

Beam Overview and Updates

Anna Soter and Peter Kammel

- Status
- Tasks
 - G4BL
 - AI and machine learning
 - Major beam design
- Plans

References

- Paul Fisher [DocDB 241-v1](#)
- Anna & Peter: [DocDB 212-v1](#)
- Peter: [Coll meeting 2023 talk](#)

Beam: piE5 @ PSI - World's Brightest Stopped Pion Beam

- Progress 2023

From my PAC at PSI talk in Feb. 2024

- PIONEER requirements and test beam 2022 results

- Rate: 300k π /s stopped in ATAR: ok at 65 MeV/c
 - Momentum bite: $\Delta p/p < 2\%$: marginal
 - Spot size: < 2 cm FWHM: not achieved
 - μ, e less than 10% π : needs second focus extension

- improved understanding and optimization

- non-linear effects due to large phase space
 - beamline model with G4BL
 - novel promising machine learning approach (Adelmann et al)

- Plans 2024

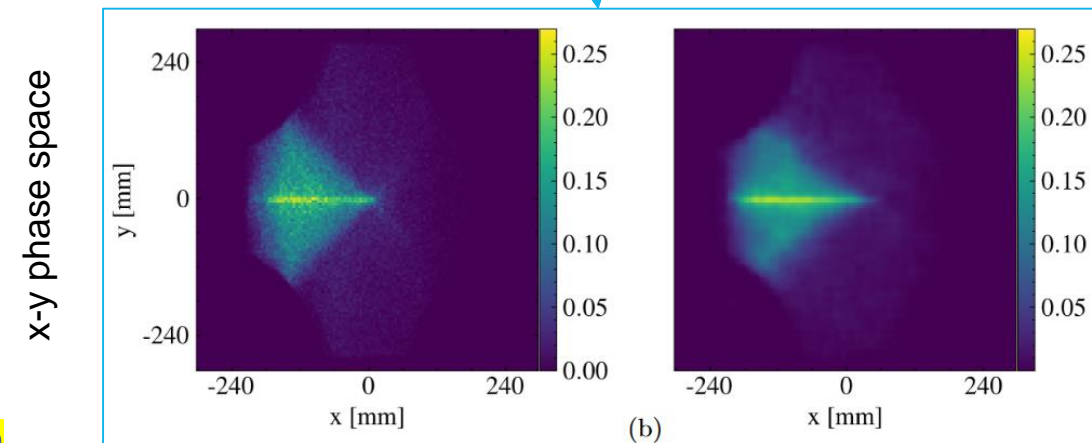
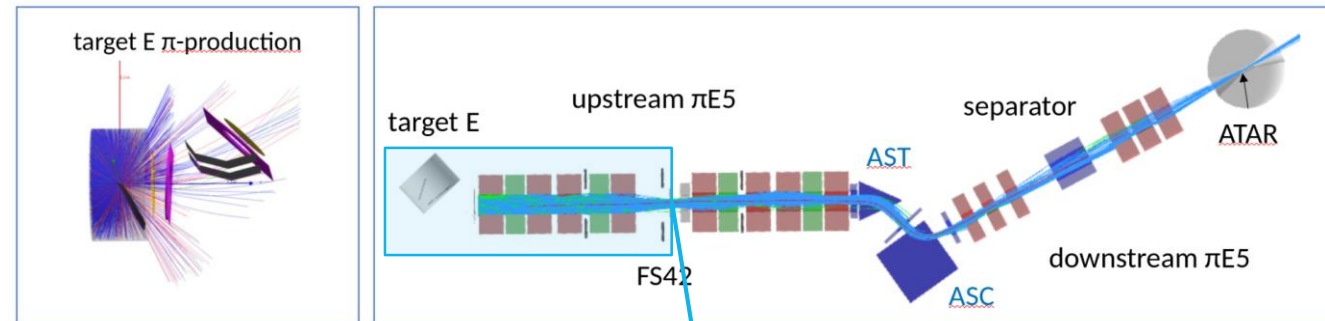
- machine learning

