Kalman Filter status update

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DUNE Italia Collaboration Meeting – Lecce

7th November 2023

Info

- Repo: baltig.infn.it/dune/STTTrackReco
  - First commit: winter 2020
- Best-effort development
- People working on it: Matteo Tenti, Valerio Pia, Michele Pozzato, Giulia Lupi

Ingredients

- Track state vector (a_k)

$$\begin{pmatrix} x \\ y \\ 1/\tilde{R} \\ \tan\lambda \\ \phi \end{pmatrix}$$

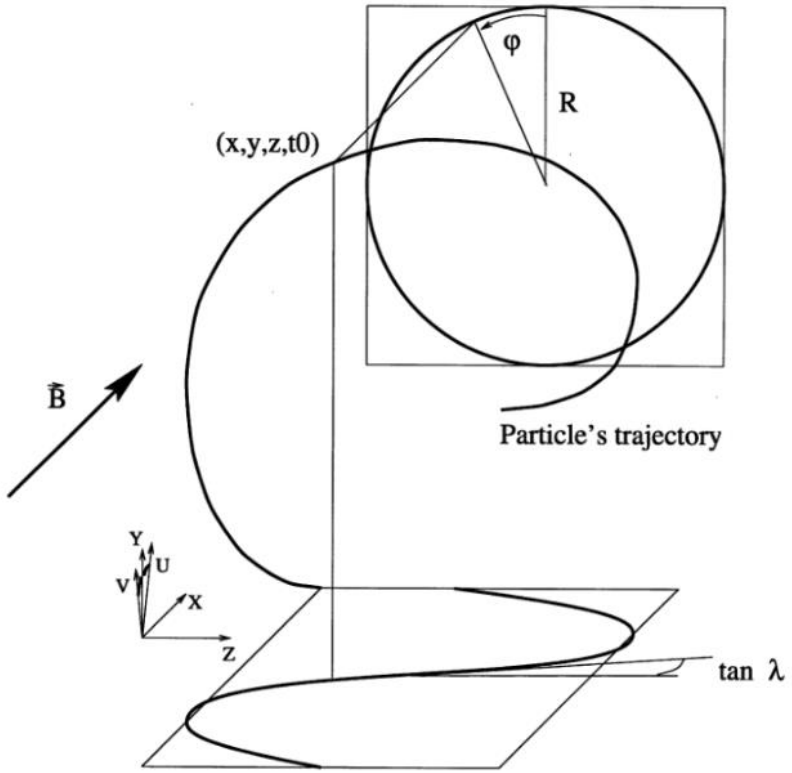
X coordinate
Y coordinate
Signed inverse radius
Tangent of dip angle
Rotation angle

- Track model: helix
- Measurement vector:

$$m_k = \begin{pmatrix} x \\ \theta_{xz} \end{pmatrix} \quad \theta_{xz} = -\kappa \cdot \arctan\frac{\tan\lambda}{\sin\phi}$$

$$m_k = \begin{pmatrix} y \\ \theta_{yz} \end{pmatrix} \quad \theta_{yz} = \phi + \kappa \cdot \frac{\pi}{2}$$

Either one depending on the STT plane



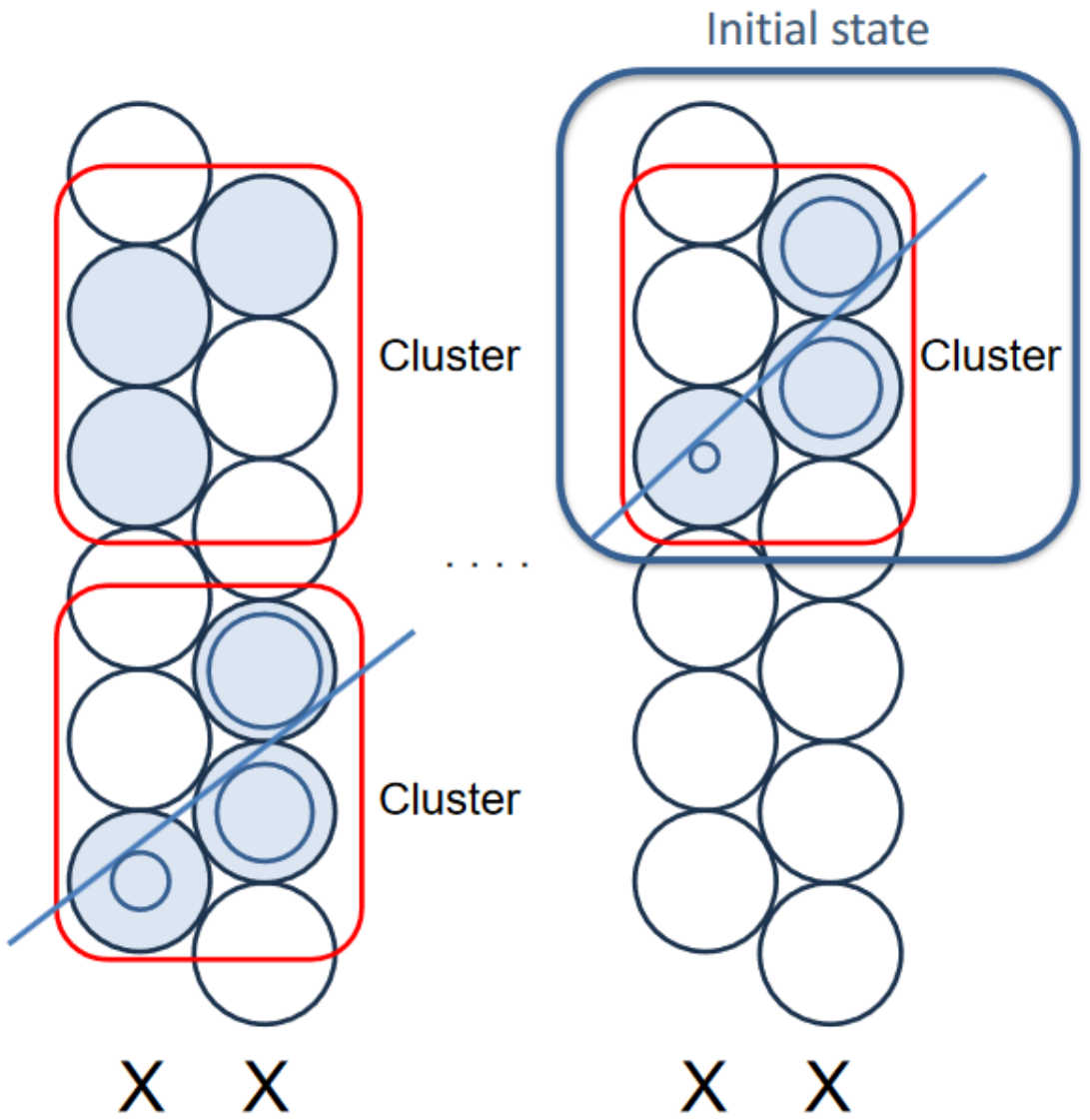
Pierre Astier et al. *Kalman filter track fits and track break point analysis.* Nucl. Instrum. Meth. A, 450:138–154, 2000.

