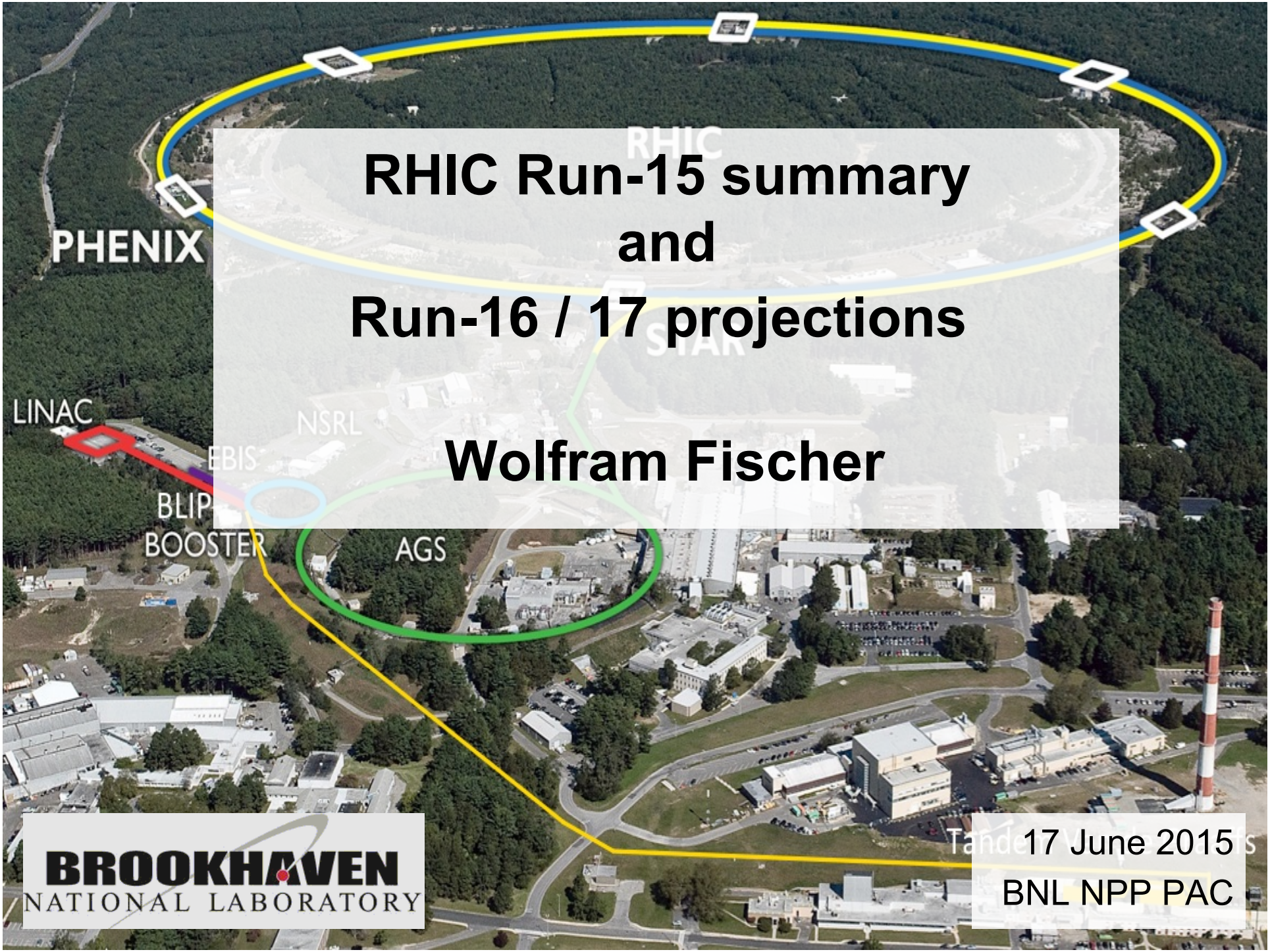


RHIC Run-15 summary and Run-16 / 17 projections

Wolfram Fischer

BROOKHAVEN NATIONAL LABORATORY

17 June 2015

BNL NPP PAC

Content

Run-15 summary

- p↑+p↑ at $\sqrt{s}$ = 200 GeV *L* with beam-beam compensation, *P*
- p↑+Au at $\sqrt{s_{NN}}$ = 200 GeV *L*, *P*, PHENIX MPC damage
- p↑+Al at $\sqrt{s_{NN}}$ = 200 GeV *L*, *P*

Preparations for Run-16 and Run-17

- Au+Au at $\sqrt{s_{NN}}$ = 200 GeV 56 MHz SRF, increased N_b (Run-16)
- p↑+p↑ at $\sqrt{s}$ = 510 GeV leveled *L* for STAR (Run-17)
- Other modes in BUPs:

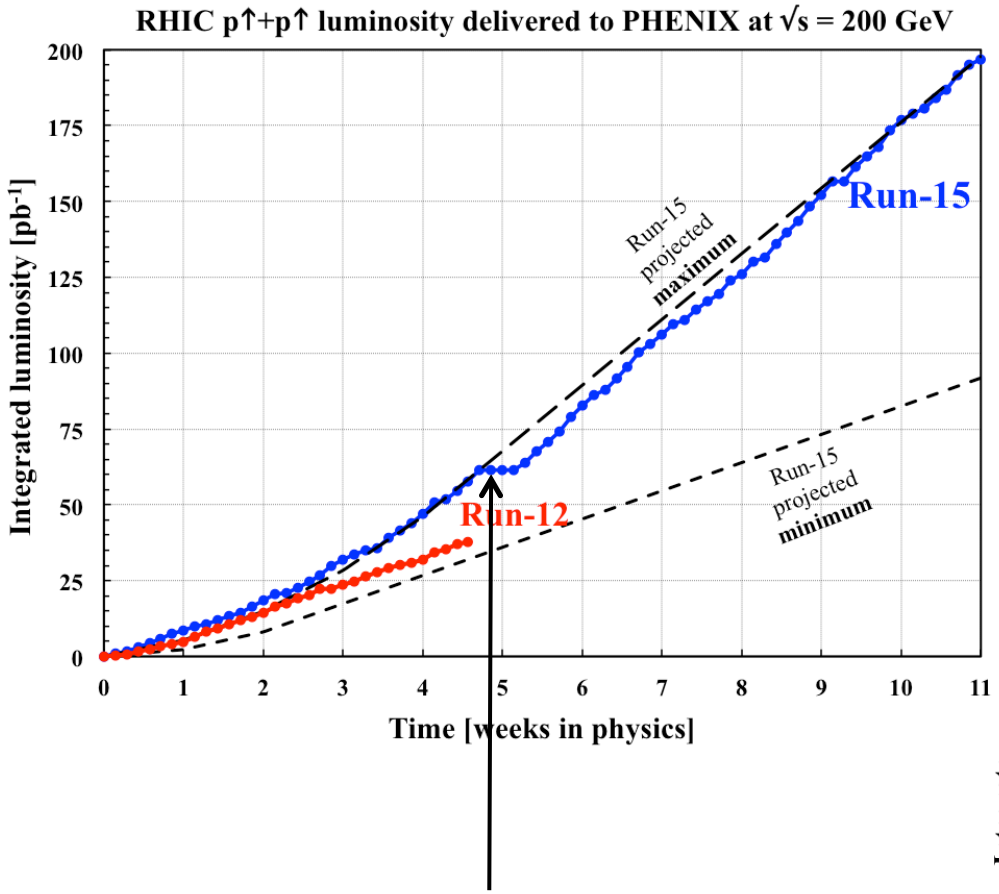
  Au+Au at $\sqrt{s_{NN}}$ = 62.4, 19.6 GeV
  p↑+p↑ at $\sqrt{s}$ = 62.4GeV
  d+Au at $\sqrt{s_{NN}}$ = 200, 62.4, 39, 20 GeV
  Ru+Ru and Zr+Zr at $\sqrt{s_{NN}}$ = 200 GeV