- extend machine learning to full beam line
 - optimization of beam properties
 - prepare experimental verification

- beam design

- 2nd focus extension
 - better focus
 - retune for smaller $\Delta p/p < 2\%$

request PSI support in design

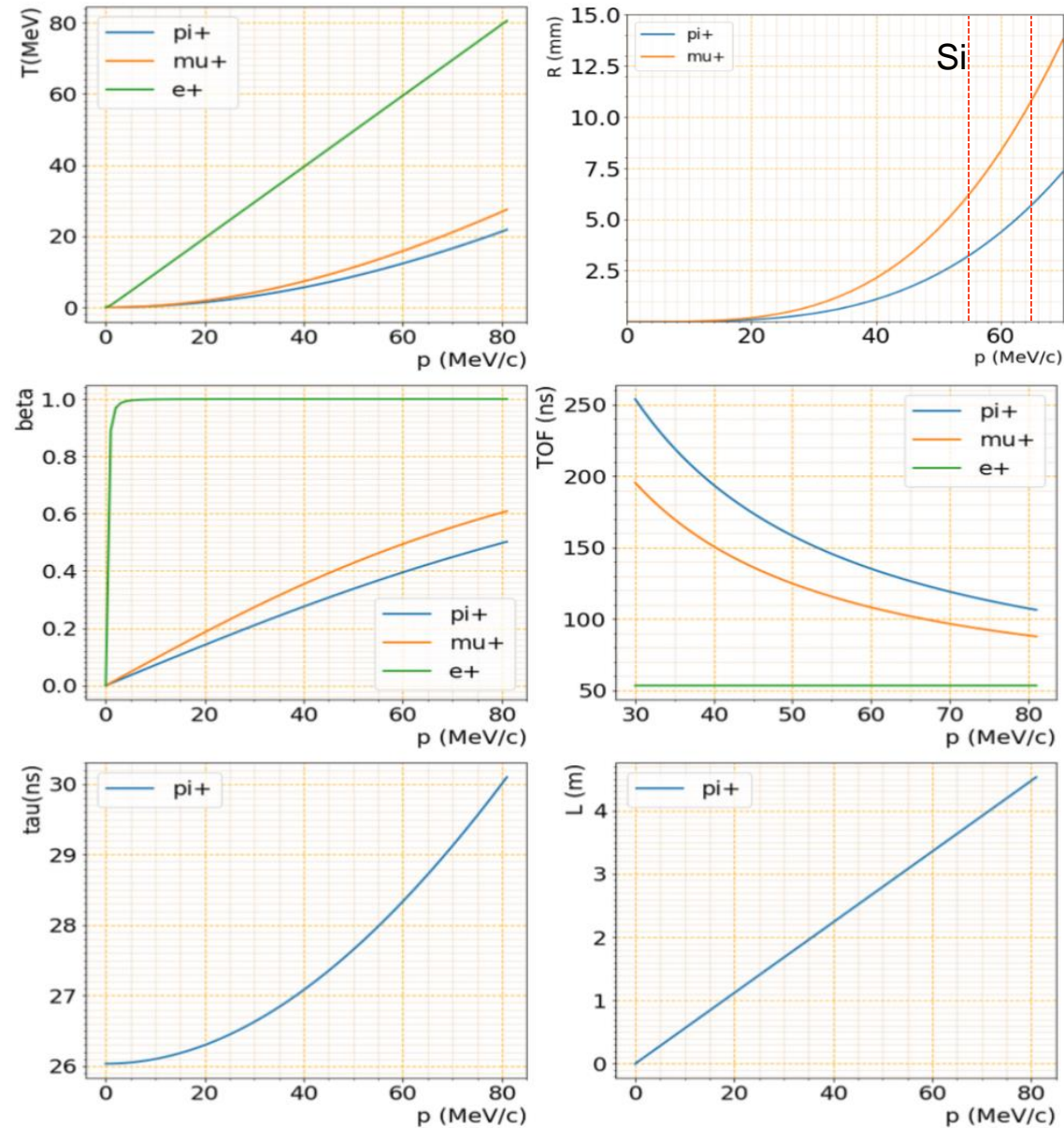


G4BL

surrogate model
~ 10⁴ faster

P. Fischer, Semester Project ETH

Kinematics



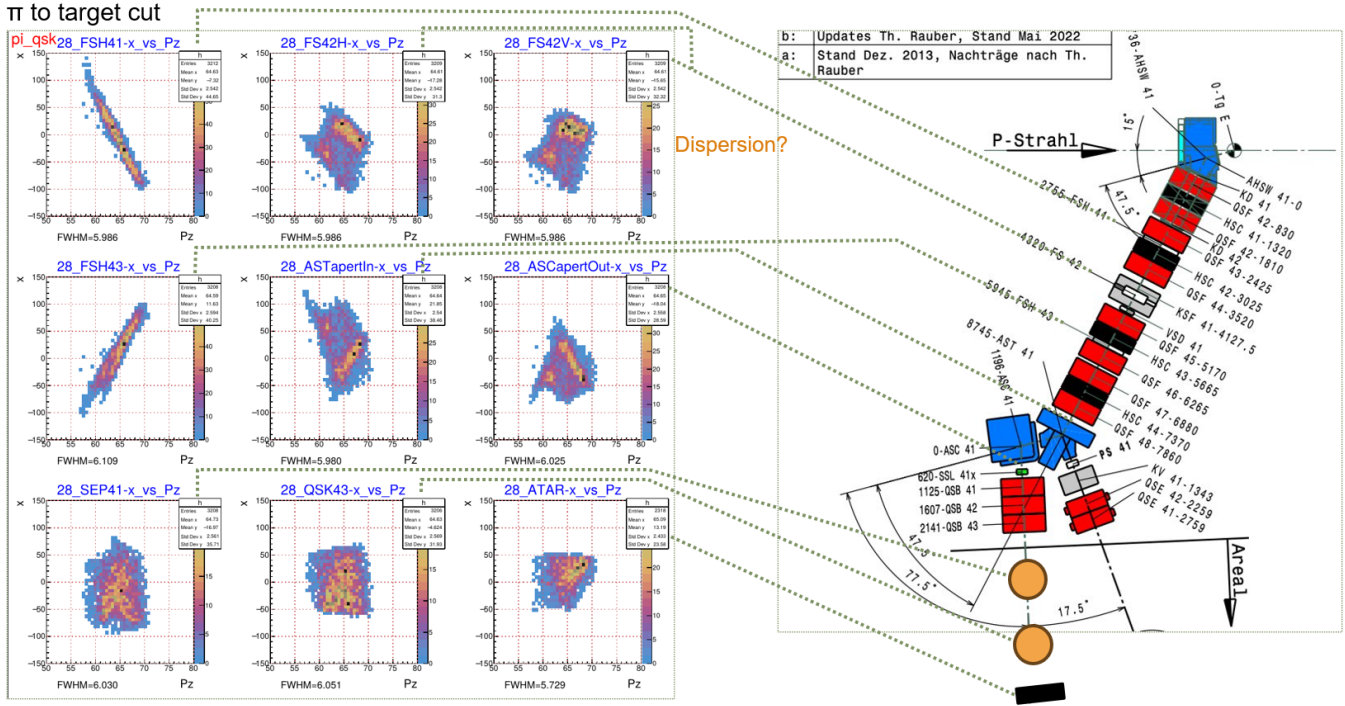
G4BL Model shows Strong Non-linear Effects