- Covariance matrix Ck
- Prediction for the measured state $h_k(f_{k-1})$

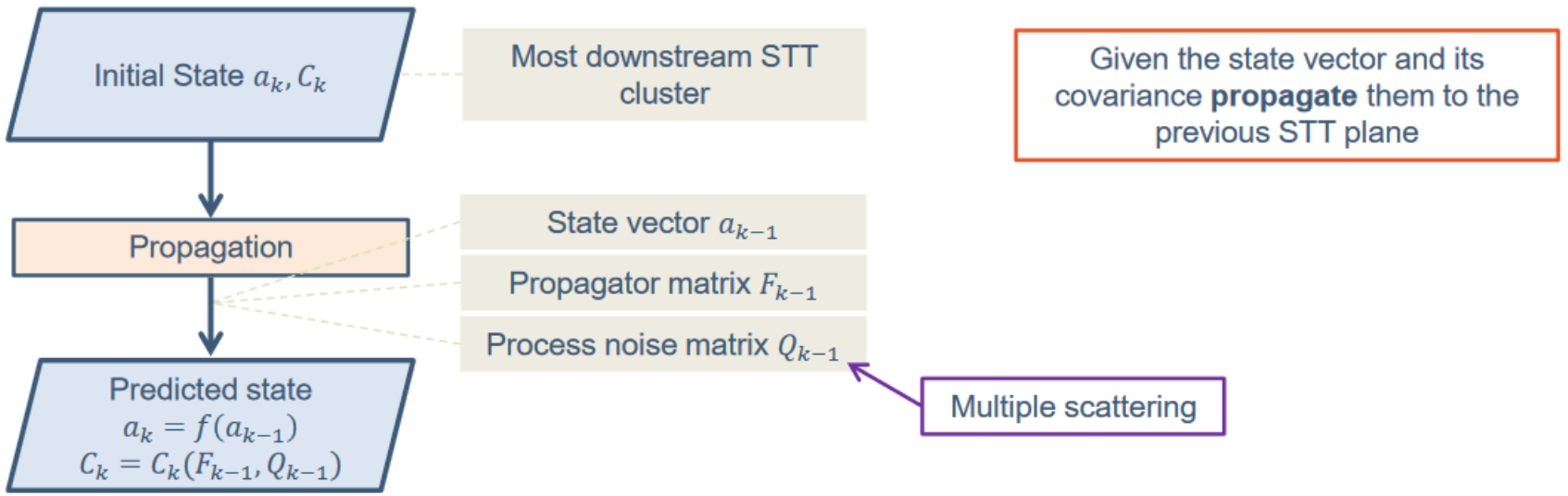
- Energy loss and MCS currently NOT taken into account

