Heavy Photon Search at Jefferson Lab

HPS Overview

Online Collaboration Meeting, June 23, 2021

University of New Hampshire

Maurik Holtrop

Outline

- The Collaboration
- Organization
- Beam time
- Completing the 2016 publication.
- The 2019 run
- This Fall: the 2021 run
- Future runs

HPS Collaboration

Membership

- New members: Prof. Laura Tompkins (Stanford)
- Graduated: Dr. Sam McCarty
- What is happening with the HPS membership?
  - **For 2019 run:**
    - 74 members (as reported by shiftbot)
    - 58 members took shifts.
  - **For 2021 run:**
    - 50 members (shiftbot & self reporting they will participate.)

Shiftbot: https://www.jlab.org/Hall-B/hpsshifts/index.php?display=utils&task=ComplInst

HPS Organization

Spokespeople:

Stepan Stepanyan (JLab), Tim Nelson (SLAC), Maurik Holtrop (UNH)

Executive Committee:

Stepan Stepanyan (JLab - chair), John Jaros (SLAC-ex officio), Maurik Holtrop (UNH), Tim Nelson (SLAC), Norman Graf (SLAC), Marzio De Napoli (INFN Catania), Omar Moreno (SLAC), Rafayel Paremuzyan (JLab)

Publications and Presentations Committee:

Norman Graf (SLAC - chair), Gabriel Charles (Orsay), Alessandra Filippi (INFN Torino), Rouven Essig (Stony Brook), Matt Graham (SLAC)

Analysis Review Committees:

Vertexing analysis 2016, lead by Matt Graham:
Cameron Bravo (SLAC), Tongtong Cao (UNH), Andrea Celentano (INFN - Chair).

HPS Organization

Working groups and Coordinators:

Preparations for 2021 Run:

SVT - T. Nelson (SLAC)

ECal/Hodoscope - R. Paremuzyan (JLab)

Beamline - S. Stepanyan (JLab)

DAQ - S. Boyarinov (JLab), R. Herbst (SLAC)

Trigger - V. Kubarovsky (JLab)

Monitoring - M. Graham (SLAC)

Slow Controls - N. Baltzell (JLab) O. Moreno (SLAC)

Data Calibration, Analysis :

Analysis - M. Graham, C. Bravo (SLAC)

Calibration, reconstruction - N. Graf, P. F. Butti (SLAC)

Monte-Carlo - T. Cao (UNH)

Software, computing - N. Graf (SLAC)

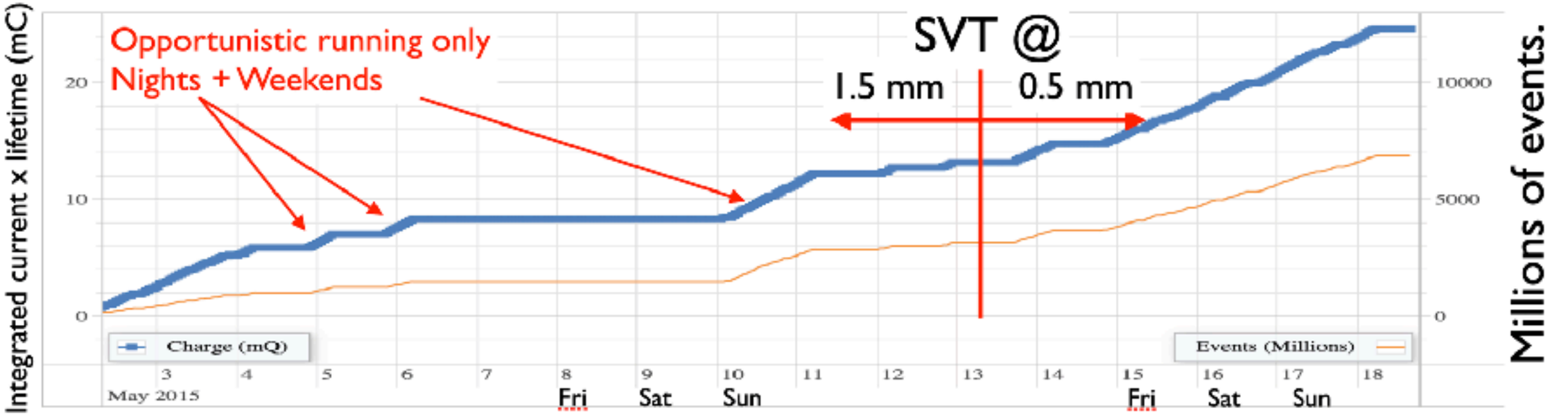
Data: Engineering Runs

- Data from our engineering runs in 2015 and 2016.
- 2015: Beam Energy 1.1 GeV
  - Mar 1 - May 18 = 79 days of shifts*.
- 2016: Beam Energy 2.2 GeV
  - Feb 5 - April 25 = 54 days of shifts*.

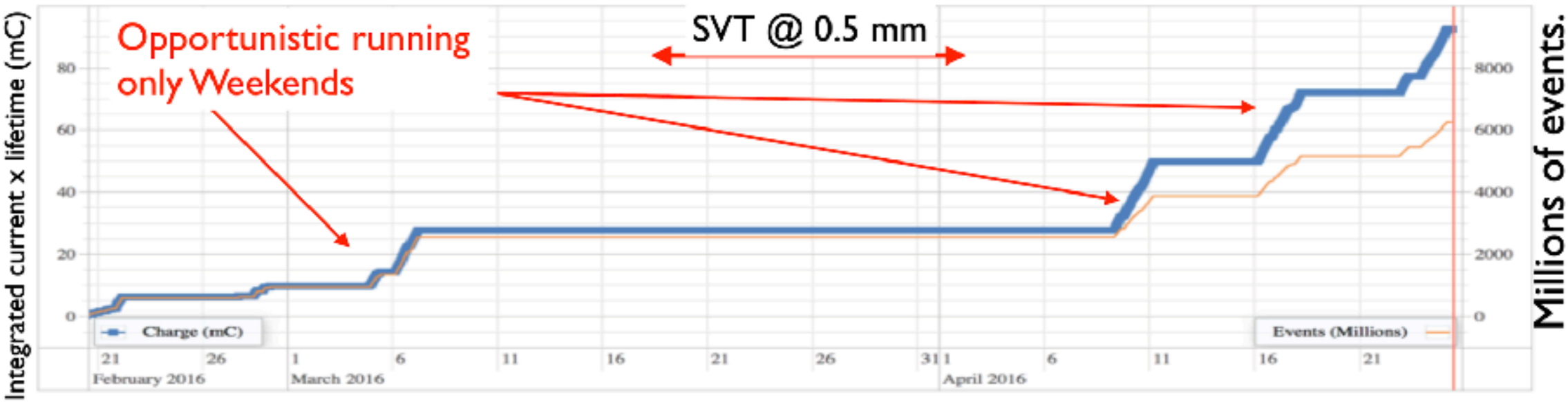
* Scheduled shifts, actual shifts had a lot of cancellations and gaps.