Higher order effects: X vs P_z

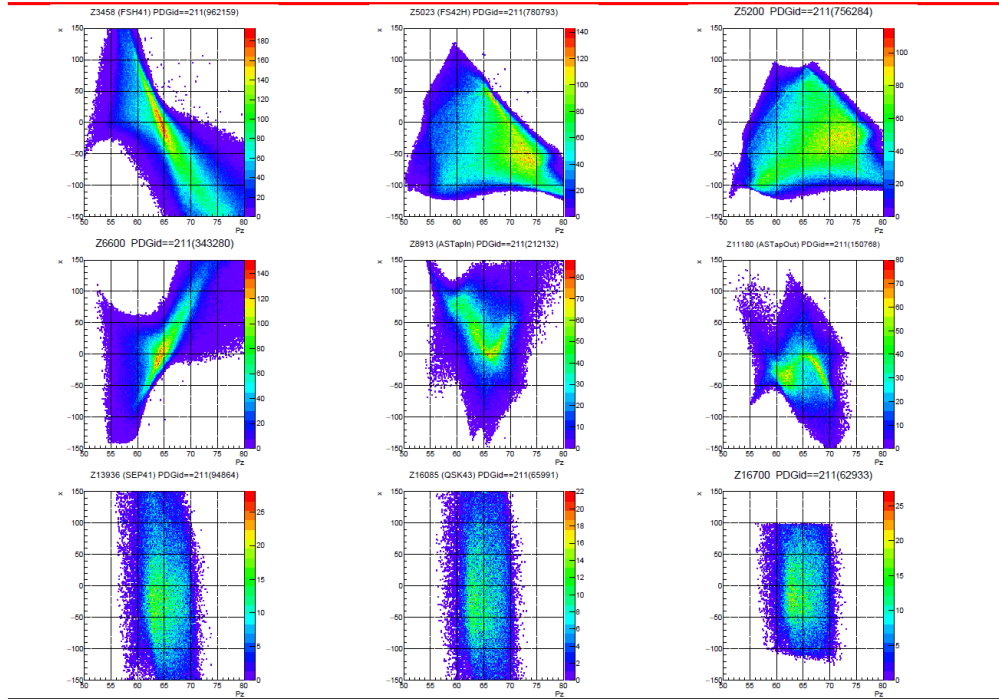
Peter 2023

Urs June 2024

very preliminary



Pions x vs p_z All pions



Oct 2023

Peter Kammel - piE5 overview

13

Urs Langenegger

pioneer (2024/06/14)

2

Peter - Urs

- Not directly comparable, but non-linear behavior confirmed
- Compare magnet current/field conversion

More work

- Understand main non-linear matrix elements
- Rough beam tuning, currently it does not represent measured reality

Paul's AI/ML Work

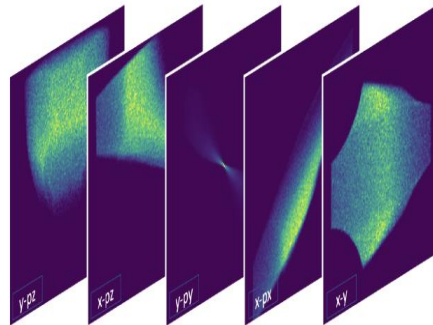
Advisors: Andy A. and Sebastian H.

Paul Fischer

Simulating Simulations:
Optimizing the π E5-beamline at
PSI for PIONEER

1. Design variables $\mathbf{x} \in R^{18}$
 - 18 currents of the quadrupole and sextupole magnets
2. Final phase space $\mu_f \in R^6$
 - Function of initial phase space and design variables
3. Optimize for m objectives functions $f(\mu_i, \mathbf{x}, z)$
4. Use G4BL as “virtual” reality