State vector

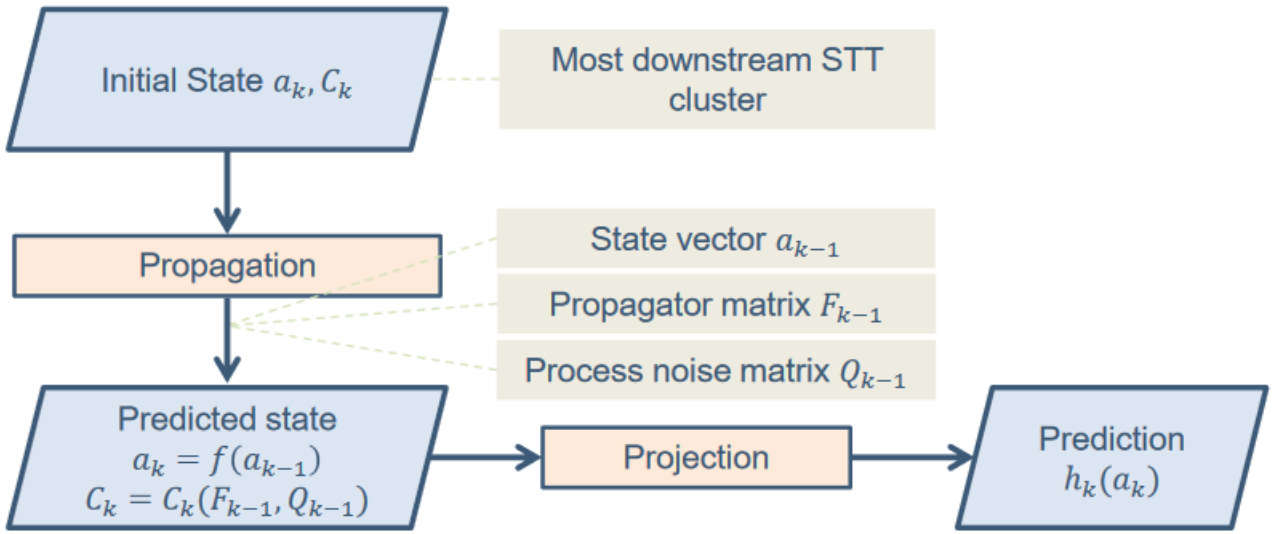
- Input: straw digits
- Input tube-digits are grouped in plane
- Within plane adjacent tube-digits are clustered
- Reconstruct radius for tube-digits
- Evaluate common tangents and take the best one according to a likelihood
- Clusters are reconstructed: m, q, t0, quality



