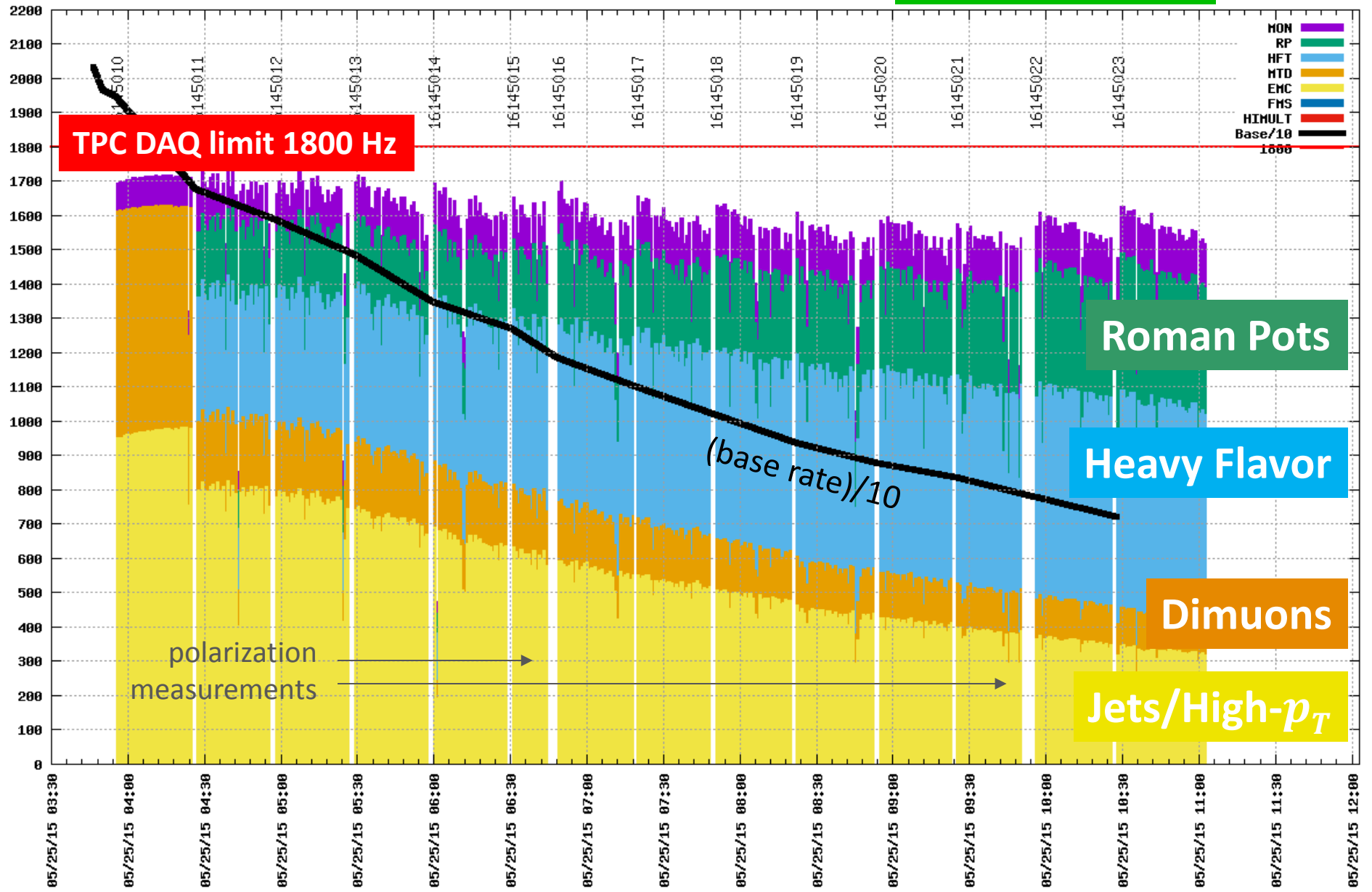


full transverse polarization:

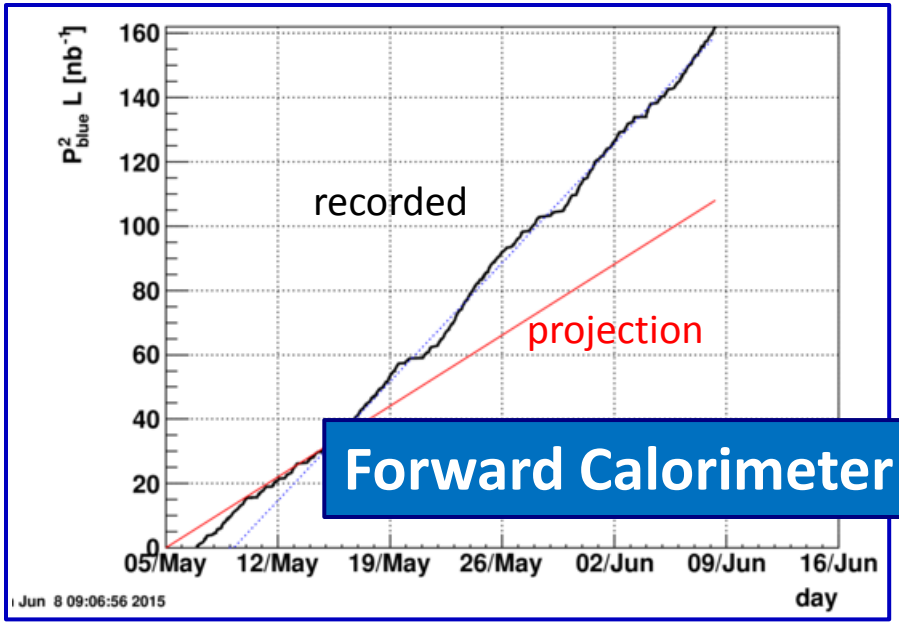
$\epsilon_{\max} \approx 0.02$

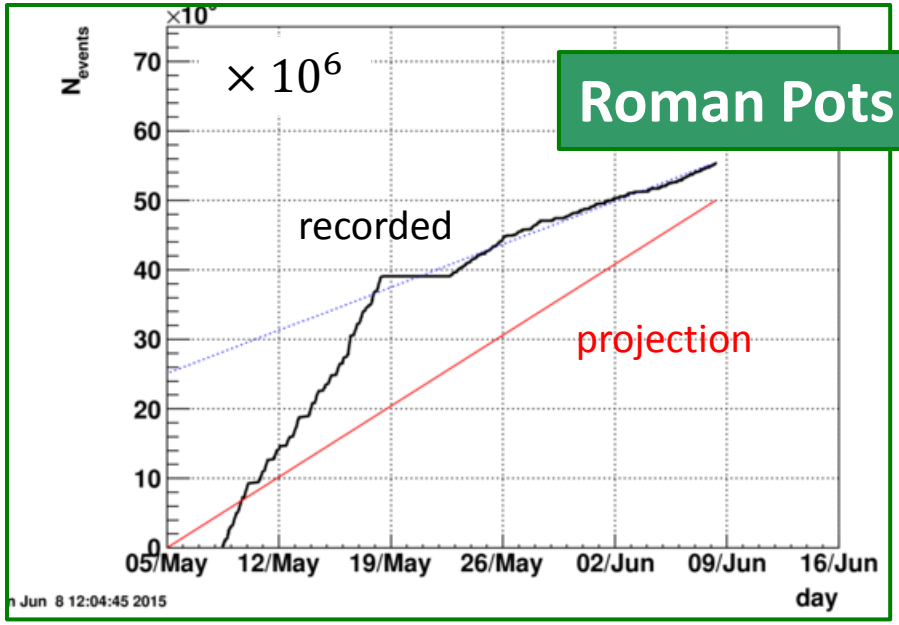
Trigger Bandwidth in $\vec{p} + Au$

example fill 19100



$\vec{p} + Au$





- Transverse polarization
- Figure of Merit $\propto P^2 \cdot \mathcal{L}$
- Based on $\mathcal{L} = 300\ \mathrm{nb}^{-1}, P = 60\%$
- Roman pots only on proton side
- $\vec{p} + Au$ goals reached or exceeded!

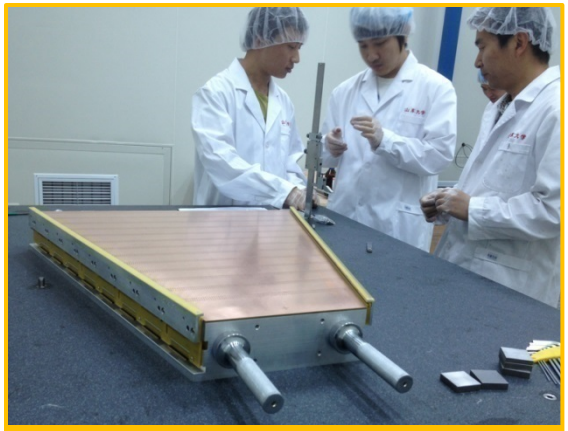
Run 15 Summary

- Very successful operation in 2015
- Reached or exceeded goals
  - Reduced time compared to original beam use request
  - Only exception: highest p_T range in A_{LL}(jet)
  - New and unique: transversely polarized $\vec{p} + Au$ collisions

Recording $\vec{p} + Al$ collisions since early Tuesday morning…

Looking Forward 2017+

- Drell-Yan production in Run 17
  - $\vec{p} + p$ @ 500 GeV
  - Forward rapidities $3 < \eta < 4$ (FMS)
  - Refurbish preshower SiPM
  - Add tail catcher: hodoscope similar to preshower



Prototype at Shandong

BES II (2018+)

- Inner TPC Upgrade
  - Increased active area, optimized pad size
  - $|\eta| < 1.5$
  - Improved $\Delta p/p$ and dE/dx
- Event Plane Detector
  - Large acceptance with radial segmentation
  - Fine granularity (single hits)

EEMC megatile prototype in Run 15

Collider-Accelerator Department
& main control crews

Operations team
and support

Detector experts

Shift crews,
Bill Christie &
period coordinators

Trigger experts,
board & computing