Data: Engineering Runs

2015: 50 nA, 1.1 GeV beam on target, 10 mC at 0.5 mm (1.7 PAC days)

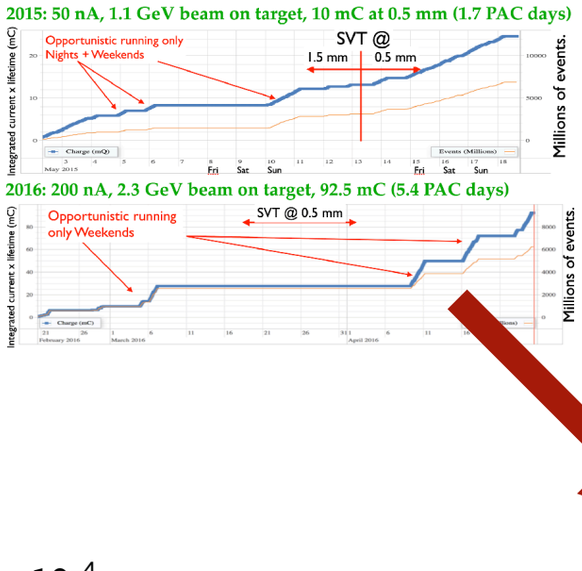


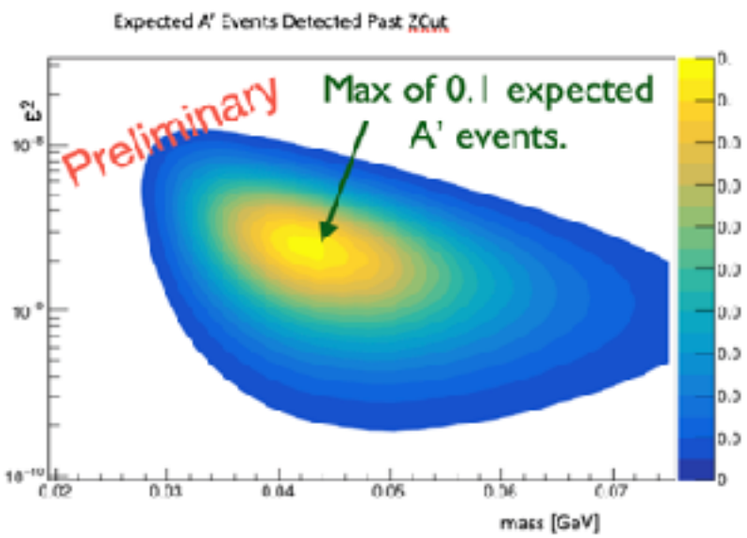
2016: 200 nA, 2.3 GeV beam on target, 92.5 mC (5.4 PAC days)

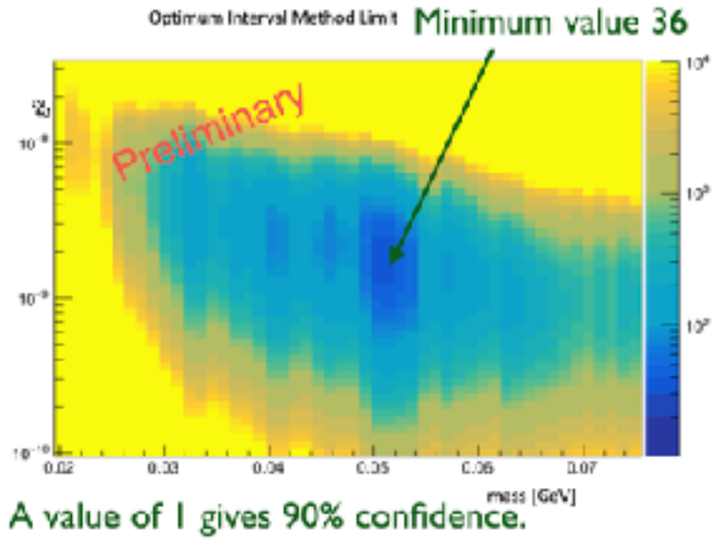


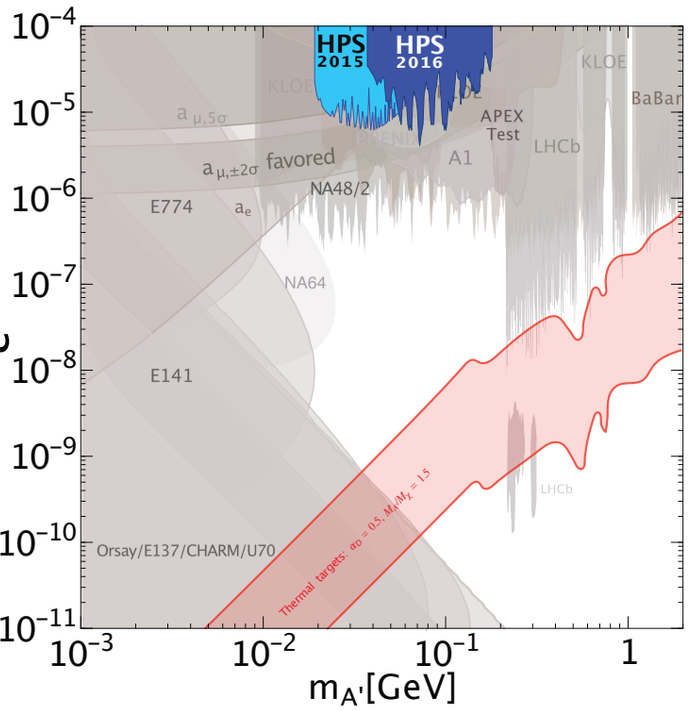
Data taken under challenging circumstances in 2015 and 2016

Data: Engineering Runs









Papers:

HPS 2015 bump-hunt search (Phys.Rev. D98 (2018) no.9, 091101)
HPS Test Run NIM (NIM A777, pp 91-101)
HPS Ecal NIM (NIM A854, pp. 89-99)
HPS Beamline NIM (NIM A859, pp. 67-75)
HPS SVT NIM (tbd)
HPS 2016 Bump-hunt + vertex paper. (tbd)

Dissertations:

"Heavy photon displaced vertex search at 2.3 GeV with prospects for true muonium discovery" (Bradley Yale, UNH)
"Dark Photon Search with the HPS Experiment at JLab" (Ani Simonyan, Yerevan)
"Search For a Heavy Photon in the 2015 Engineering Run Data of the Heavy Photon Search Experiment" (Omar Moreno, UCSC)
"Searching for heavy photons in the HPS experiment" (Sho Uemura, SLAC)
"Searching for displaced heavy photons in 2015 engineering run" (Holly Szumila-Vance, ODU)
"Searching for a Dark Photon in the HPS Experiment" (Sebouh Paul, W&M)
"Search for an A' Resonance in the Heavy Photon Search 2.3 GeV Data Set" (S. McCarty, UNH)

Data: Engineering Runs

- The engineering runs:
  - Got the rest of the HPS beam time approved.
  - Taught us the importance of WABs.
  - Motivated an upgrade of the SVT.
  - Motivated an upgrade of the Trigger by adding a Hodoscope.
  - Enabled the development of calibrations & alignment.
  - Enabled the development of analysis techniques.
- **A lot was accomplished!**

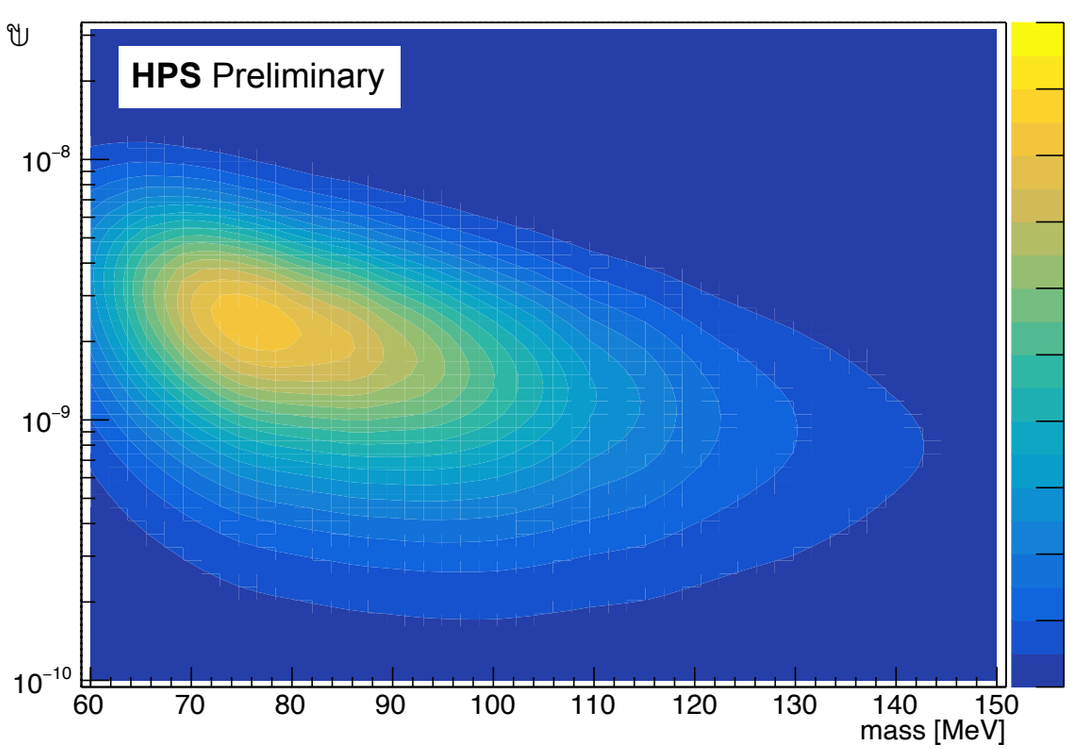
Completing the 2016 publication

- Nearly there! See Matt Graham's presentation Friday.
- This has been a long time coming!

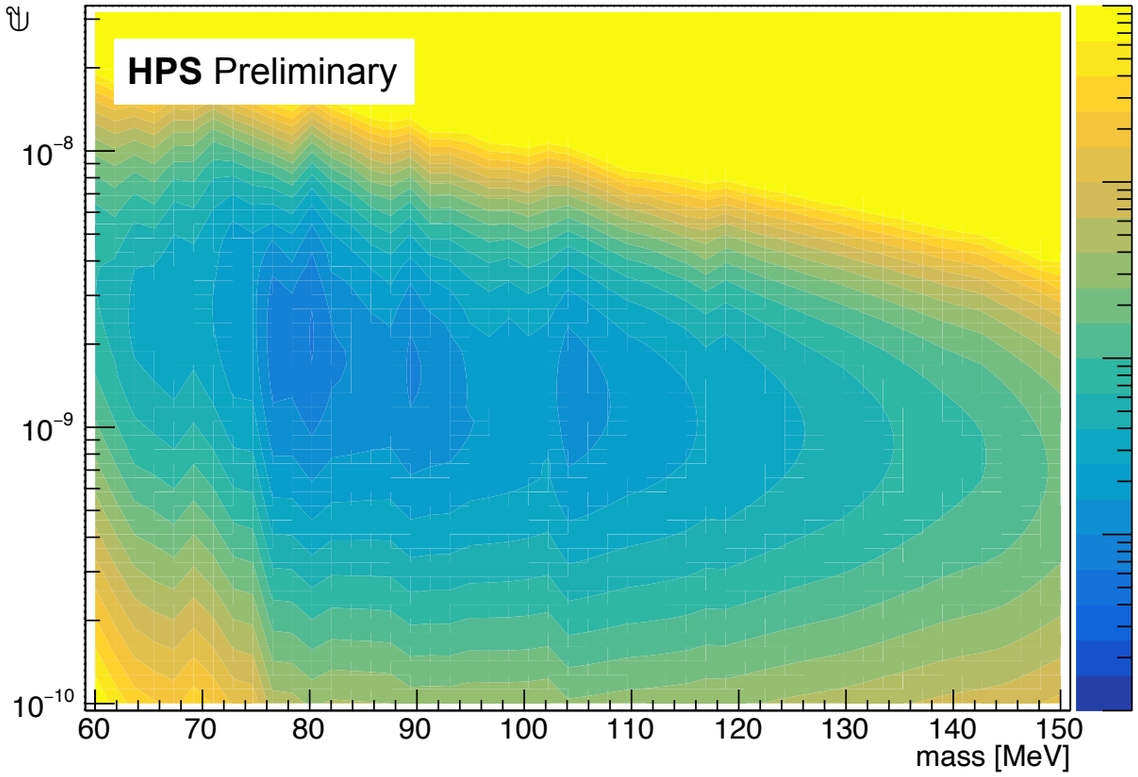
Vertex Results 2016

Yellin, S. Finding an Upper Limit in the Presence of Unknown Background. *Phys. Rev. D* 66, 3873 (2002). arXiv:physics/0203002v2

Minimum value of ~7x$\sigma_{A'}$ @ 90% C.L.