$$\mu_f = \mu_{G4BL}$$
$$f = f_{G4BL}$$



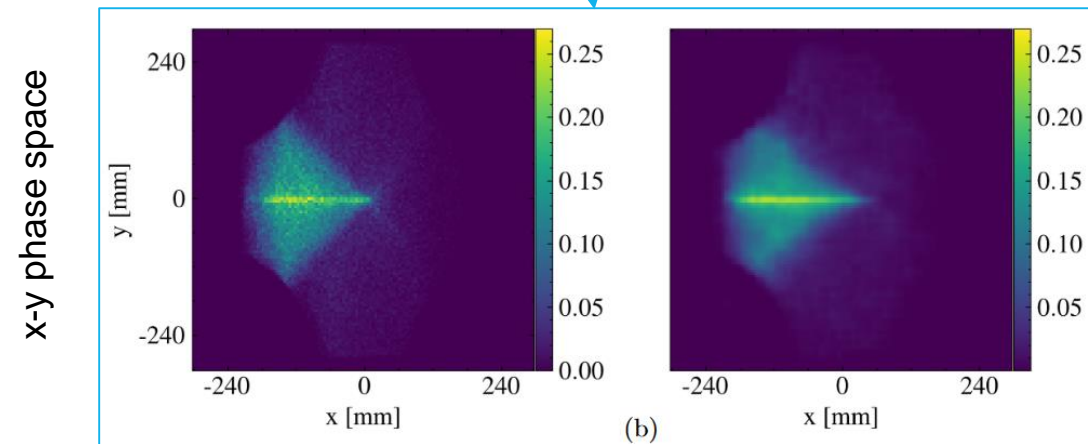
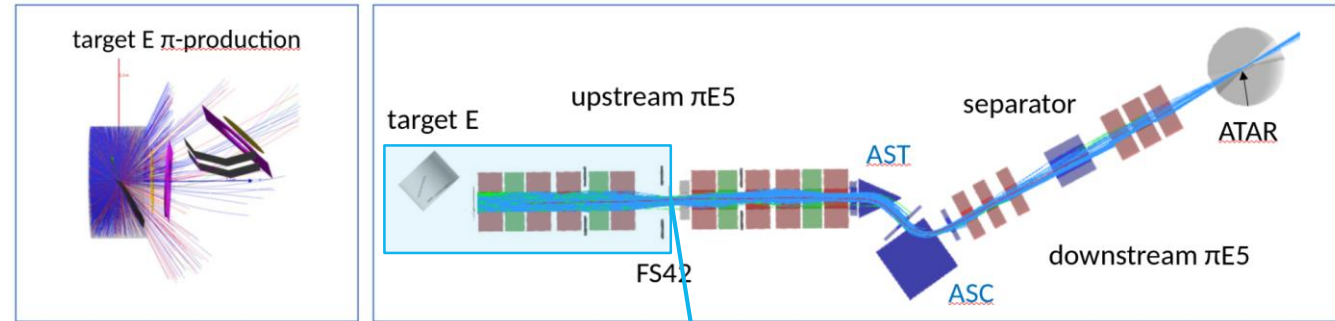
5. Fast surrogate model

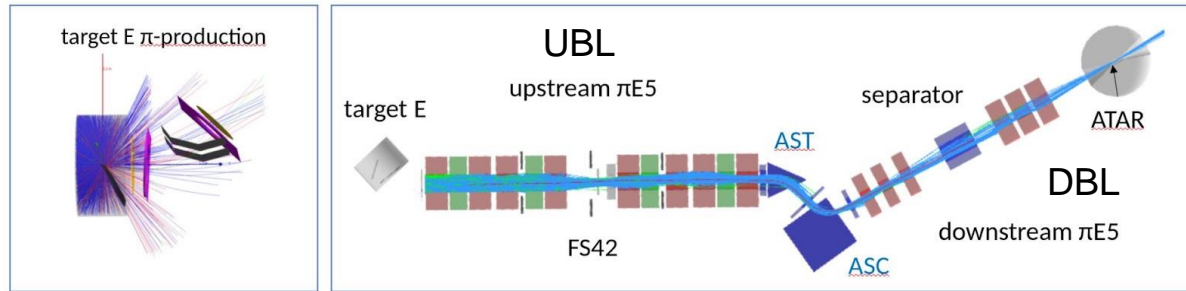
$$\mu_{surrogate} \sim \mu_{G4BL}$$

$$f_{surrogate} \sim f_{G4BL}$$

Results - Proof of Principle

- Analyzed upstream 6 magnets
- Varied current ± 20 A for training set in G4BL
- Optimized surrogate model for 2-D pictures





• Method Developments

- Unified surrogate model for simultaneous 5-6d phase space description
- Include (selected) virtual plane in surrogate model definition, **slits**.