Run-15 p↑+p↑ at √s = 200 GeV

Luminosity

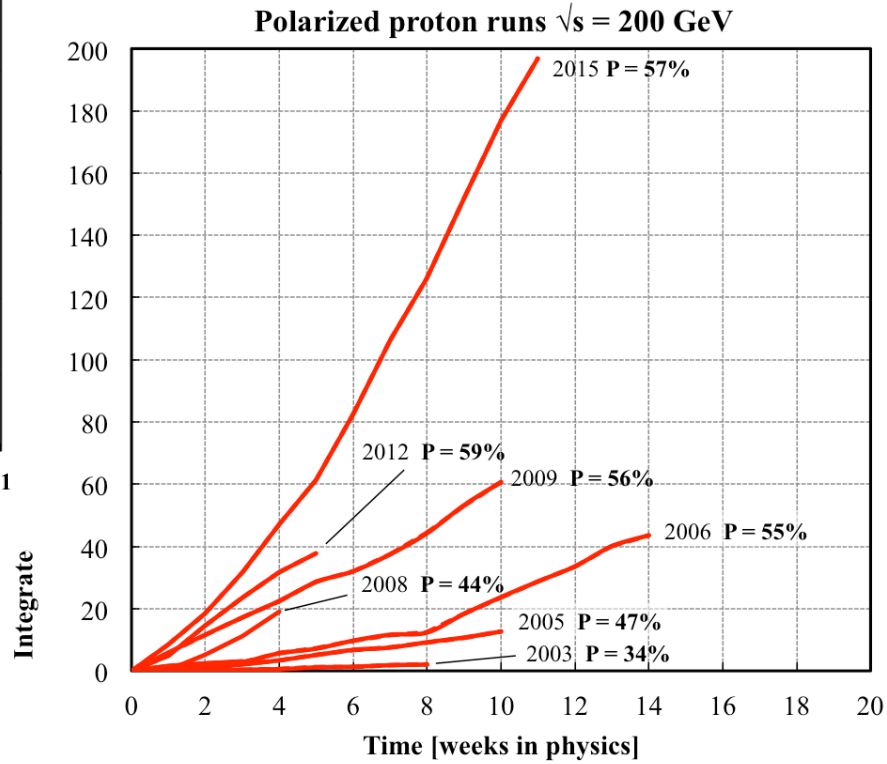
Run Coordinator: Vincent Schoefer

L = 25 pb^{-1}/week (2.7× 2012)



2/3 of liquid He inventory evaporated after power outage – 3 days for re-liquefaction

Run-15 integrated luminosity at √s = 200 GeV exceeds sum of all previous runs



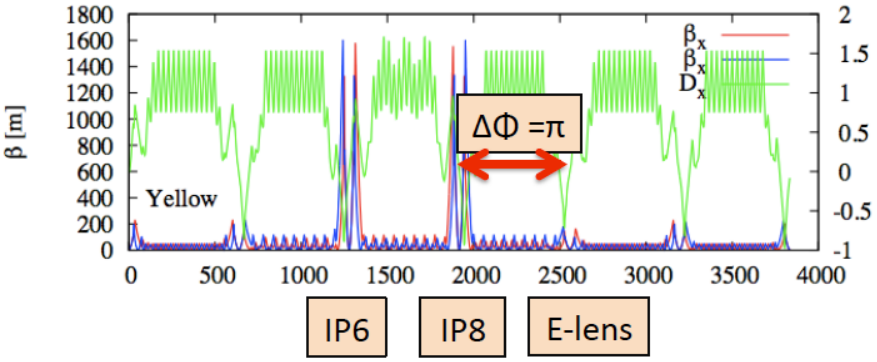
Run-15 p↑+p↑ at $\sqrt{s}$ = 200 GeV

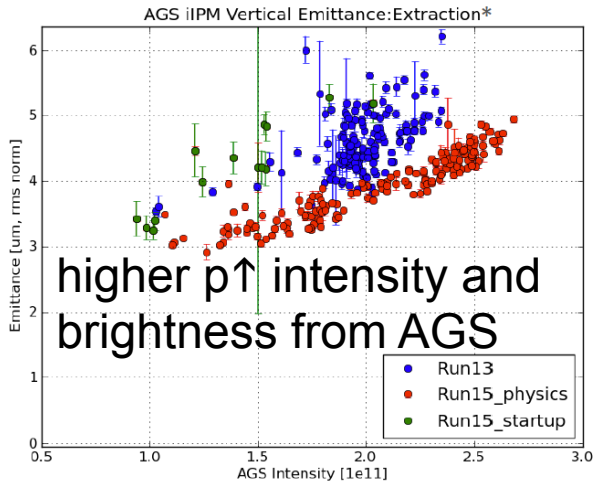
Luminosity

Luminosity increases from:

1. Head-on beam-beam compensation scheme (lattice + e-lenses)
2. Increased bunch intensity from injectors

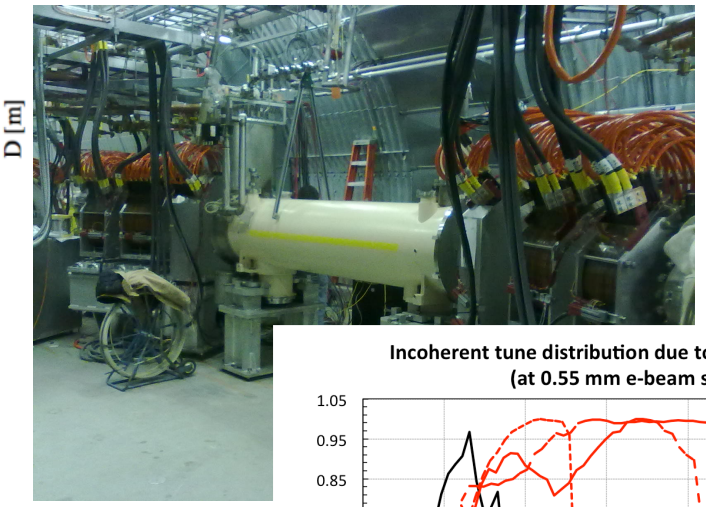
ATS type lattice (S. White) – minimizes beam-beam resonance driving terms

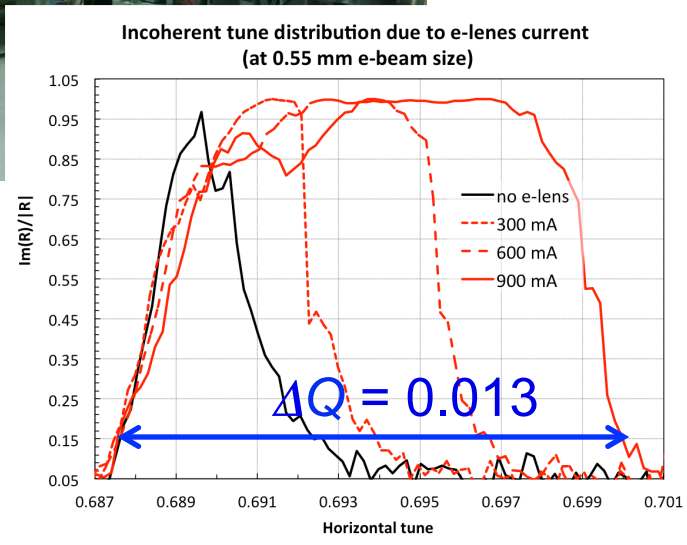




Wolfr

Electron lenses – reduce BB tune spread by creating tune spread with sign opposite to p-p