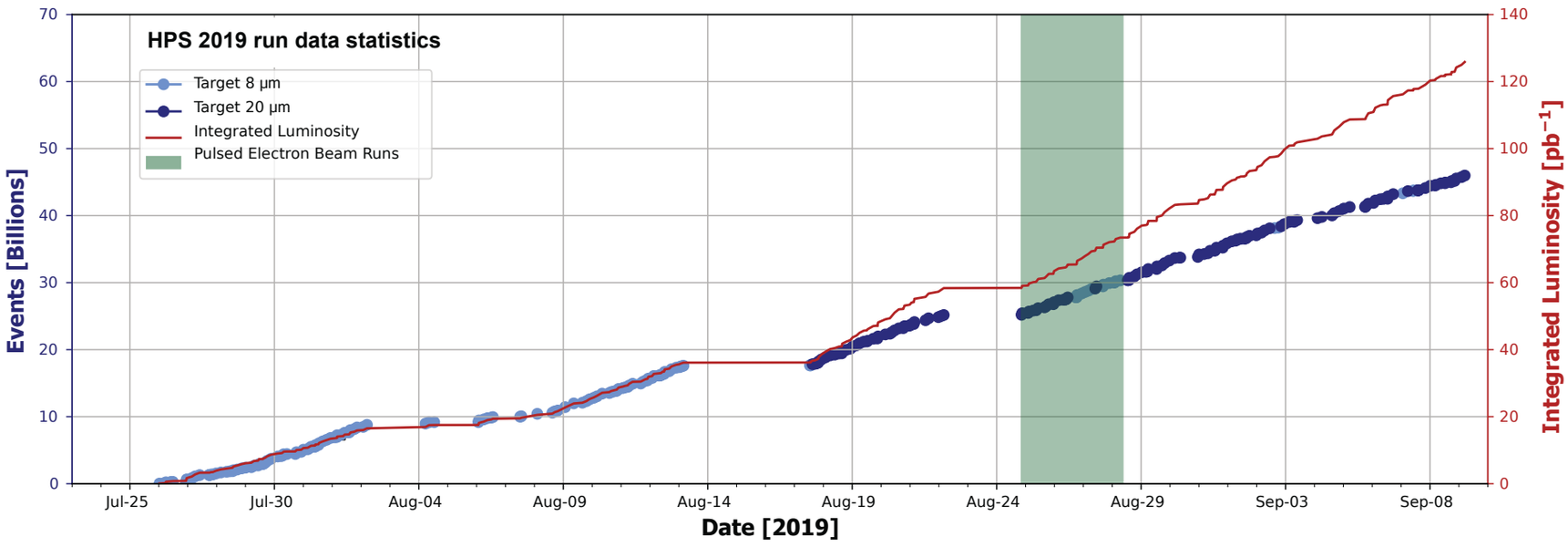


Max of expected ~0.3 expected A' events



A value of 1 gives 90% confidence exclusion.

Physics Run 2019 @ 4.55 GeV



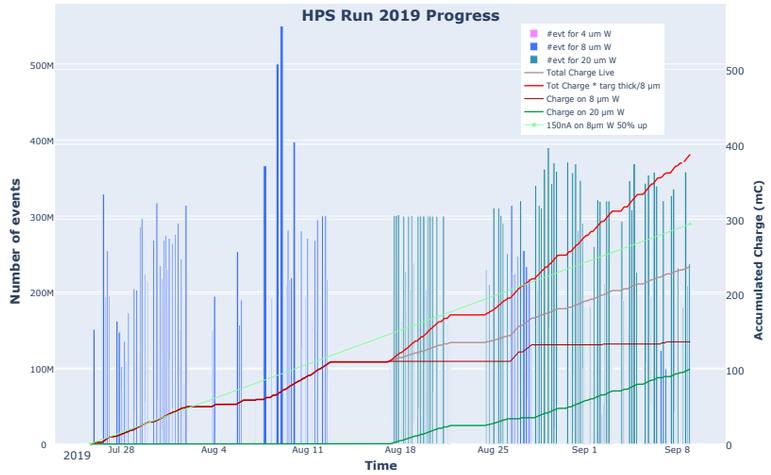
graph from PF

Proposed:
4 Weeks @ 4.4 GeV
I = 300 nA on 8μm W target
Integrated charge = 725 mC
$\mathcal{L} = 2.29*10^{38}$ cm^{-2} = 229 pb^{-1}

Measured:
3.5 Weeks @ 4.4 GeV
I~150 nA on 8μm & 20 μm W
Integrated charge ~ 386 mC
$\mathcal{L} = 1.22*10^{38}$ cm^{-2} = 122 pb^{-1}

Again a challenging run, but for different reasons:

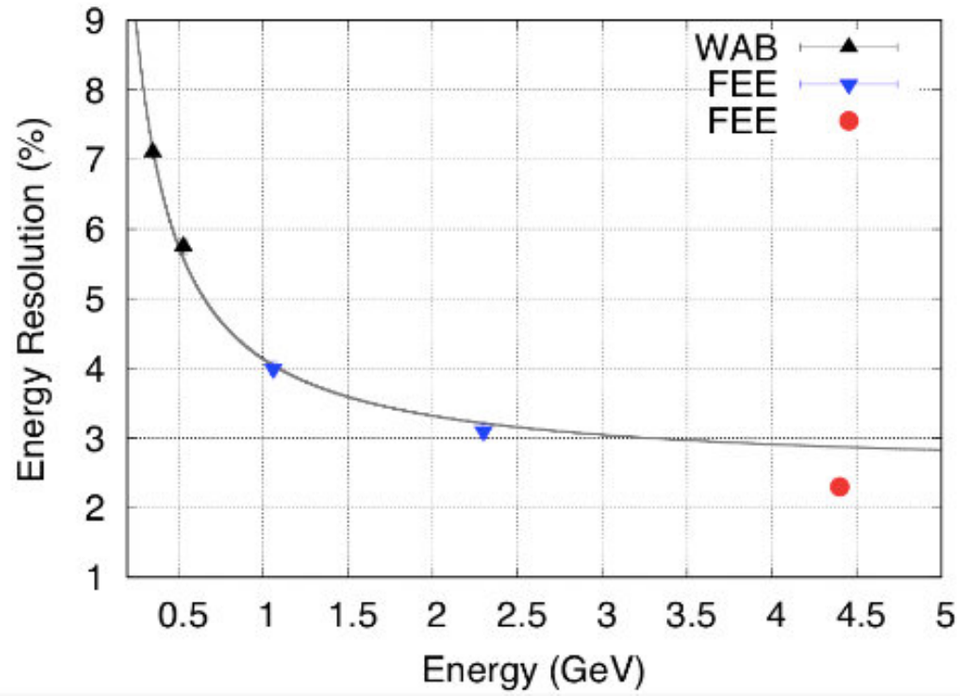
- CEBAF issues: power loss, other equip issues, running parallel to parity exp = beam tuning!
- Conditions in alcove causing SVT issues, FEB damage.
- First running with a lower current, then using a thicker target.