• Full Beamline

- Extend the surrogate model to the full beam line. Particles making it to ATAR will exhibit very distinct features compared to initial flux.
- Does Urs confirm Peter's non-linear effects? partially done.

• Optimization Method

- Fit to optimize objective functions
 - rate on ATAR, $\sigma_x, \sigma_y, \sigma_p$

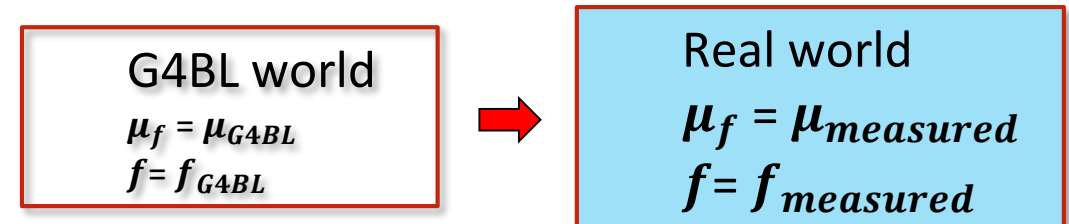
- *Anna: What does that have to do with reality?*
Answer: 2 steps

– Step 1:

- Use G4BL as “virtual” reality to develop and establish method
- Importantly, study required input data set for robust prediction

– Step 2:

- Replace input-output relation with measured phase space (chamber tracker at ExB location)
- Re-optimize based on data

