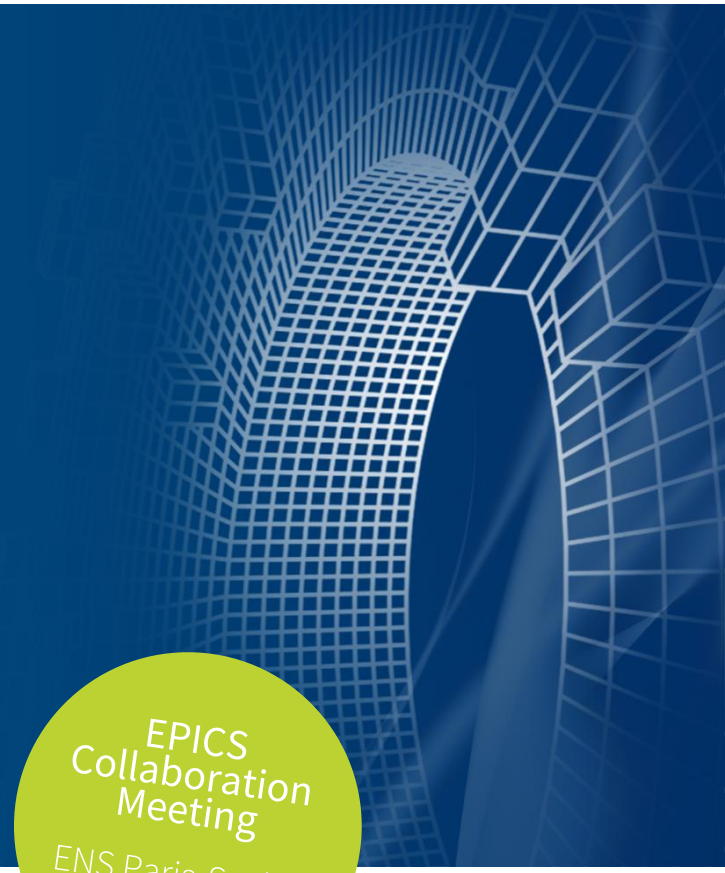
HZB BESSY II Light Source

AREADETECTOR GAUSSIAN FITTING PLUGIN FOR ROBUST BEAM CHARACTERIZATION AND ALIGNMENT SUPPORT

Luca Porzio



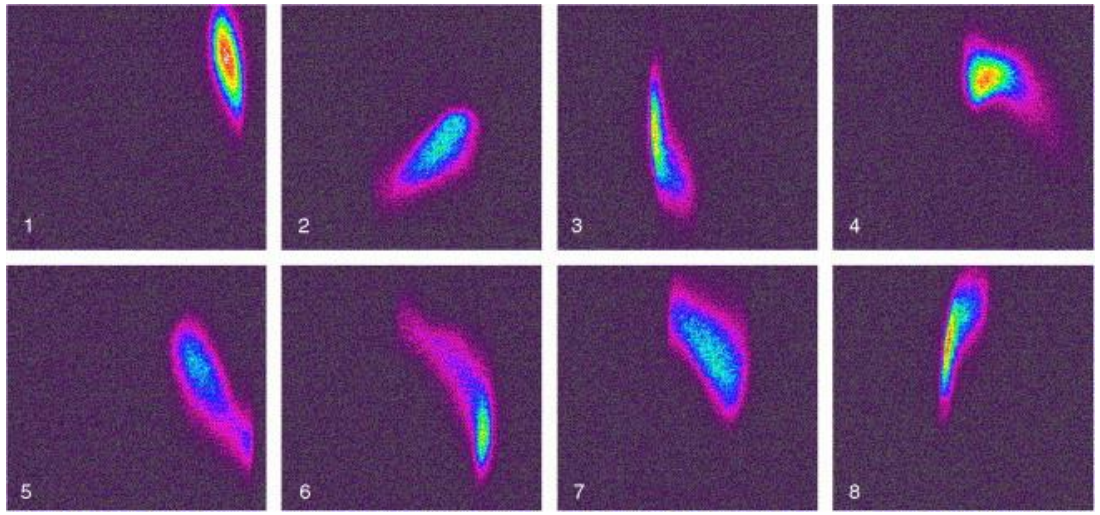
EPICS Collaboration Meeting

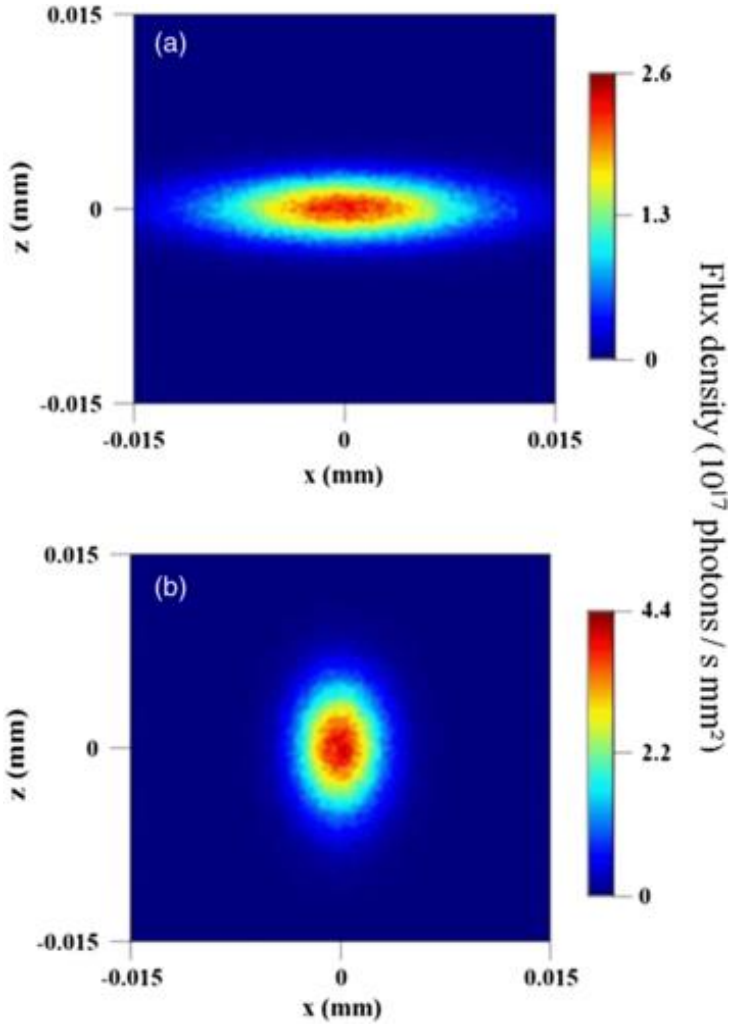
ENS Paris-Saclay Spring 2026

MOTIVATION

While areaDetector is the standard for DAQ, it currently lacks a robust, built-in way to perform true nonlinear curve fitting.

Doing the fit outside of EPICS introduces challenges on **synchronization** and **timestamping** as well as increasing the **system complexity**.





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NDPluginGaussianFit

ARCHITECTURE & CORE FEATURES

Ceres Solver (Google) – Used on Google Maps, Android Camera, Project Tango – Released under *Apache 2.0* License .

Additional Features:

- Data Sparsification (thresholding)
- Robust Loss Function (resilience to outliers)
- N-1 frame tracking (closed-loop)