Kalman Filter algorithm



Kalman Filter algorithm



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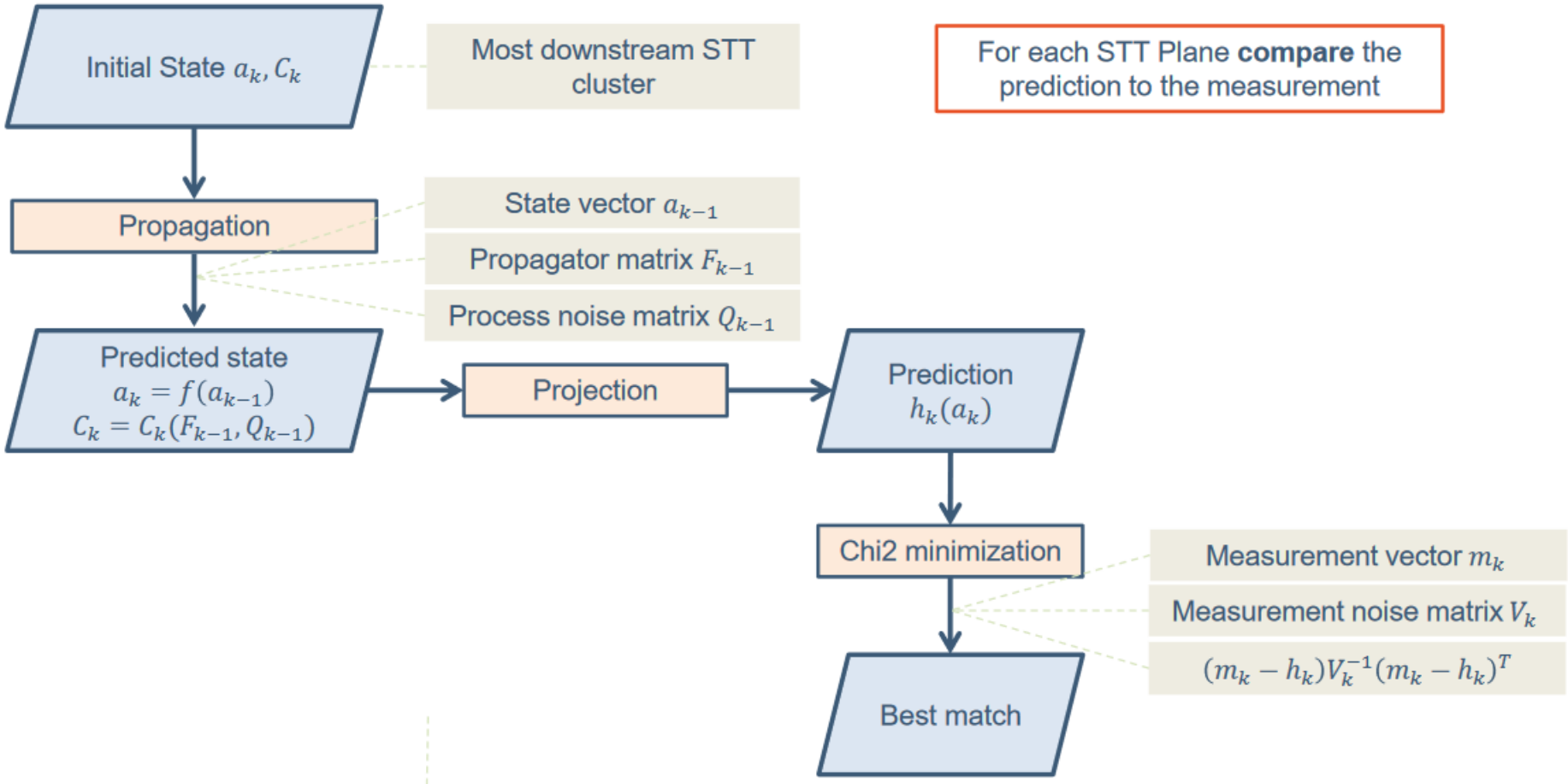
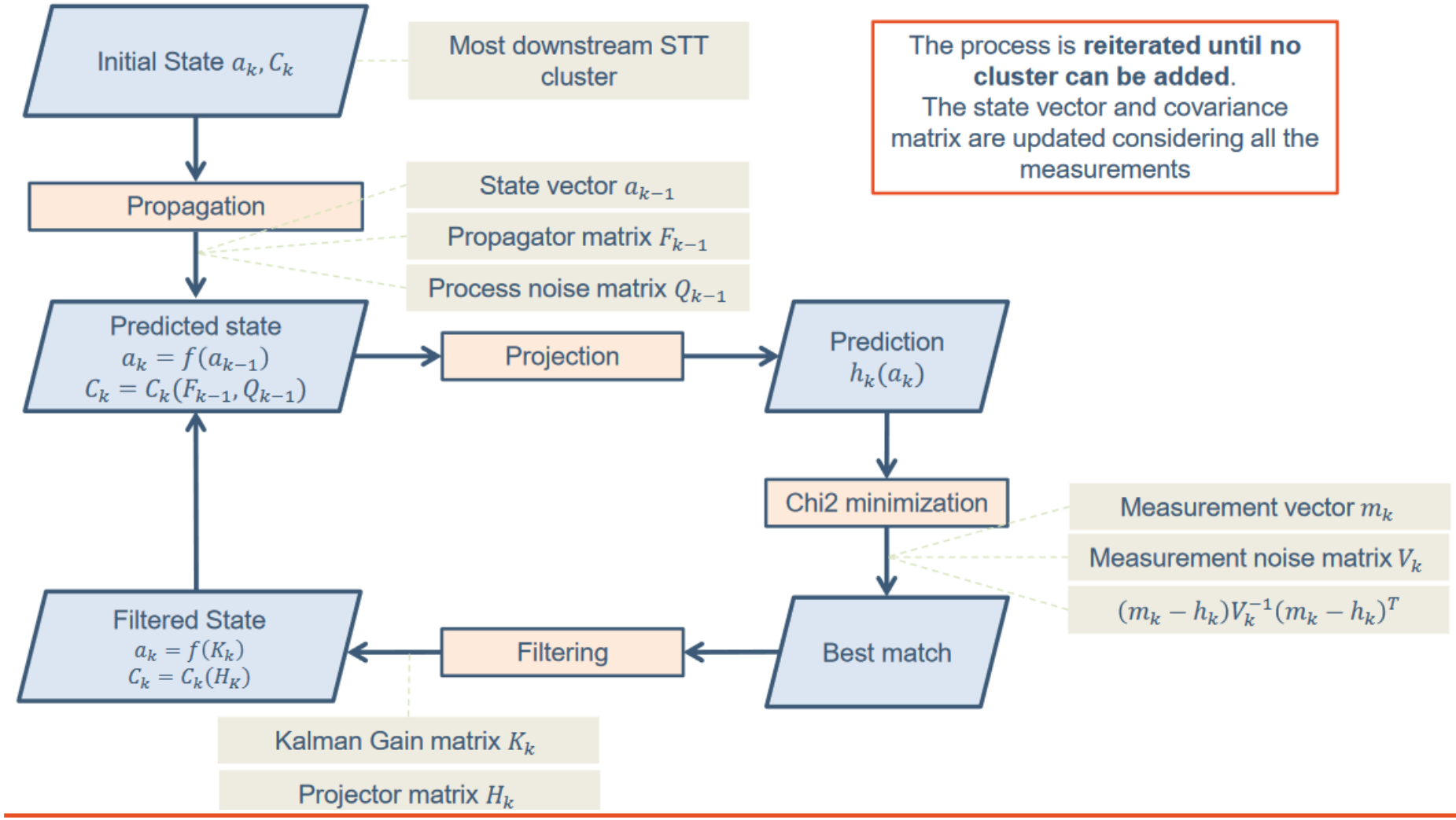
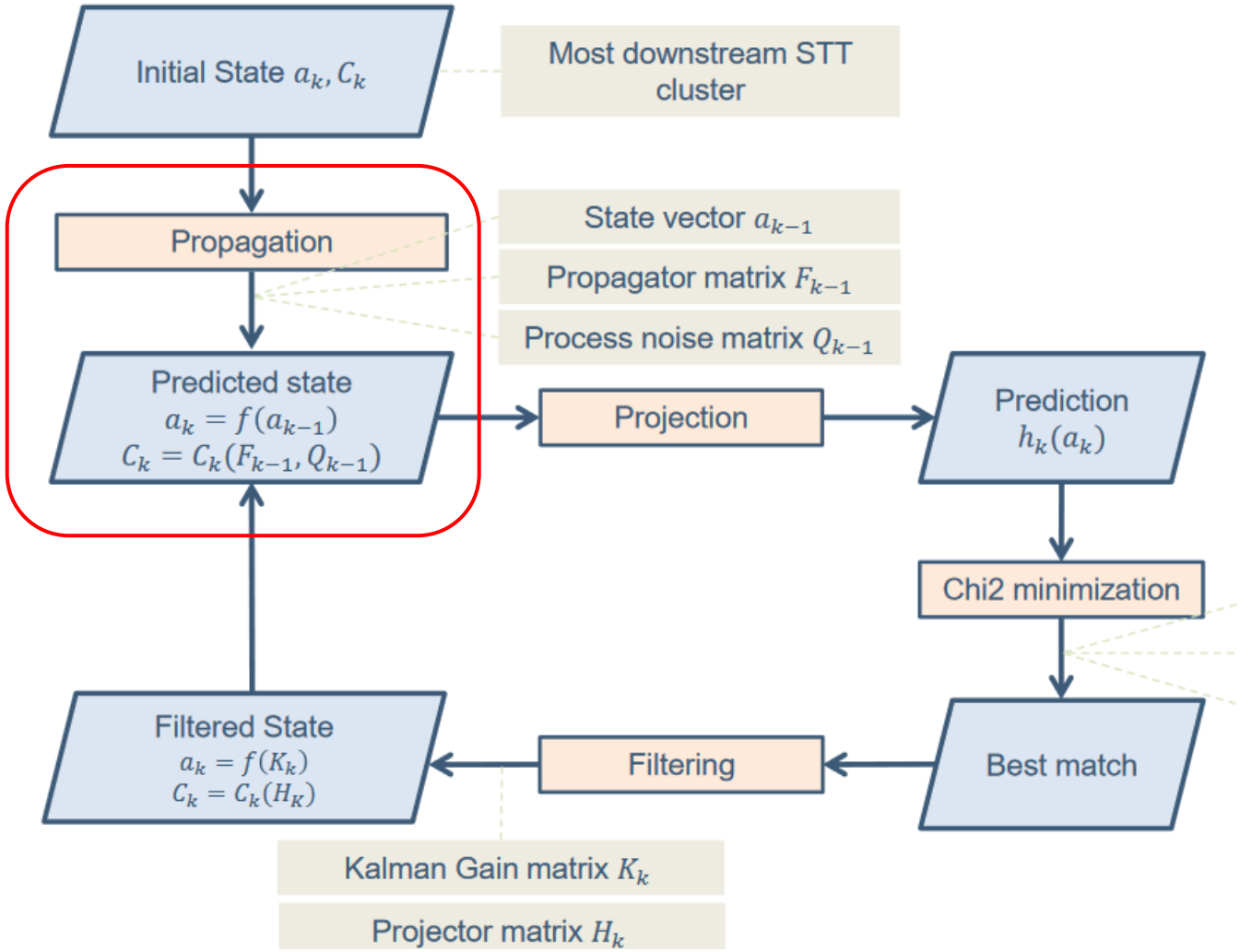