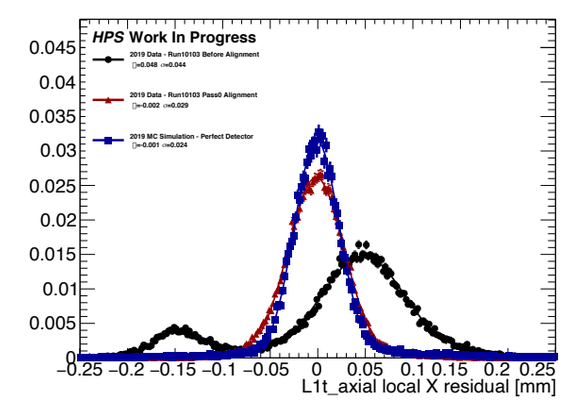


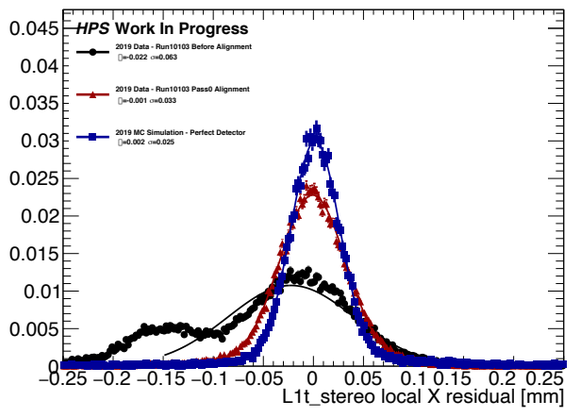
⇒ About 1/2 the expected luminosity (on a thicker target.)

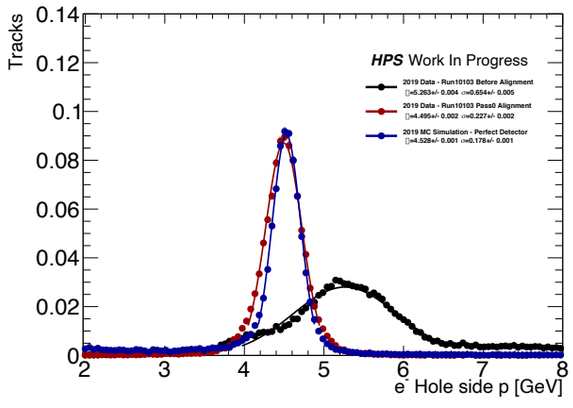
2019 data: Calibrations

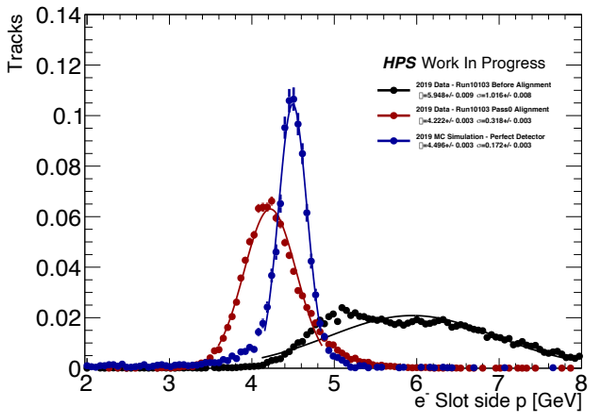
- Calibrations for 2019 data are still not quite complete:
  - After this talk:
    - Kalman Filter - Robert
    - Tracker Alignment - PF
    - Data Processing - Norman

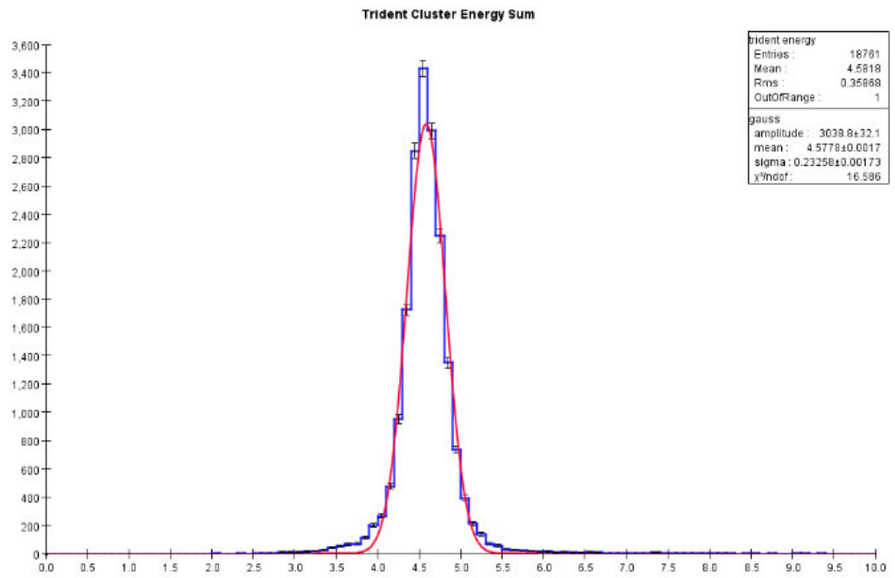












2019 data: Processing

- So far we have processed only a tiny fraction.
  - Pass 0:
    - ~1% of data - Check calibrations, consistency, …
  - Pass 1: After calibrations are done. ⇐ We are almost here!
    - 10% of data - For the actual analysis tune up.
  - Pass 2: After analyses are solid, preparing to unblind.
    - 100% - For publication.
- We need to keep in mind the CPU time required to process all this data, and the storage space required for the output.
  - New Kalman Fitter and seed finder will help.
  - Code speedups: early cuts, optimizing algorithms.
  - Reduce the LCIO output file size drastically. ⇐ Needs input!