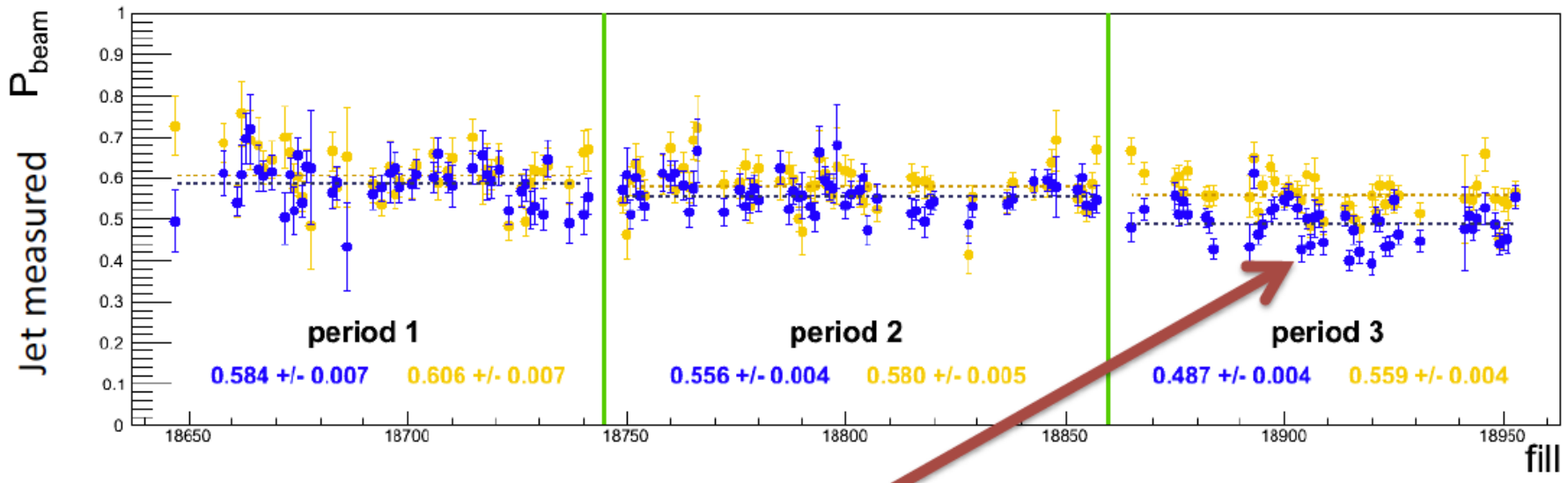


Run-15 p↑+p↑ at $\sqrt{s}$ = 200 GeV

Polarization

Run Coordinator: Vincent Schoefer

	Spin Direction		
PHENIX		Transverse	
STAR	Longitudinal	Transverse	Longitudinal



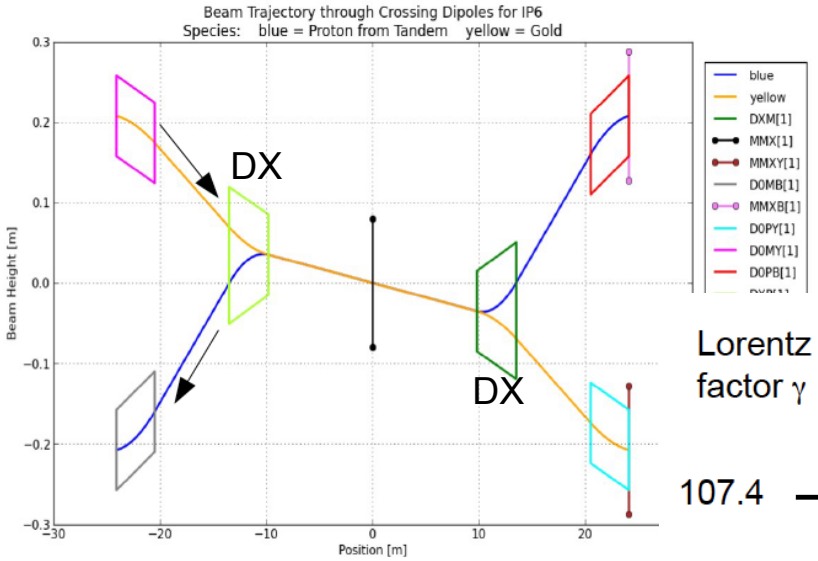
Revisiting longitudinal operation at STAR
- AGS polarization drops off
- Blue polarization lifetime at store nearly 2%/ hour

Plot courtesy of K.O. Eyser

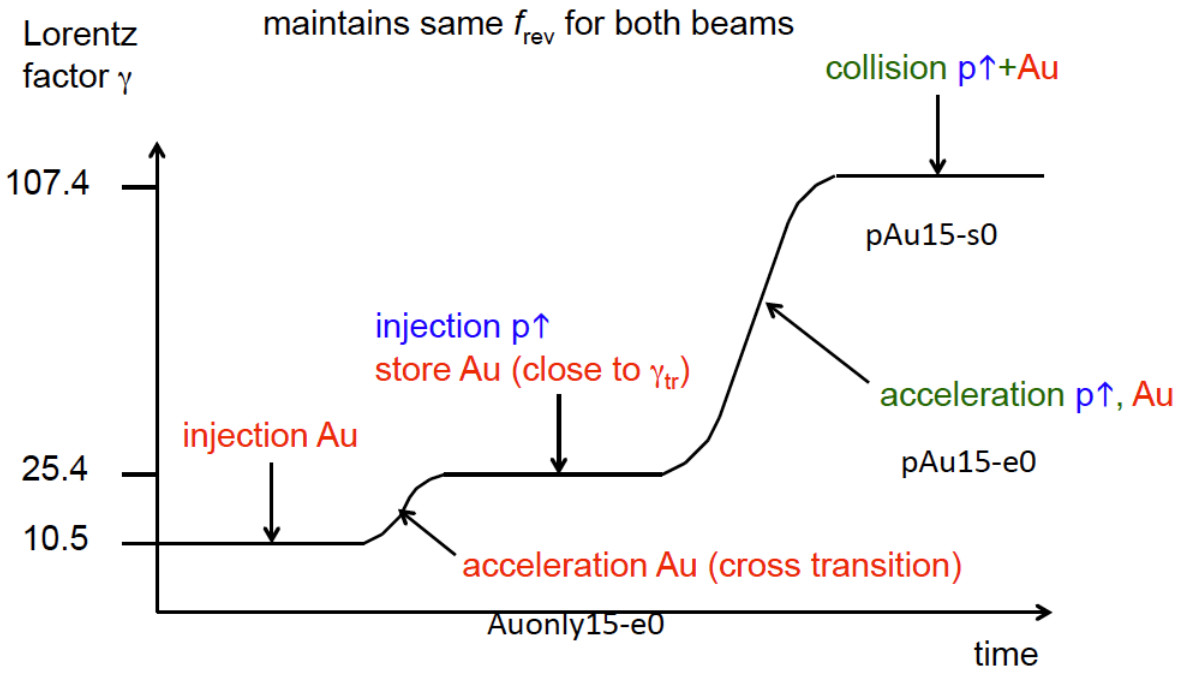
Run-15 p↑+Au at √s = 200 GeV luminosity and polarization

Run Coordinator: Chuyu Liu

First operating mode that required moving DX magnets (~2 cm)