Kalman Filter algorithm



Last update



Last update:

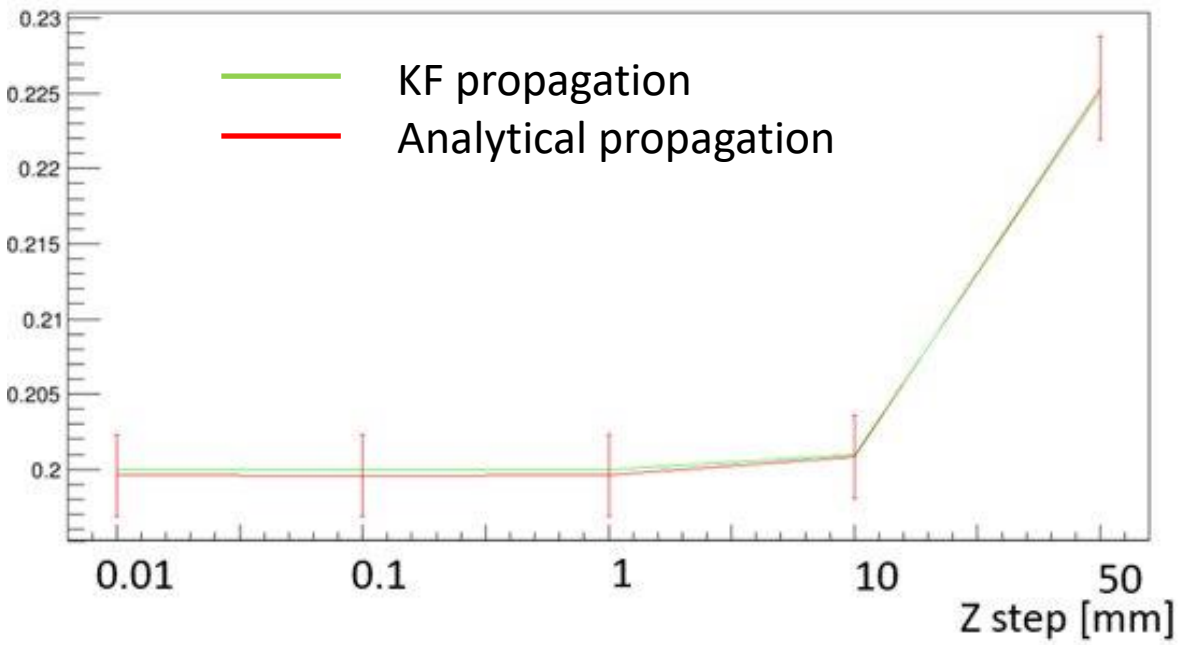
- Check of state propagation
- Check of covariance matrix propagation