2019 data: Monte Carlo

- Much more data will also require much more Monte Carlo.
- Pass 0: MC samples are already being generated. -Tongtong
  - Need: improve MC - Data agreement.
  - Already quite a bit of incremental progress made here.
- Pass 1: Analysis will require large (very large) data MC sets.
    - Better scripting and job submission ✓
    - MC speedup will be required:
      - WAB biassing (needs completion/testing)
      - Background merging ✓ (needs a bit more testing)
      - Use Open Science Grid (not much done, do we need this?)
- Producing a lot of MC will need to start early, but it requires freezing the detector model: Alignment needs to be done.

2019 data: Analysis

- Some analysis started, but mostly calibrations.
- **We had promised results in 2021!**
- Needed:
  - Refining the golden run list.
  - Trigger study: The trigger was very different.
  - Tracking efficiency: Promising early results from Kallman Filter.
  - Mass resolution: No more Møllers, so this will be new.
  - Radiative fraction
  - Cut optimization
- From the 2015 & 2016 analyses, there is now a fairly clear recipe for resonance search & vertexing.
  - Refinements always needed.
  - As always, things will be a little different this time around…

SIMPS

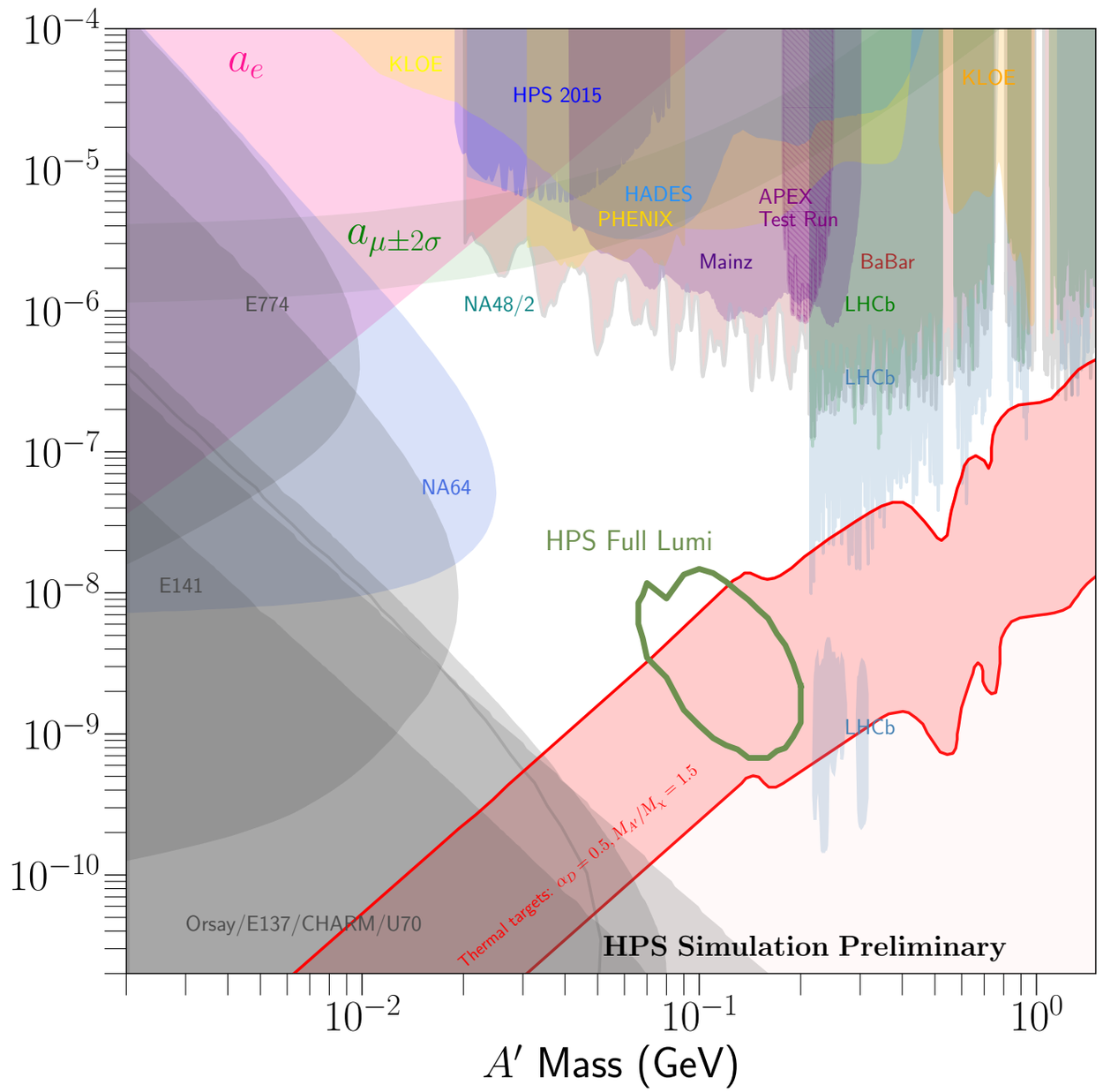
- As a collaboration, we should not loose sight of the additional physics we can get from our data.
- The 2019 dataset will possibly be a rich place to look.
- So will 2021 data set.

HPS Remaining Beam Time

- At PAC 48 we successfully defended our remaining beam time.
  - Remaining beam time is ~135 PAC days.
    - 27.5 PAC days (~ 4 weeks) in 2021 @ 3.7 GeV
    - 10 more weeks at ~ 4 GeV
    - 6 more weeks at ~2 GeV

Summary of PAC report:
The PAC recommends the approval of 135 PAC days of beam time for running with beam energies from ≈ 2 GeV to ≈ 4 GeV.

Full luminosity vertex reach.



HPS approved plots: Cameron

This Fall: 2021 Run

- **Run Group I:**
- Beam energy = 3.7 GeV, Targets 8 + 20 μm W.
- On Accelerator schedule: August 23 - October 16
- 55 calendar days, or 27.5 PAC days (almost 4 weeks)
- Shifts: on-site experts, remote workers.
  See Marzio's talk on Thursday.