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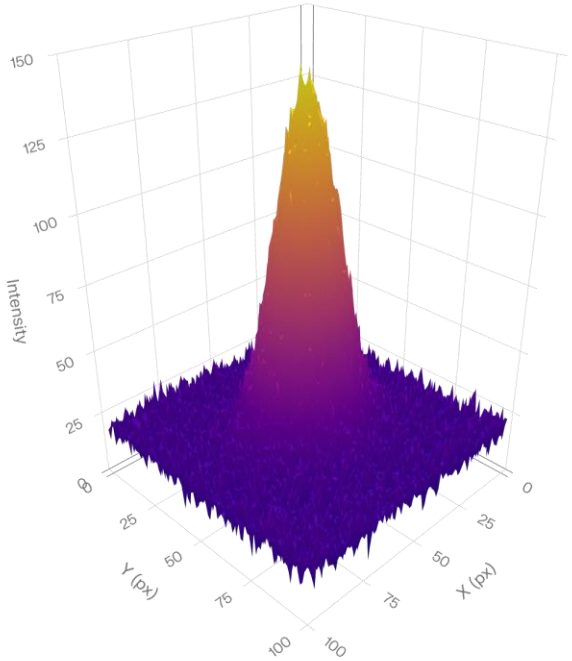
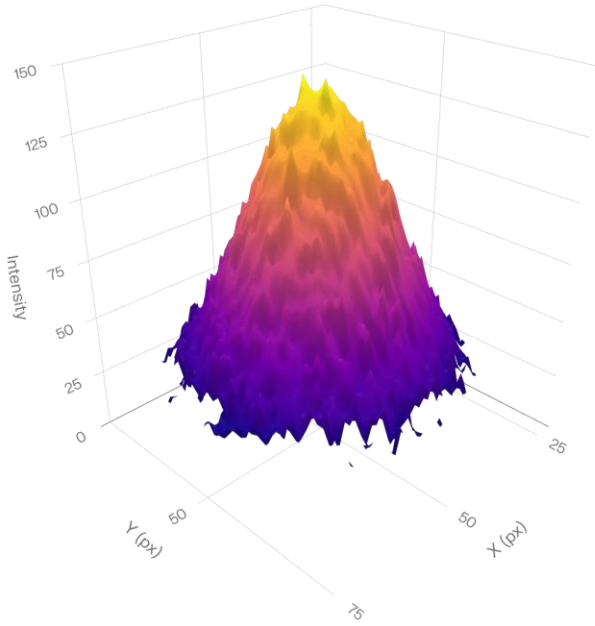


Dense
(40.000px)



Sparse
(5.000px)

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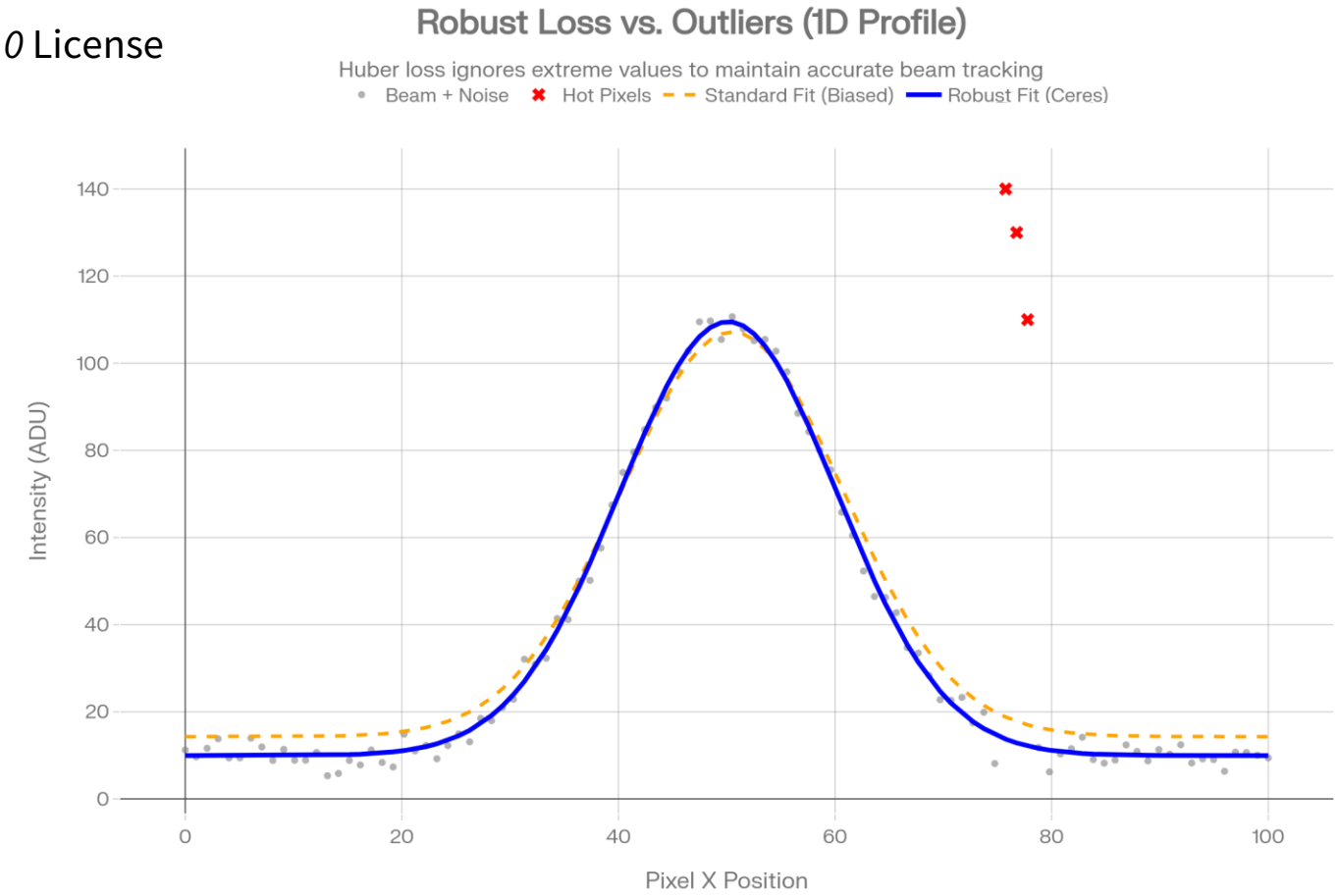