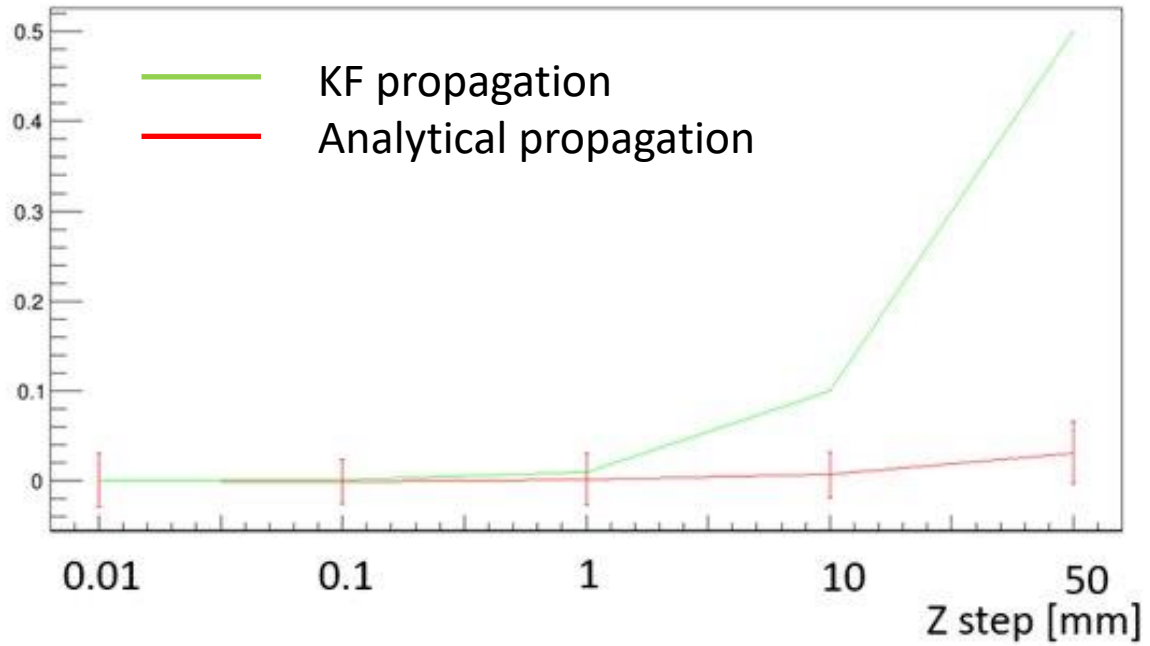
Problems were found in the propagation of the covariance matrix

Last update

Elemen-wise comparison of covariance matrix obtained with KF and from analytical computation.

Some elements were not in aggreement.