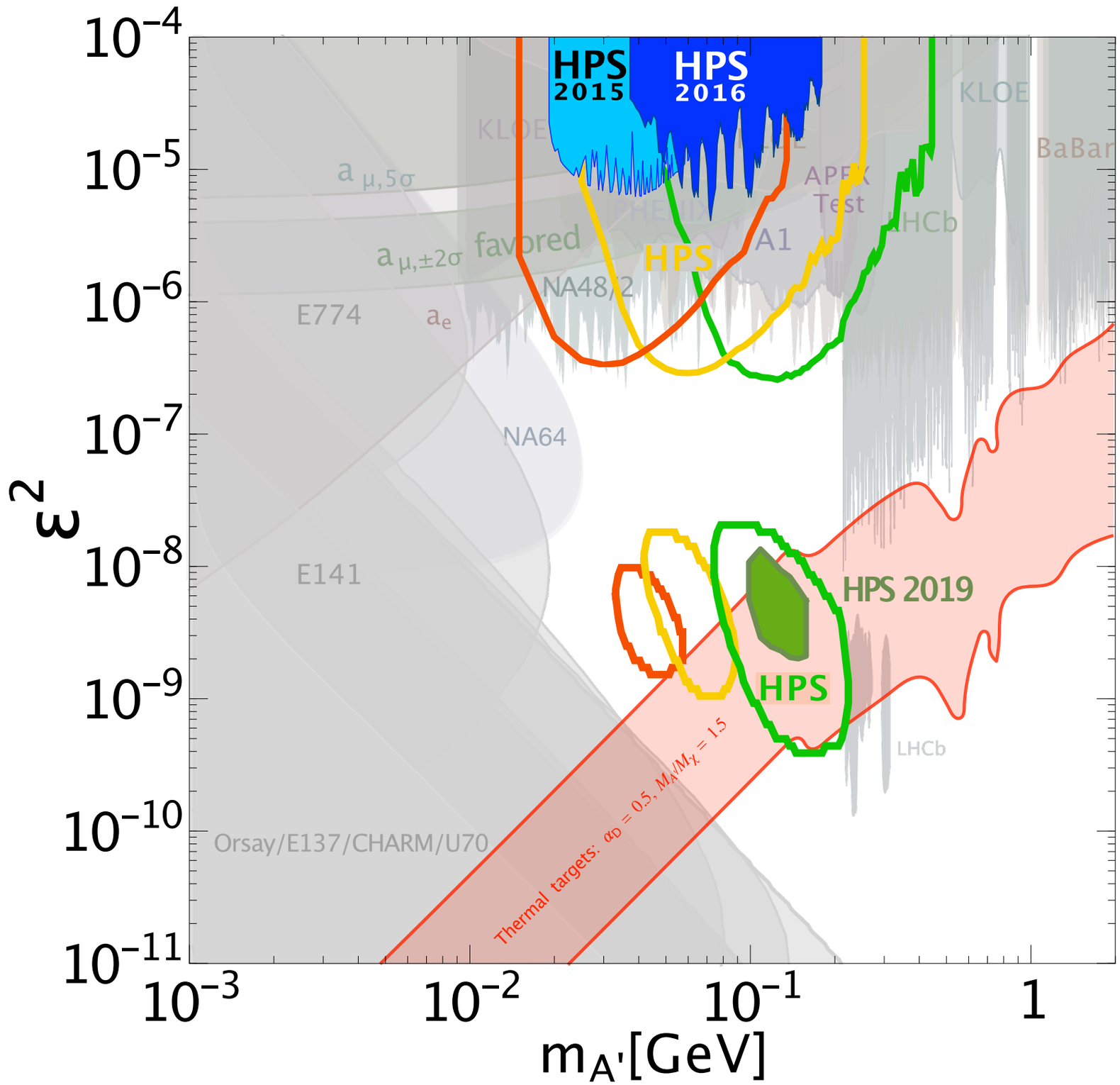
This Fall: 2021 Run

- Preparations for the run, after coffee break:
  - Timeline for installation - Stepan/Bob
  - Update and plans for SVT - Tim
  - New modules - Cameron
  - New FEBs - Omar
  - SVT/DAQ - PF
  - DAQ - Sergey
- Tomorrow morning:
  - Beamline - Stepan
  - ECal/Hodoscope - Nathan
  - Trigger for HPS - Valery
  - Singles Trigger - Sam
  - Moller and pair trigger - Tongtong
- Tomorrow after coffee:
  - Slow controls/remote shifts - Nathan
  - DQM - Matt
  - Shifts/Remote shifts - Marzio
  - Run Plan/ Run Conditions - Tim

Reach

Summer 2019 Run
2 PAC Weeks @ 4.55 GeV

Previous estimate: Full HPS Program
2019 Run
4 PAC Weeks @ 4.4 GeV
4 PAC Weeks @ 2.2 GeV
~~4 PAC Weeks @ 1.1 GeV~~