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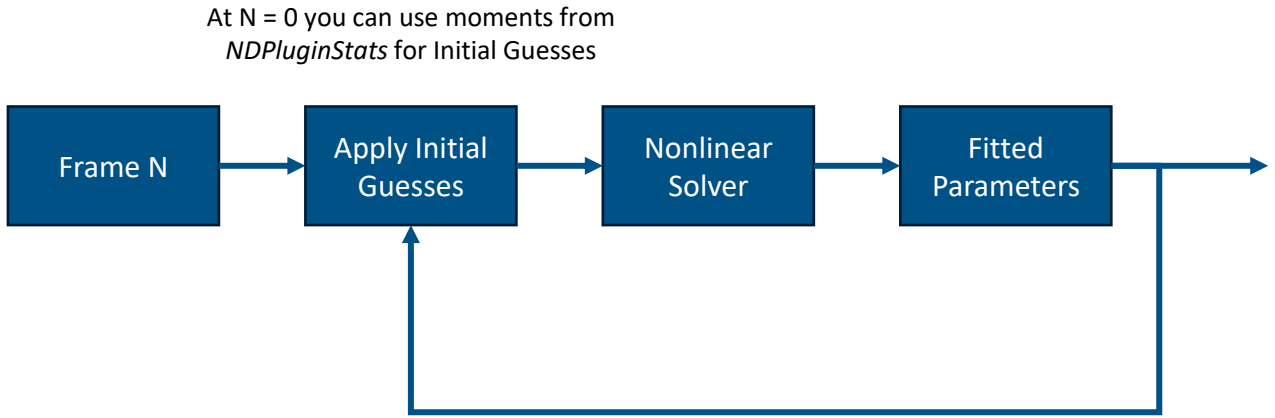