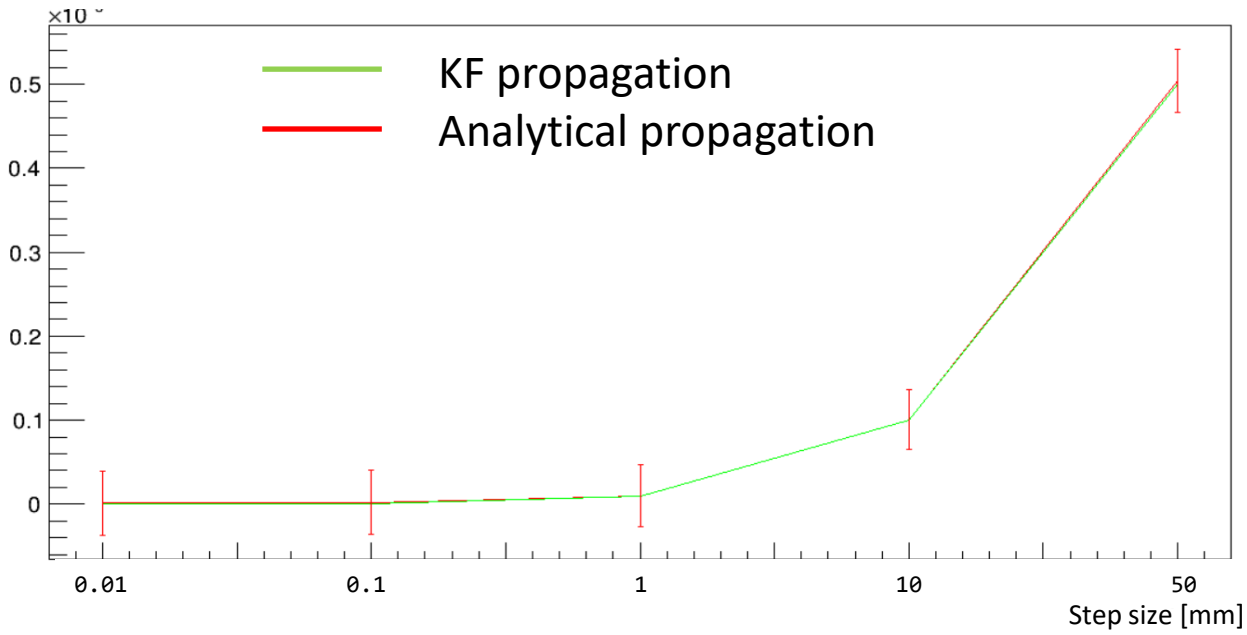


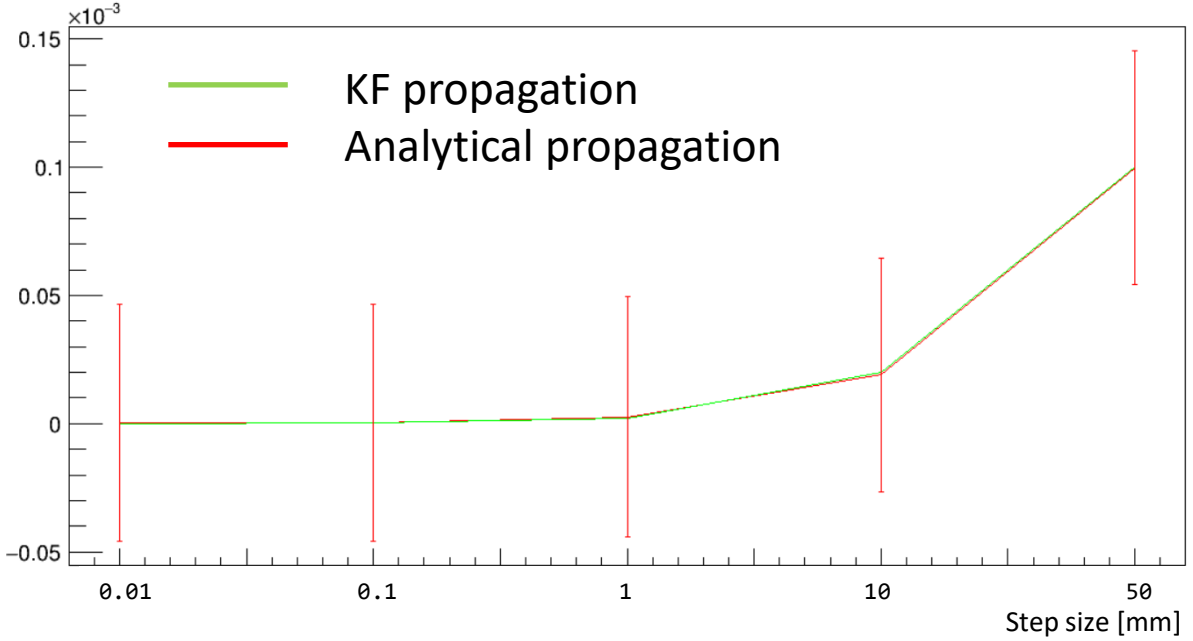


New update

Starting matrix values were too big and the algorithm didn’t converge.