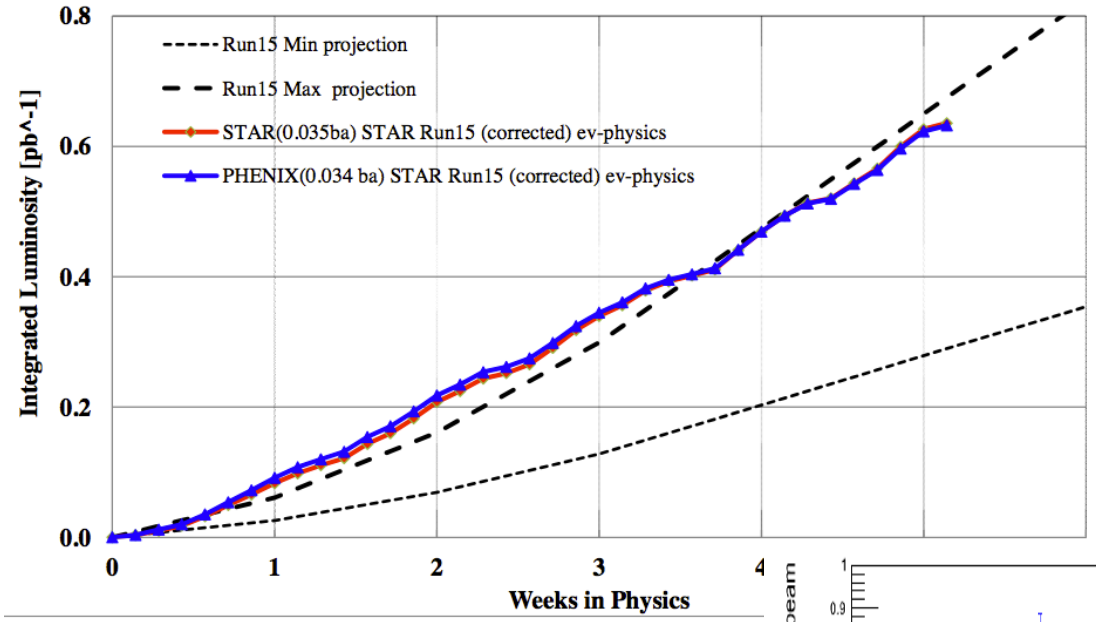


protons injected after
Au beam accelerated
to intermediate energy

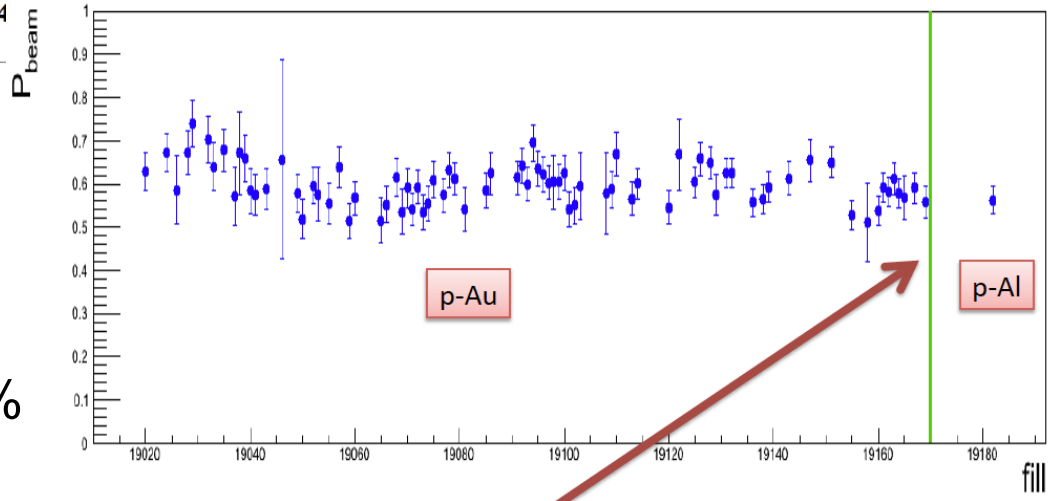


Run-15 p↑+Au at $\sqrt{s}$ = 200 GeV luminosity and polarization

Run Coordinator: Chuyu Liu



luminosity close to projected maximum



average polarization ≈ 60%

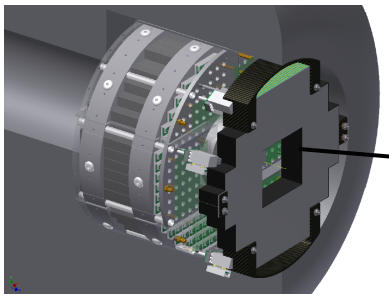
16 hours between last p-Au store and first p-Al store

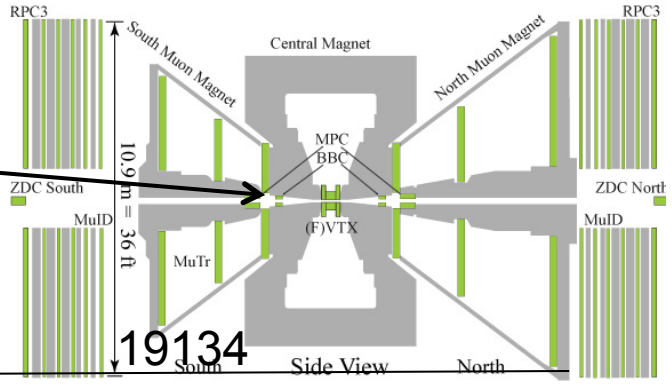
(plot courtesy of O. Eyser)

Run-15 p↑+Au at $\sqrt{s}$ = 200 GeV

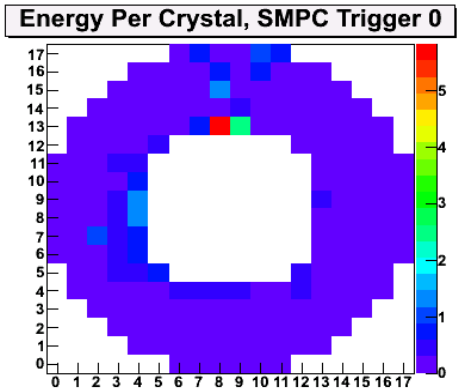
PHENIX MPC damage

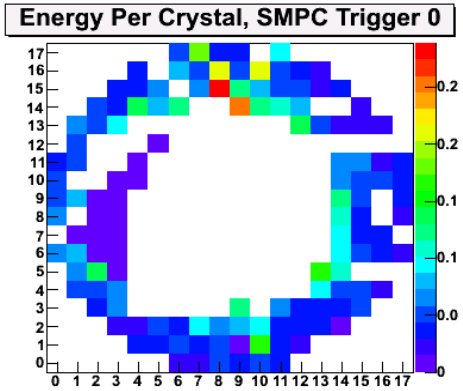
with Yellow abort kicker pre-fire

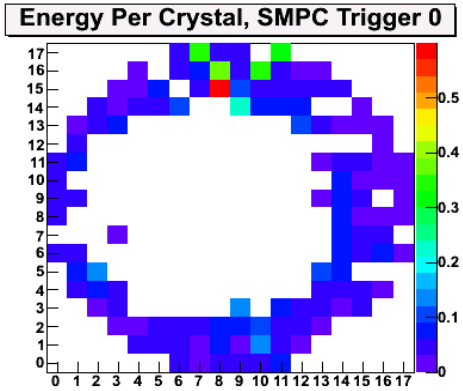


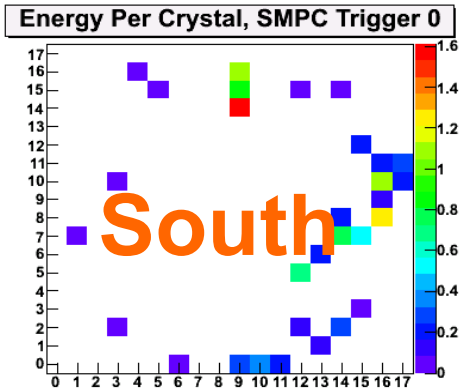


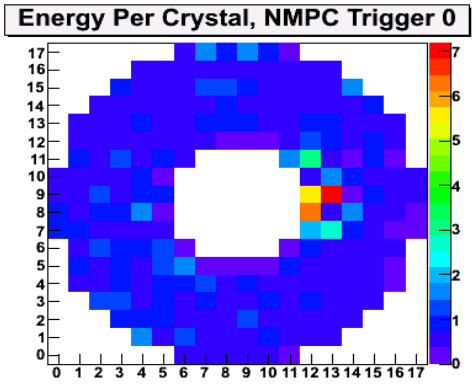
Store	19050	19116/18	19134
	May 11	May 28	June 1
	Damaged South Impacted North	We got lucky No addt'l damage	The end of the MPC in Run 15

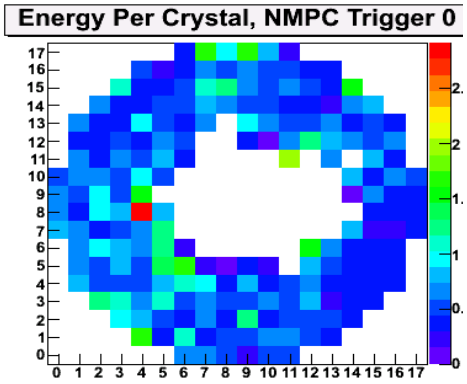


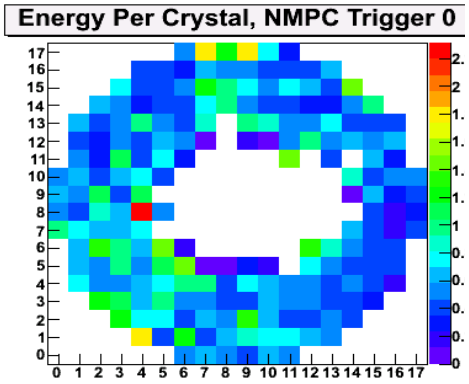


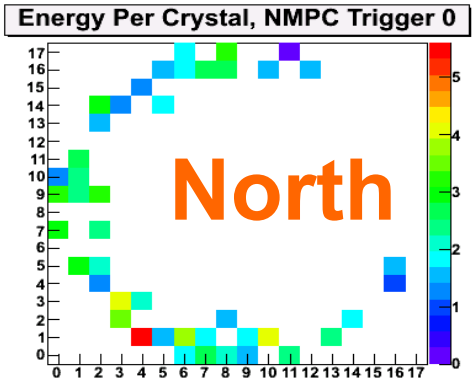












Run-15 p↑+Au at $\sqrt{s}$ = 200 GeV

PHENIX MPC damage

In response to previous damage after pre-fire (Cu+Au 2012), in order to intercept kicked beam before it reaches detector:

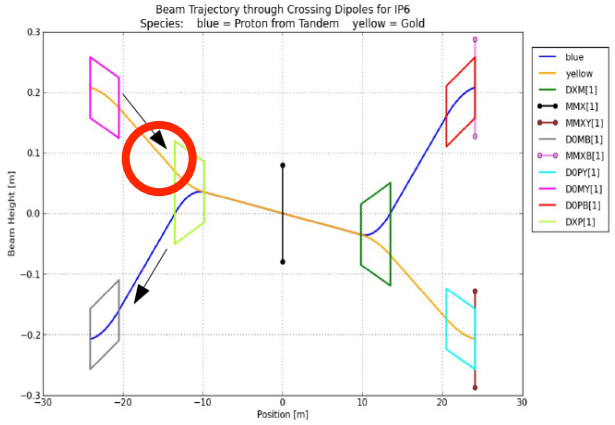
- Installed large (20 mm) orbit bumps in arcs for Run-14
- Installed additional masks for Run-15
  (No large-scale damage in Run-13 and Run-14)

Provides insufficient protection in asymmetric operation:

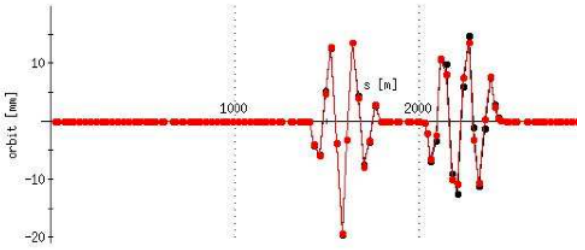
- Smaller distance beam-to-DX-chamber can lead to interception of primary particles after Yellow pre-fire
- Secondary particles reach MPC (and other detector components)

Better protection requires:

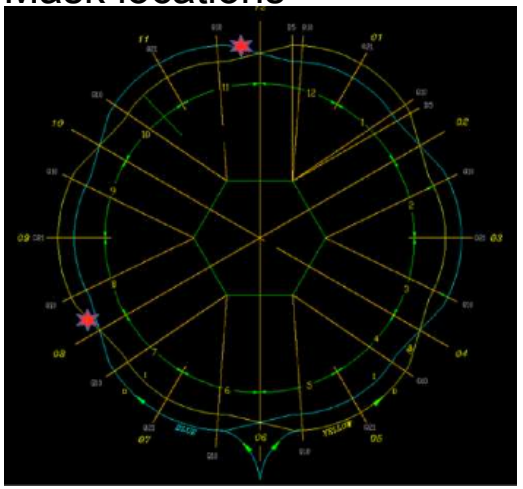
- Yellow abort re-location,
- Or masks in cryo-regions



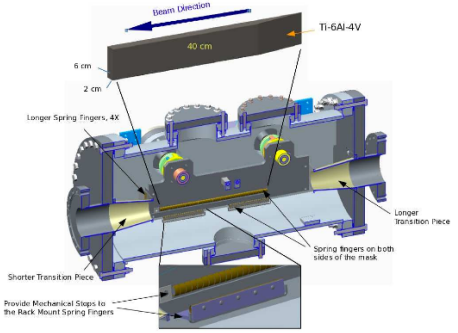
Horizontal arc orbit bump



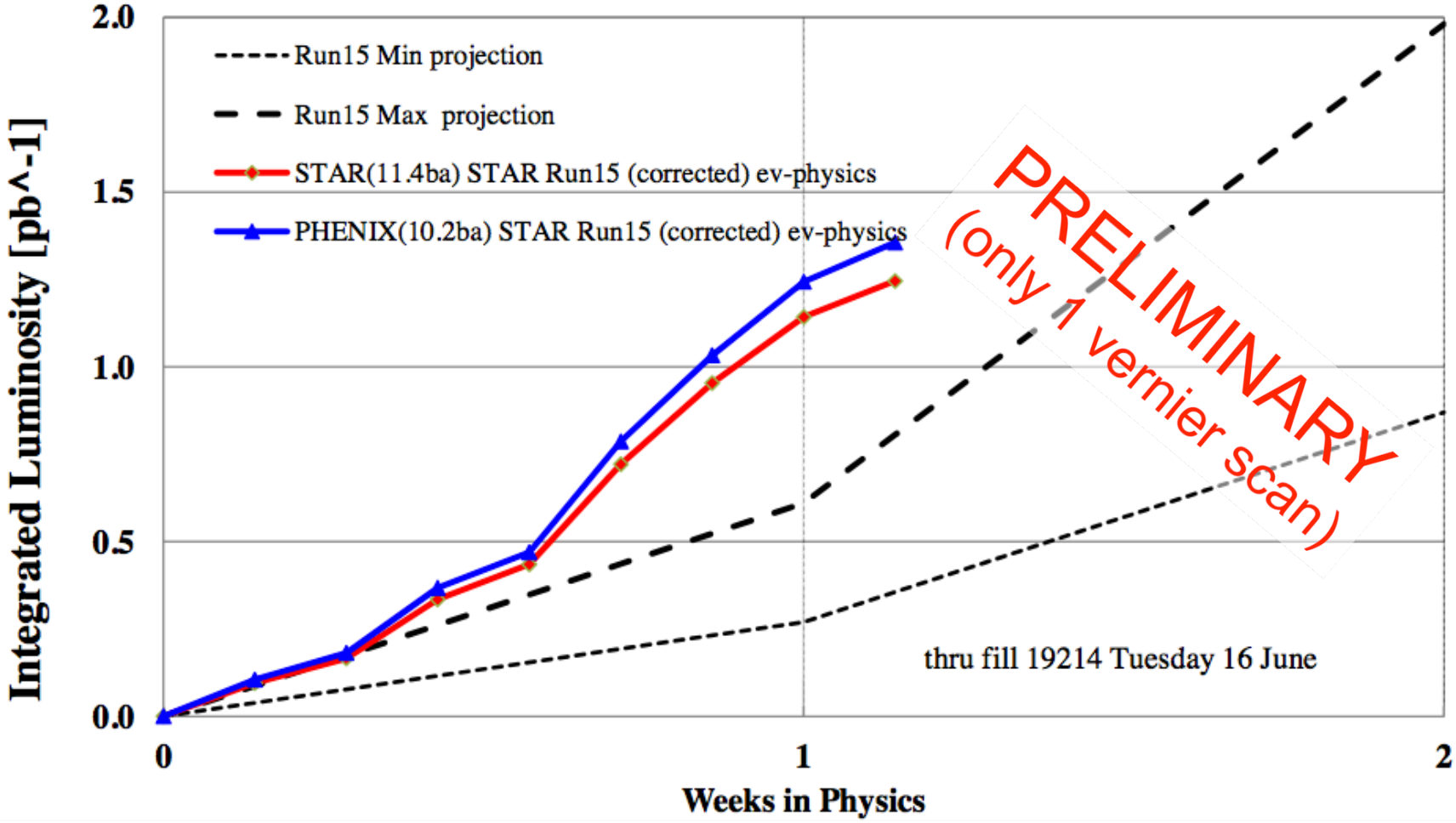
Mask locations



New masks



Run-15 p↑+Al at $\sqrt{s}$ = 200 GeV luminosity and polarization



So far on track to meet max luminosity projections (APEX and MD coming up)
Polarization ≈ 55%, lower than in p↑+Au (≈ 60%)

Possible modes for Run-16 and Run-17

Run-16

STAR:

Au+Au at $\sqrt{s_{NN}}$ = 200 GeV 13 wks

Au+Au at $\sqrt{s_{NN}}$ = 62.4 GeV 4 wks

d+Au at $\sqrt{s_{NN}}$ = 19.6 GeV 1 wk

PHENIX:

Au+Au at $\sqrt{s_{NN}}$ = 200 GeV 10 wks

Option A

Au+Au at $\sqrt{s_{NN}}$ = 62.4 GeV 5 wks

p↑+p↑ at $\sqrt{s}$ = 62.4 GeV 2 wks

Option B

d+Au at $\sqrt{s_{NN}}$ = 200 GeV 1.5 wks

d+Au at $\sqrt{s_{NN}}$ = 62.4 GeV 1.5 wks

d+Au at $\sqrt{s_{NN}}$ = 39 GeV 2.0 wks

d+Au at $\sqrt{s_{NN}}$ = 20 GeV 2.0 wks

Run-17

STAR:

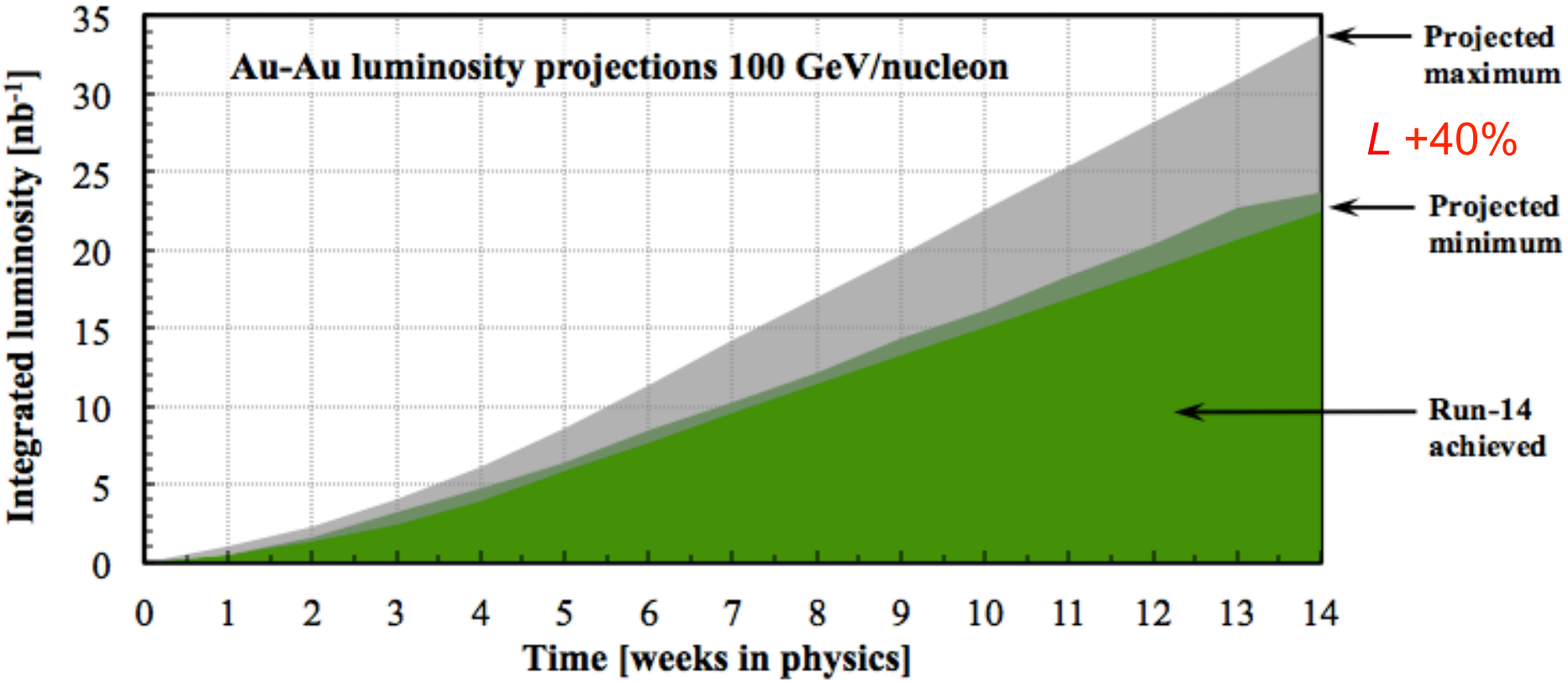
p↑+p↑ at $\sqrt{s}$ = 510 GeV 11 wks

p↑+p↑ at $\sqrt{s}$ = 19.6 GeV 1 wks

Ru+Ru at $\sqrt{s_{NN}}$ = 200 GeV 3 wks

Zr+Zr at $\sqrt{s_{NN}}$ = 200 GeV 3 wks

Run-16 Au+Au at $\sqrt{s_{NN}}$ = 100 GeV

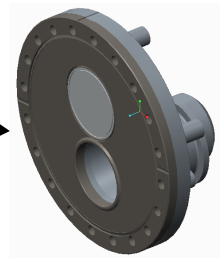


Upgrades:

56 MHz SRF operational

increases in bunch intensity

(upgraded beam dump window in 2014)



Au+Au at $\sqrt{s_{NN}}$ = 62.4, 19.6 GeV and p↑+p↑ at $\sqrt{s}$ = 62.4, 19.6 GeV

Estimates based on previous run experience

Au+Au $\sqrt{s_{NN}}$ = 62.4 GeV (STAR, Run-16)

- Run-10: $N_b = 1.2\times10^9$, $L_{int} = 110\ \mu b^{-1}$/week
- Run-16 max projection: $N_b \approx 1.6\times10^9$, $L_{int} = 500\ \mu b^{-1}$/week
  (assumes 3× cooling enhancement, not present in Run-10)

d+Au $\sqrt{s_{NN}}$ = 19.6 GeV (STAR, Run-16)

- Run-16 max projection: $N_b \approx 110/1.5\times10^9$, $L_{int} = 0.9\ nb^{-1}$/week
  (no cooling enhancement)

p↑+p↑ $\sqrt{s}$ = 62.4 GeV (PHENIX, Run-16)

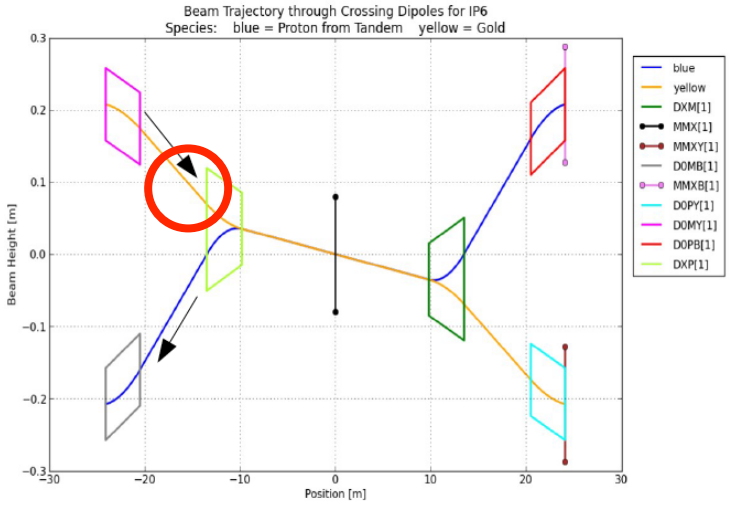
- Run-6: $N_b = 0.9\times10^{11}$, $L_{int} = 0.22\ pb^{-1}$/week
- Run-16 max projection: $N_b \approx 2.5\times10^{11}$, $L_{int} = 2\ pb^{-1}$/week

p↑+p↑ $\sqrt{s}$ = 19.6 GeV (STAR, Run-17)

- Run-10: Au+Au operation at same rigidity ($B\rho$) = 32.5 Tm
- Run-17 max projection: $N_b \approx 2.5\times10^{11}$, $L_{int} = 0.2\ pb^{-1}$/week

Run-16 operation with asymmetric species

- Run-15 RHIC machine configuration is dangerous for PHENIX with asymmetric species (damage potential to MPC amplifiers and Si vertex tracker with Yellow abort kicker pre-fire)
- Most dangerous for largest ratio of Z_1/A_1 to Z_2/A_2 (i.e. p+Au)



- Relocation of Yellow abort system in 2015 not easily possible (not fully evaluated, requires several infrastructure modifications, changes to Yellow longitudinal stochastic cooling incl. tree cutting and/or roof-top AC relocations)

- Asymmetric operation also not compatible with undulator for Coherent electron Cooling Proof-of-Principle (CeC PoP) experiment (R&D for eRHIC)
  Will delay undulator installation if asymmetric operation in Run-16

Run-16 d+Au at $\sqrt{s_{NN}}$ = 200, 62.4, 39, 19.6 GeV (PHENIX)

03/25/2015 h+Au luminosity estimates for PHENIX (request by Jamie Nagle)

$\sqrt{s_{NN}}$ [GeV]	beam E [GeV]	L_{peak} $10^{28}cm^{-2}s^{-1}$	L_{avg}/L_{peak} [%]	L/week [nb^{-1}]	σ_s [cm]	L |z|<30cm [%]	L |z|<10cm [%]	comment
200	100	17.4	58	33	35	50	20	Run-14
62	31.2	1.67	60	3.3	35	50	20	197 MHz on, cooling on for Au
39	19.5	0.66	55	1.2	35	50	20	197 MHz on, cooling off for Au
20	9.8	0.17	50	0.3	150	15	5	197 MHz off, cooling off for Au