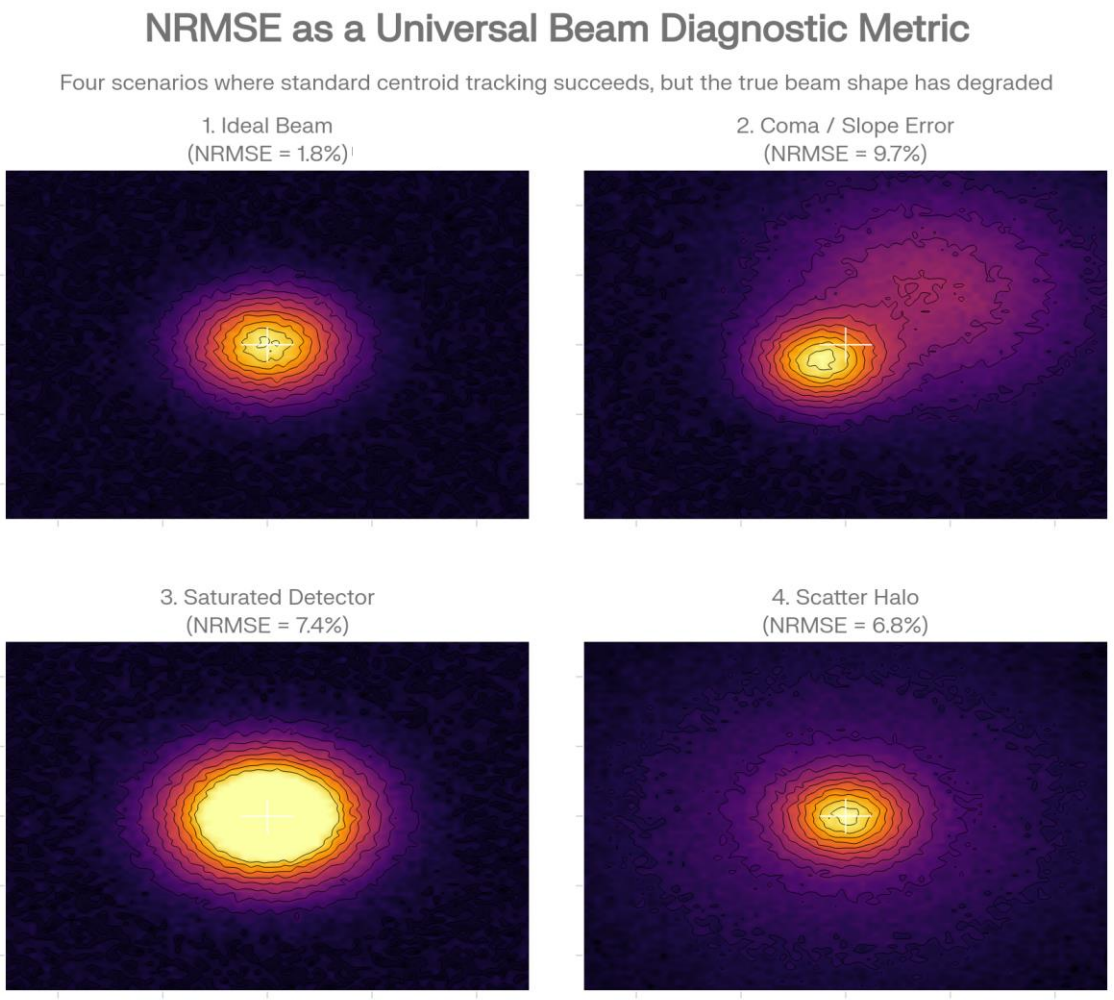
Performances:

- *300px x 200px uint8* - **40ms** in closed-loop (total plugin execution time)
  i9-12900K @ 5.2 GHz – 8 threads

USE CASES – BEAM/OPTICS CHARACTERIZATION & ALIGNMENT SUPPORT

Moving from "*where is the beam*" to "*how good is the beam*".

- **Goodness of fit (NRMSE):** data drifts from the model, even if centroid/sigma don't move.
- **Covariance matrix (from Hessian):** 1σ uncertainties and correlations on $x_0, y_0, \sigma_x, \sigma_y, \theta$,amplitude, and background in real time.