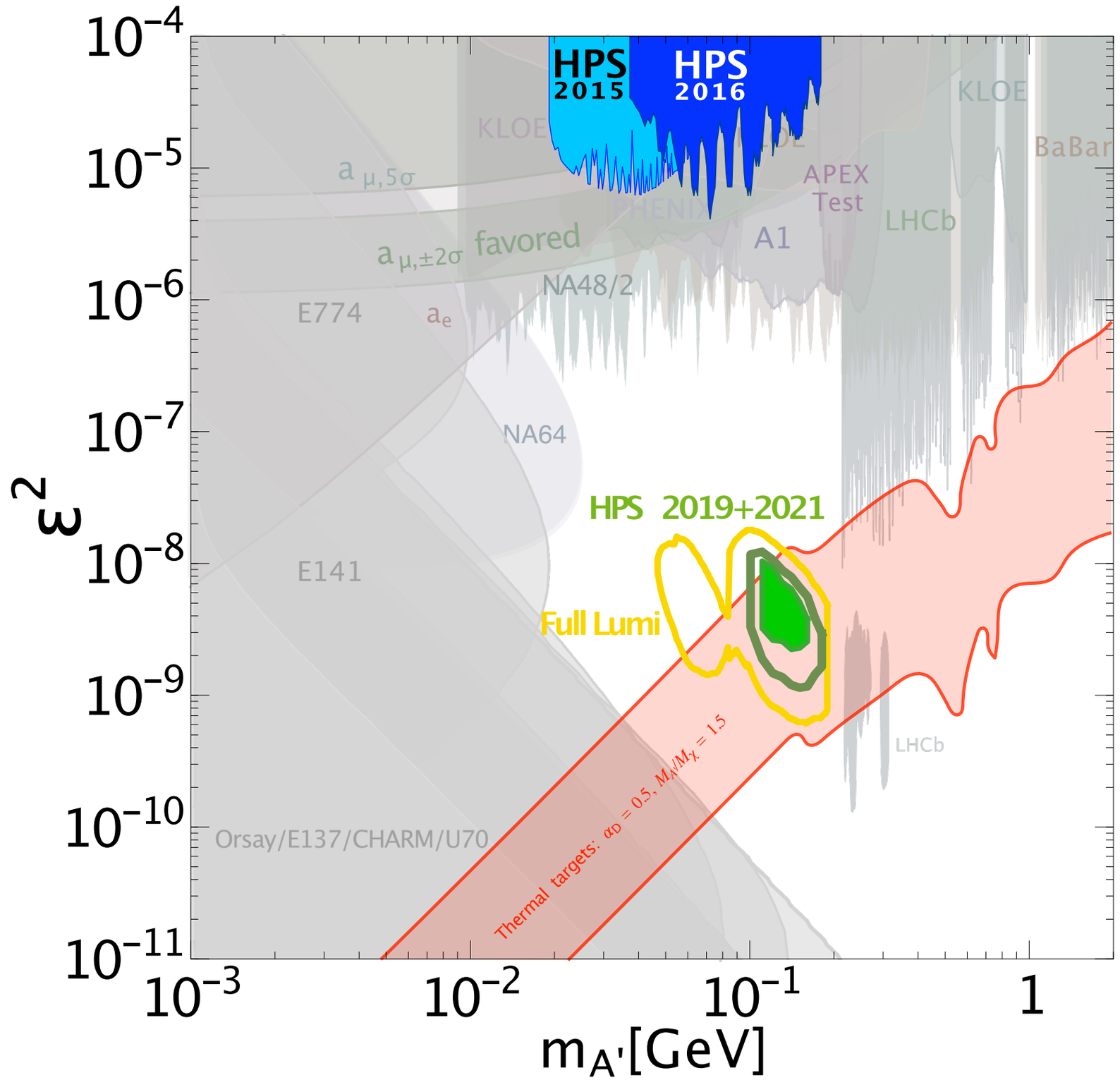


Reach revisited

Summer 2019 Run
2 PAC Weeks @ 4.55 GeV

New estimates:
Full HPS Program
2019 Run
2019+2021 Run
Full Luminosity
(+6 weeks 4.4 GeV
+4 weeks 2.2 GeV)

Caveat: I created the overlay of these plots



Reach perspective

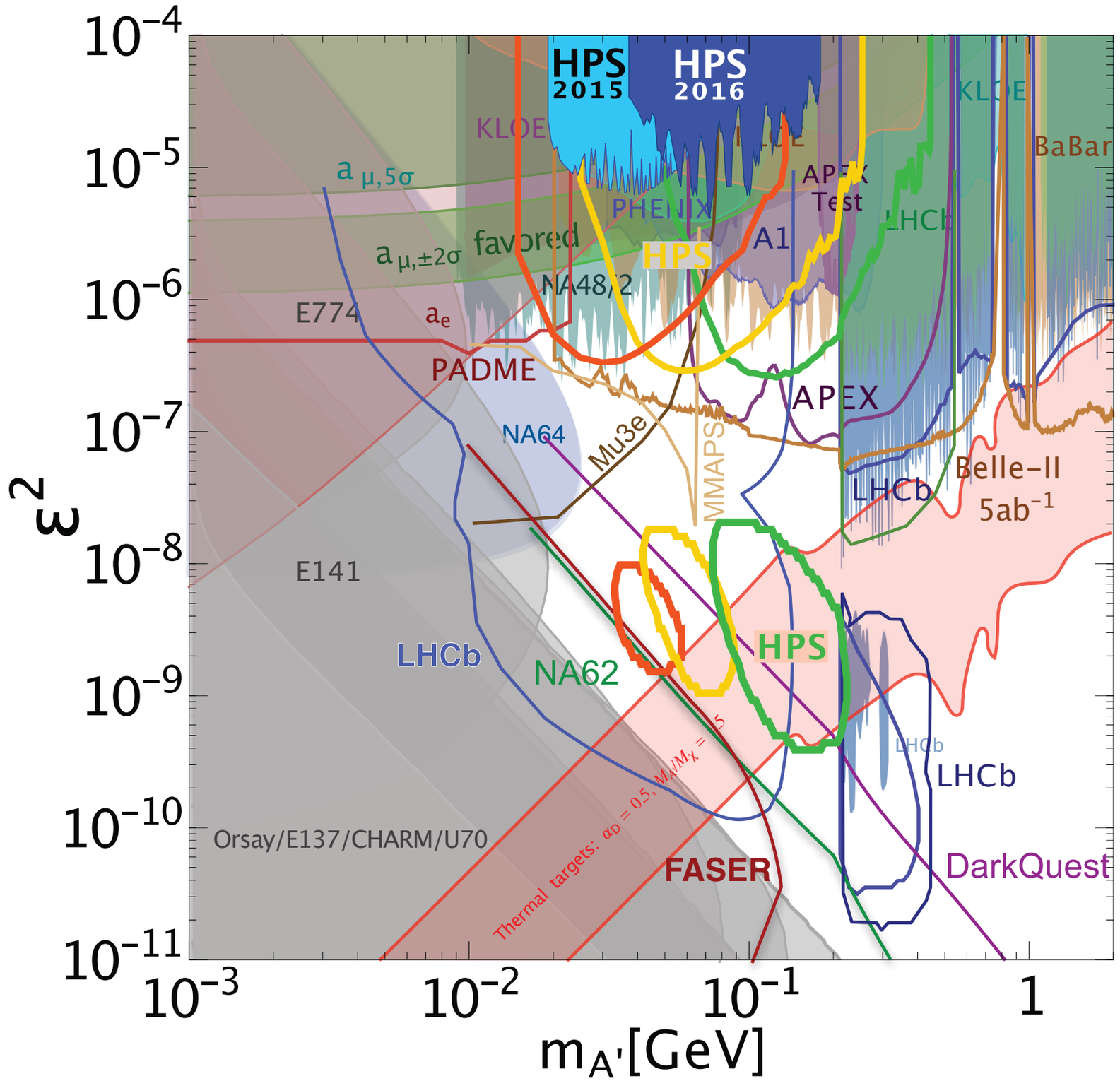
Adding all the other future experiments, it gets crowded.

HPS still has a unique region.

Warnings:

- Not all systematics are generally taken into account.
- Experiments often do not quite get what they hope for.
- Combining these curves is not (quite) as simple as this plot.

Caveat: I created the overlay of these plots.
Other experiment limits from Tim's talk @ iDMEu



Concluding

- A decade and a pandemic later:
  - Heavy Photon Searches are still exciting
  - HPS is still quite relevant.
- We must publish 2016 soon!
- We have a significant amount of data at 4.55 GeV from the 2019 run.
  - Calibration is under way, initial analysis starting soon.
- We are getting ready for the 2021 run
  - Working on detector repairs.
- Prospects are good for future runs and more physics results.