04/16/2015 d+Au luminosity estimates for PHENIX (request by Jamie Nagle)

$\sqrt{s_{NN}}$ [GeV]	beam E [GeV]	L_{peak} $10^{28}cm^{-2}s^{-1}$	L_{avg}/L_{peak} [%]	L/week [nb^{-1}]	σ_s [cm]	L |z|<30cm [%]	L |z|<10cm [%]	comment
200	100	56	60	110	35	50	20	Run-14
62	31.2	5.37	60	10.6	35	50	20	197 MHz on, cooling on for Au
39	19.5	2.12	55	3.8	35	50	20	197 MHz on, cooling off for Au
20	9.8	0.55	50	0.9	150	15	5	197 MHz off, cooling off for Au

04/20/2015 d+Au luminosity estimates (Christoph Montag)

$\sqrt{s_{NN}}$ [GeV]	beam E [GeV]	L_{peak} $10^{26}cm^{-2}s^{-1}$	L_{avg}/L_{peak} [%]	L/week [nb^{-1}]	σ_s [cm]	L |z|<30cm [%]	L |z|<10cm [%]	comment	
14.6	7.3	65	50	0.7	150	15	5	$\gamma = 7.8$	197 MHz off, cooling off for Au
11.6	5.75	12.0	50	0.2	150	15	5	$\gamma = 6.2$	197 MHz off, cooling off for Au
7.7	3.85	2.4	30	0.02	150	15	5	$\gamma = 4.1$	197 MHz off, cooling off for Au

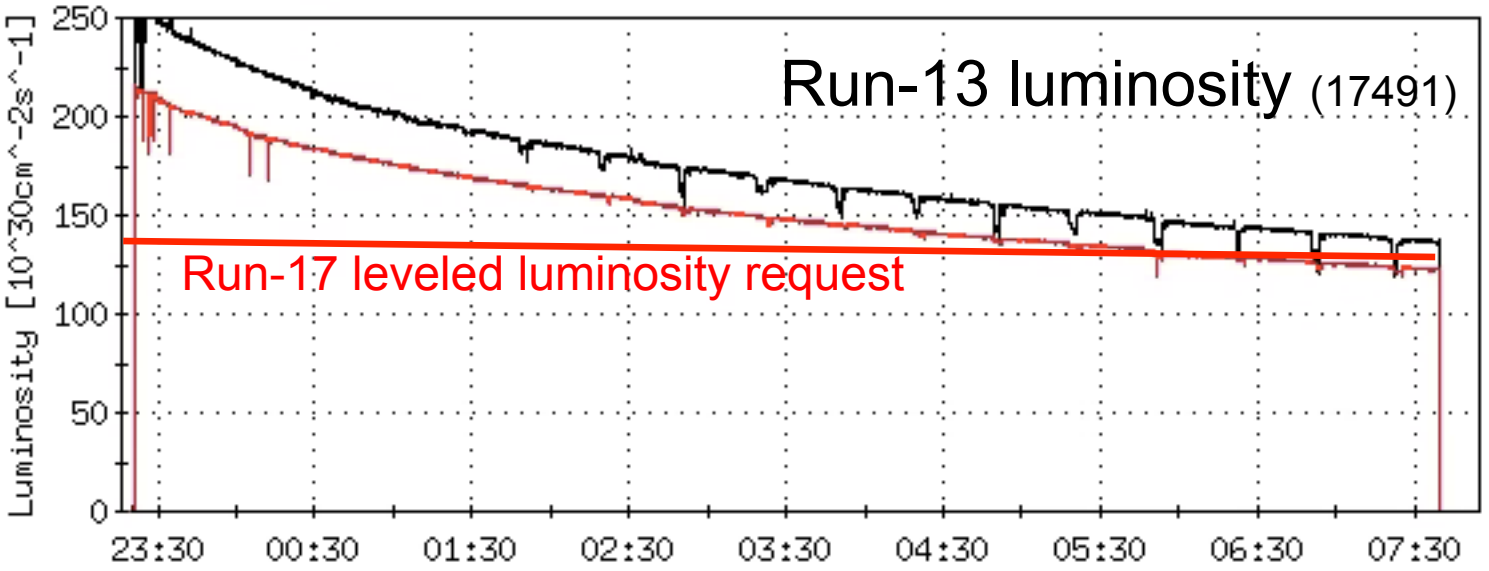
05/04/2015 p+Au luminosity estimates for PHENIX

$\sqrt{s_{NN}}$ [GeV]	beam E [GeV]	L_{peak} $10^{28}cm^{-2}s^{-1}$	L_{avg}/L_{peak} [%]	L/week [nb^{-1}]	σ_s [cm]	L |z|<30cm [%]	L |z|<10cm [%]	comment
200	100	80	50	120	35	50	20	Run-15
62	31.2	7.7	60	13.8	35	50	20	197 MHz on, cooling on for Au
39	19.5	3.0	55	5.0	35	50	20	197 MHz on, cooling off for Au

Run-17 p↑+p↑ at $\sqrt{s}$ = 510 GeV (STAR)

STAR requested level luminosity at 1.3×10^{32} cm^{-2}s^{-1}

(0.9 events per bunch-bunch crossing, ≈ 50% of Run-13 max, ≈ 30% of Run-17 expected max)



Possible methods for leveling:

- Dynamic β* change during store (tested in Run-14)
- Changing transverse offset with electron lens (needs study)

New operating mode, plan for $L_{avg} \approx 90\%\ L_{peak}$

Need Run-17 also for high-luminosity test for sPHENIX era

Ru+Ru and Zr+Zr Run-17 at $\sqrt{s_{NN}}$ = 200 GeV (STAR)

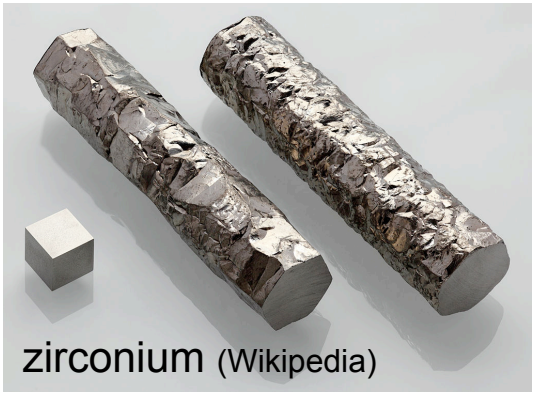
- Full intensity = Ru, Zr charge per bunch ≥ Au charge per bunch

- Need enriched source material for laser ion source or hollow cathode source
  Ru-96 abundance 5.6%,
  Zr-96 abundance 2.8%


ruthenium grown out of gas phase (Wikipedia)