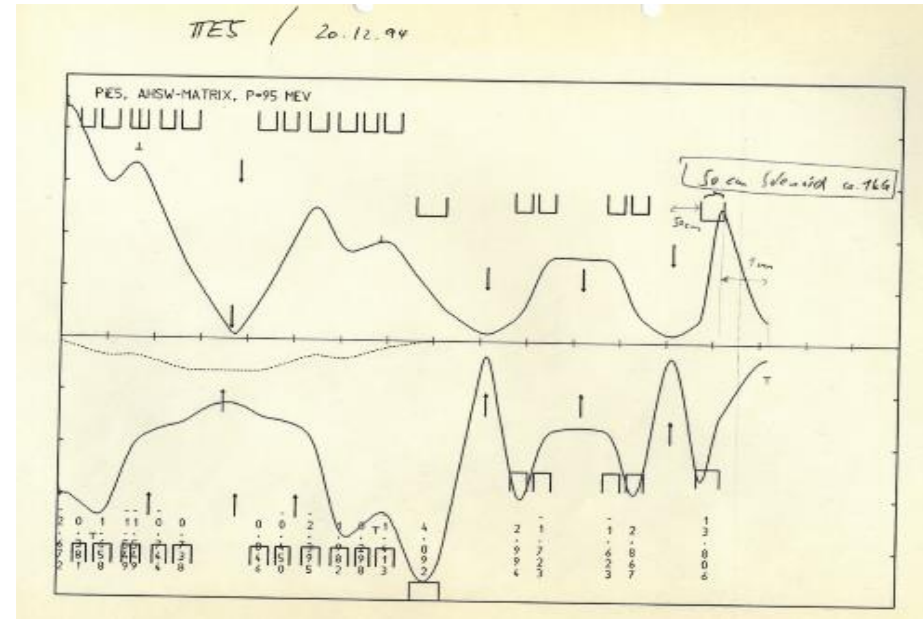
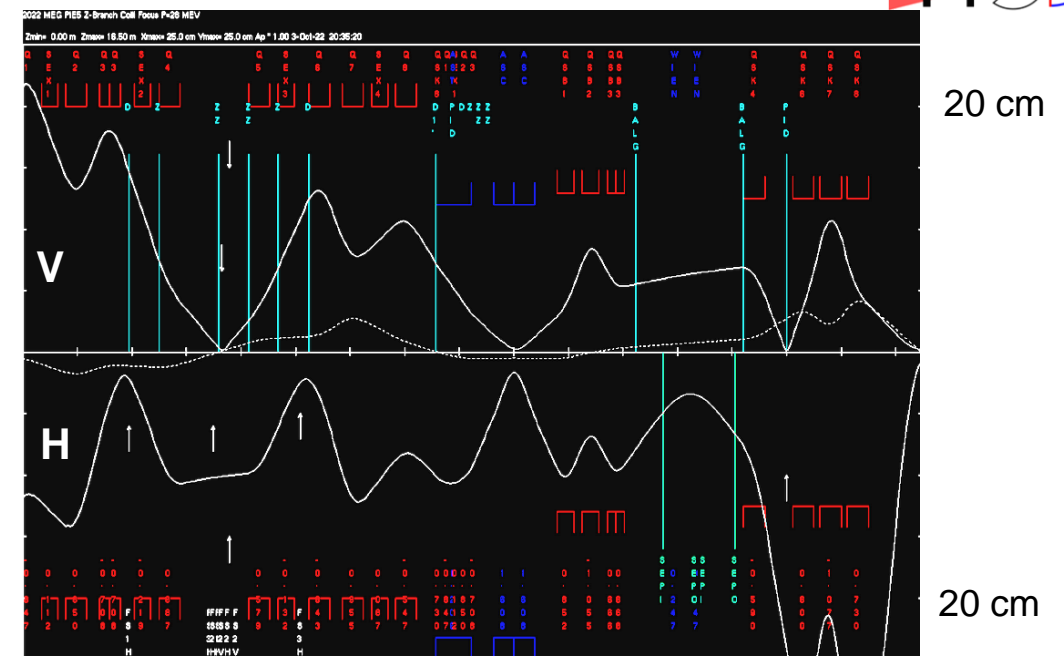
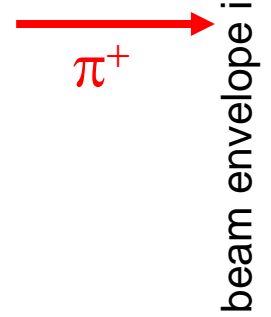


• AI/ML Tuning strategy

- Full BL or DBL (downstream) only (Black box approach)
DBL only probably not enough
- Step-by-Step optimization ?

Major Design Upgrades

- Two separate foci required so that background is rejected outside of detector
 - 1st focus separates particles after ExB velocity filter and reject μ and e on collimator
 - 2nd focus is a double x/y focus aimed at ATAR
 - First attempt with singlet triplet promising but using only linear beam dynamics
 - Large custom final quad?
-
- Smaller momentum bite
 - Retune upstream beam line to let dispersion grow
 - Degraded in dispersive section?
 - Requires dispersive double focus



People and Timeline

- People

- Andy Adelman

- No progress this year, needs student
- Kolja interested candidate

- David Tarazona

- 1st rate beam physicist
- Currently work with Lawrence
- Applied for Cornell AI in Science Postdoctoral Fellowship
- Plans to model pE5 with BMAD

- Kolja also analyzing first beam test

- Remark concerning simulation

- Prediction won't be ready on CDR timescale
- Include beam as parametrized input

- Hope that activity can resume in fall

- Other help more than welcome

- Timeline

Fall 2026	Beam test
Fall 2025	<p>AI/ML studies with G4BL finalized to justify πE5 2026 beam request.</p> <ul style="list-style-type: none"> • Extend the surrogate model to the full beam line running • Optimization demonstrated • Measurement strategy developed <p>At the same time we should have tracker system available.</p>
Fall 2025	<p>Beam design with extension ready To justify extension measurements</p>
CDR	What do we need for that?

Backup