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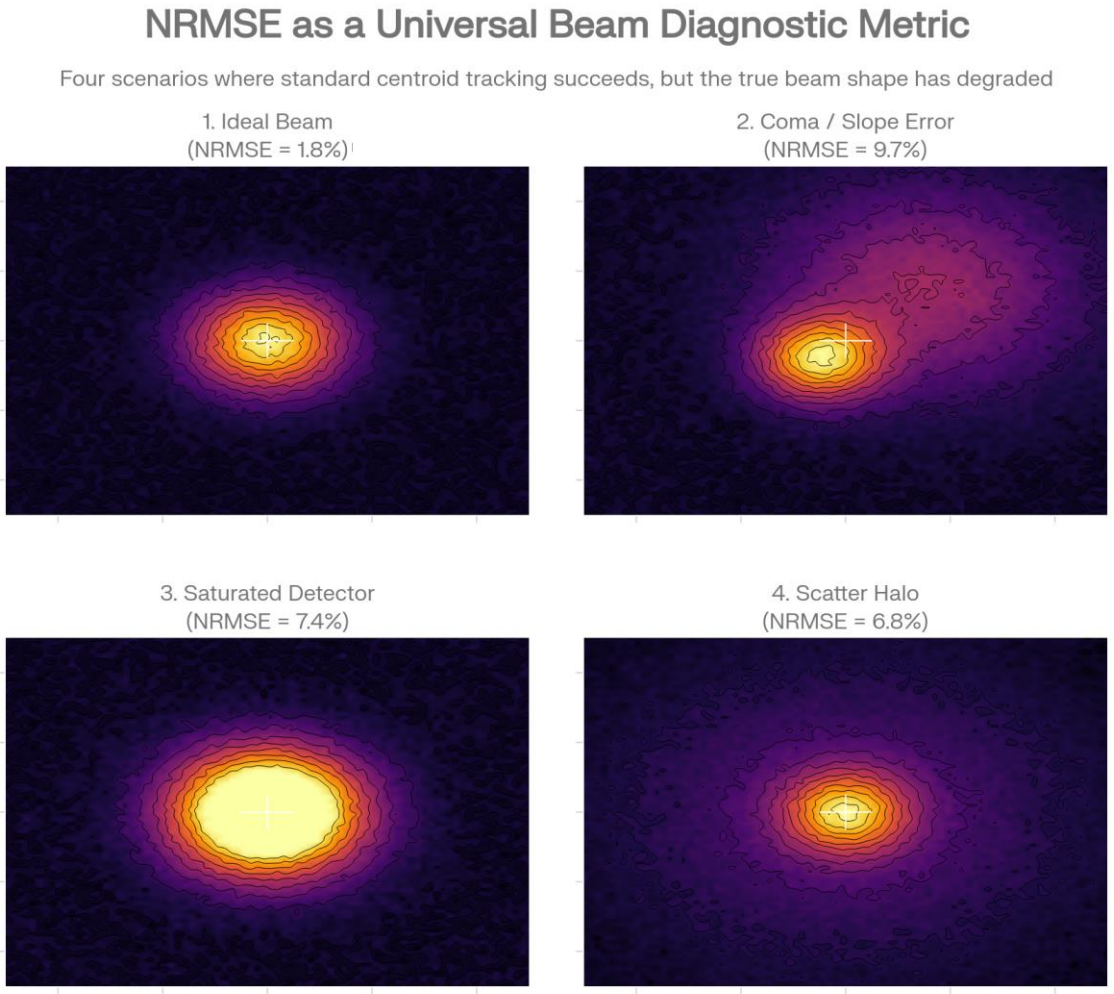

- Detection of ***Optics Aberrations*** and ***Multi Mode Beam***.
- ***Ellipticity & Astigmatism***: Extracting the major/minor axis and rotation angle (θ) maps directly to mirror slope errors and sagittal/tangential focus mismatch.
- Track slow variations in beam size (***thermal load***)

FUTURE TESTS DEVELOPMENTS

- Support to ***Voigt-like*** beams.
- ***Kalman Filter Integration***: Ceres provides per-frame Gaussian fits and local curvature (Hessian), the Kalman filter turns those into a temporally consistent state with predictive priors and uncertainties.
- ***AI & Flying Bayesian Optimization***: Acting as the high-speed "*reward function*" evaluator. Autonomous agents can adjust mirror benders and pitch/roll, using the real-time σx,σy, and NRMSE from this plugin to optimize the beamline completely hands-free.