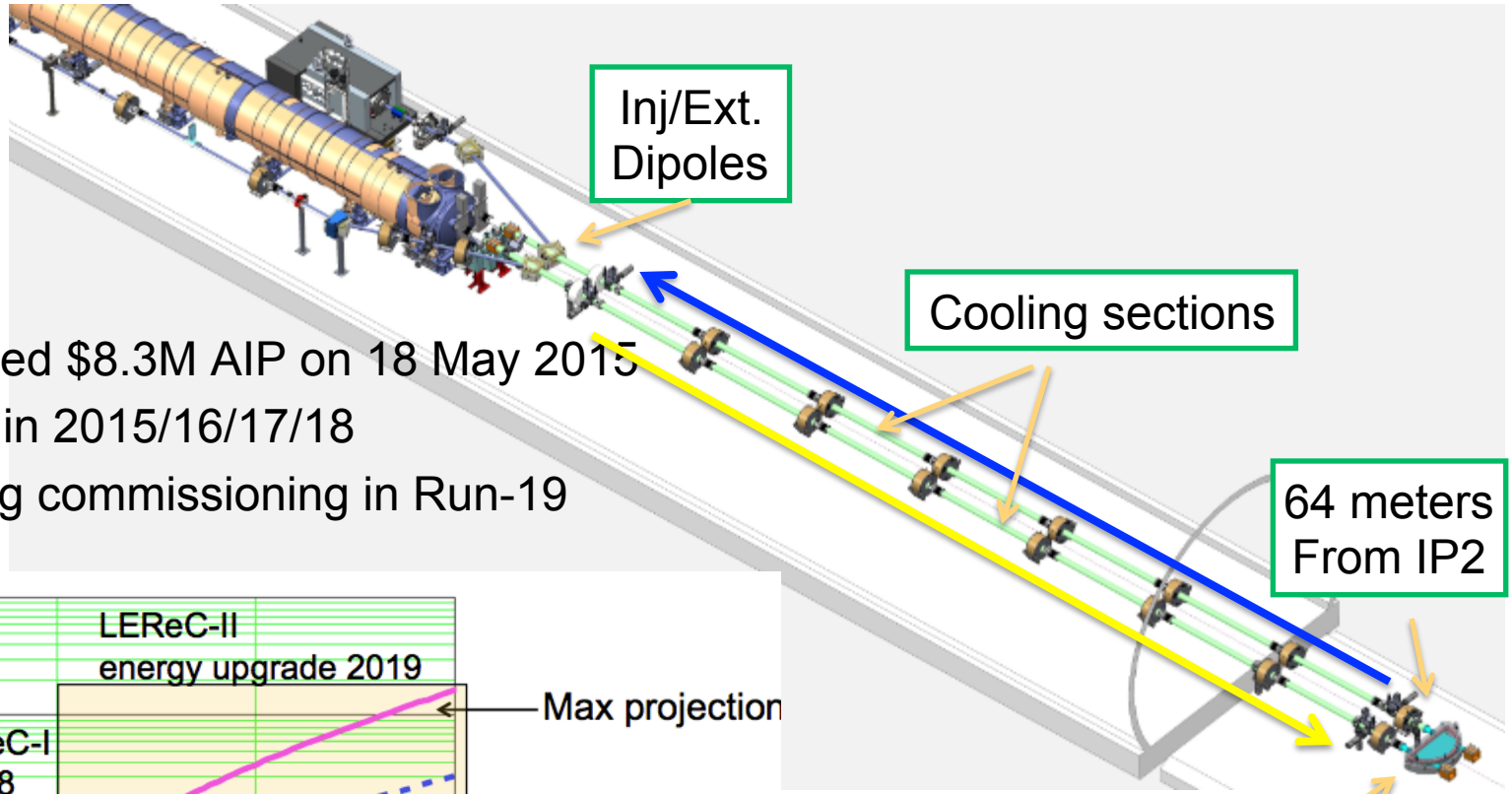
- Enriched Zr-96 available in metallic form
  => can run at full intensity

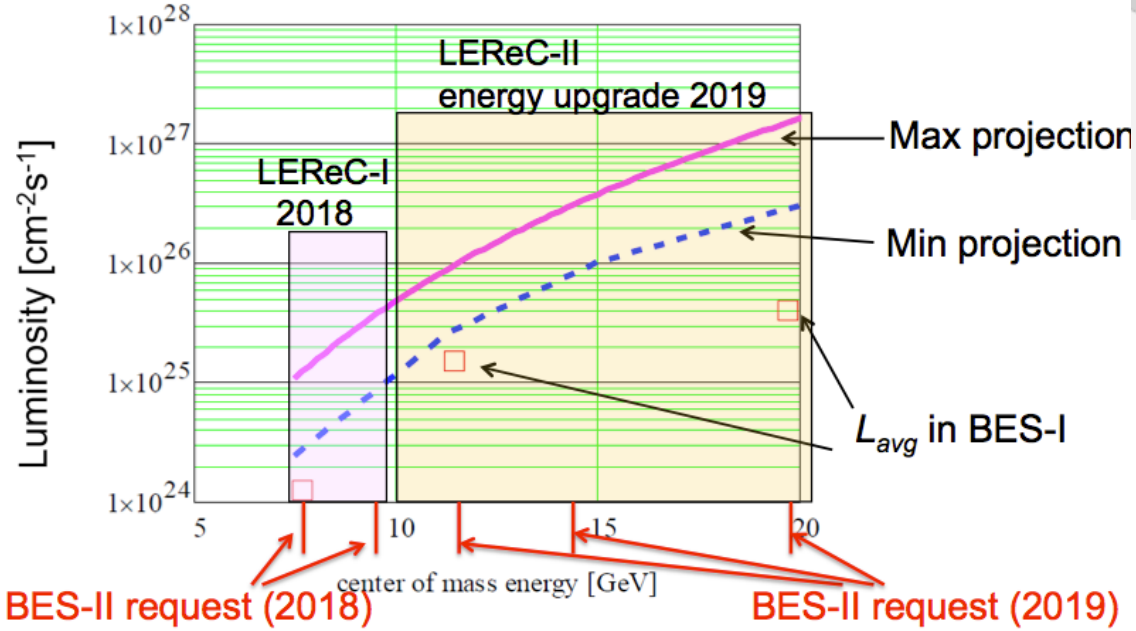
- Enriched Ru-96 not available from any source (still searching ...)
  Need ≈ 1 g for operation
  Have 40 mg in hand (97.92% enriched)
  400 mg target material at GSI
  => can likely run at 5% of full intensity
  Need test low intensity operation in Run-16


zirconium (Wikipedia)

Low Energy RHIC electron Cooling Phase-I

- DOE approved $8.3M AIP on 18 May 2015
- Installations in 2015/16/17/18
- Begin cooling commissioning in Run-19





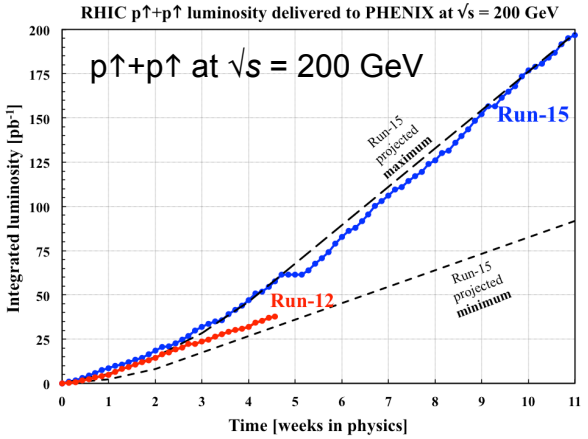
BROOKHAVEN NATIONAL LABORATORY

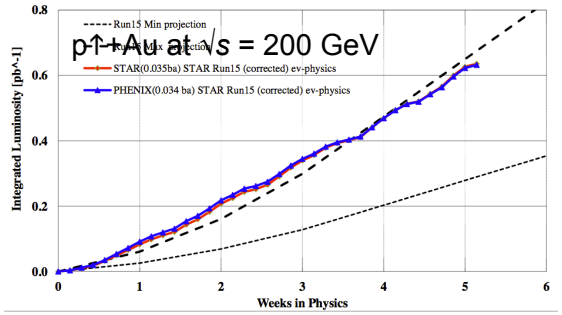
RHIC Run-15 and Run-16/17 projections

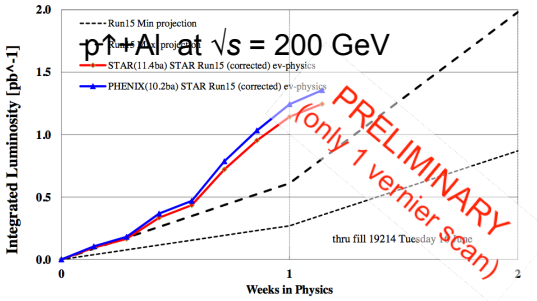
Summary

Run-15

- p↑+p↑ at $\sqrt{s}$ = 200 GeV
  - record luminosities (L_{week} = 2.7× Run-12)
  - periods of lowered P
- p↑+Au at $\sqrt{s}$ = 200 GeV
  - met max luminosities goals, $P \approx 60\%$
  - PHENIX detector damage with Yellow pre-fire
- p↑+Al at $\sqrt{s}$ = 200 GeV
  - ongoing, on track to met max luminosities goals







Run-16

- Au+Au at $\sqrt{s_{NN}}$ = 200 GeV *L* +40% relative to Run-14
- Au+Au $\sqrt{s_{NN}}$ = 62.4, 19.6 GeV and p↑+p↑ at $\sqrt{s}$ = 64.2
  - luminosity estimates based on previous runs
- Asymmetric operation risky to PHENIX without significant changes to machine (difficult to implement for Run-16)

Run-17 (STAR only)

- p↑+p↑ at $\sqrt{s}$ = 510 GeV with luminosity leveled at 1.3×10^{32} cm^{-2}s^{-1}
- p↑+p↑ at $\sqrt{s}$ = 19.6 GeV
- Zr+Zr, Ru+Ru Ru-96 intensity may be low (≈ 5% of Au charges)