Correct results obtained with steps of different lenghts and for multiple steps





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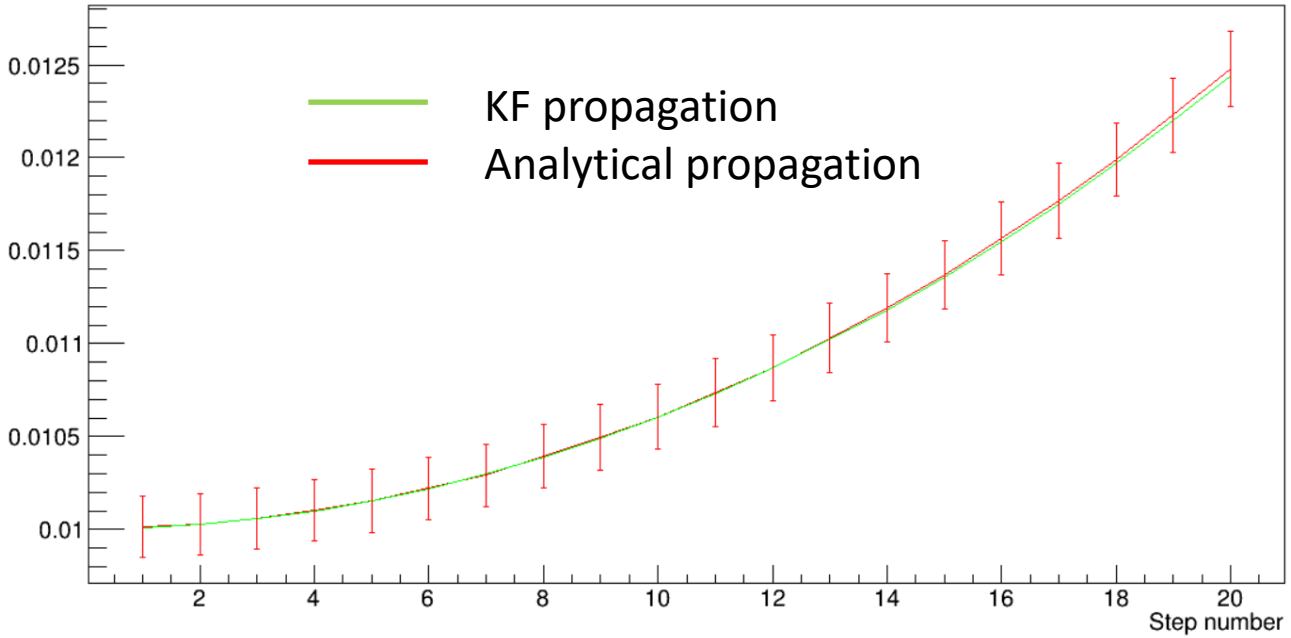
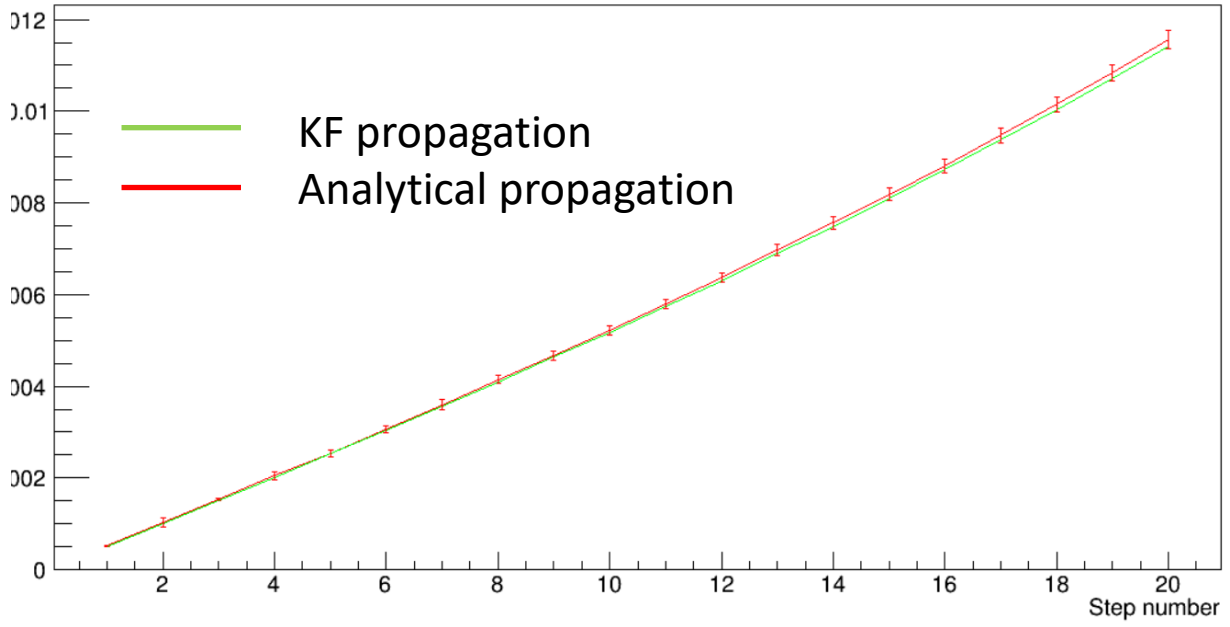
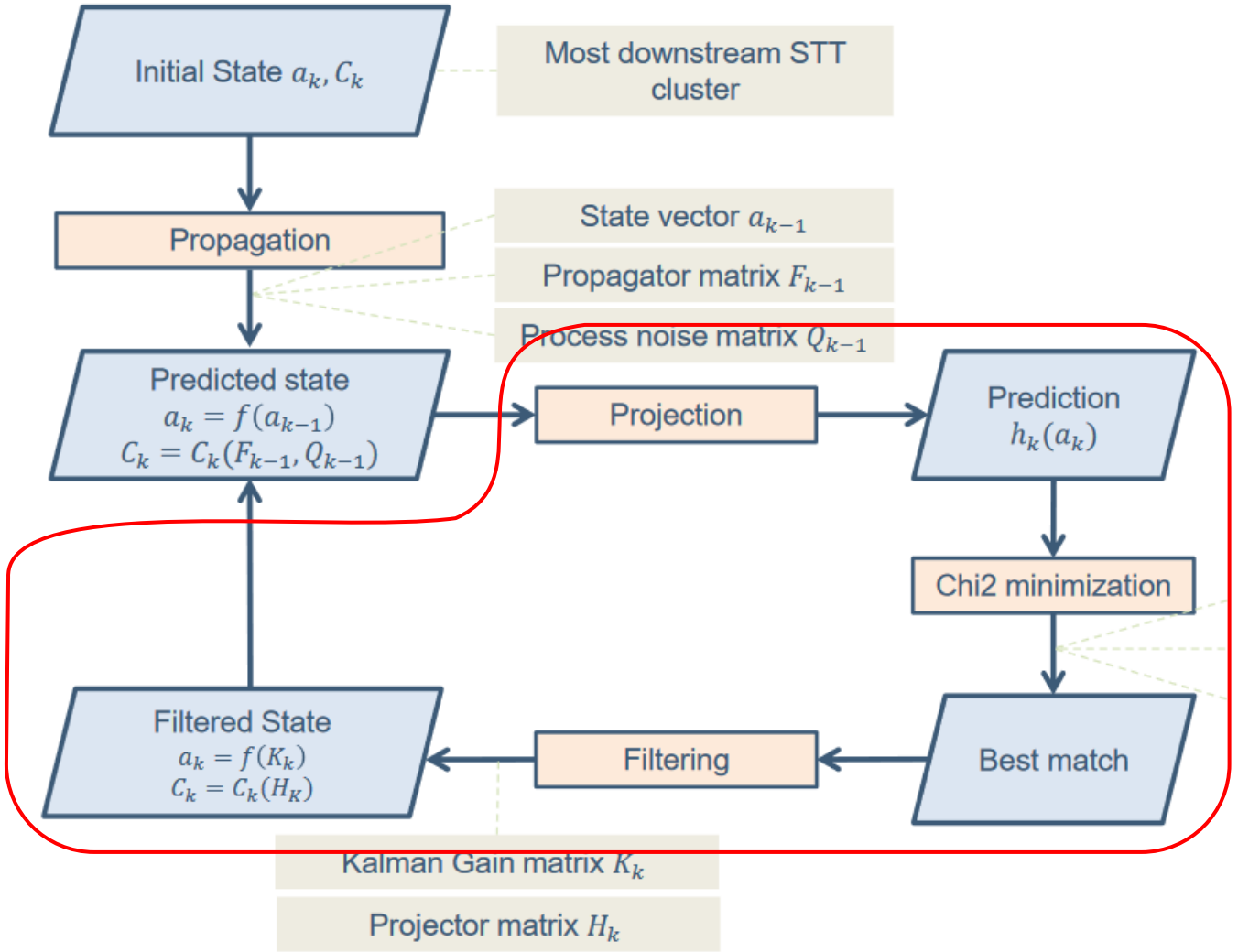




Total length 50 mm

Current checks



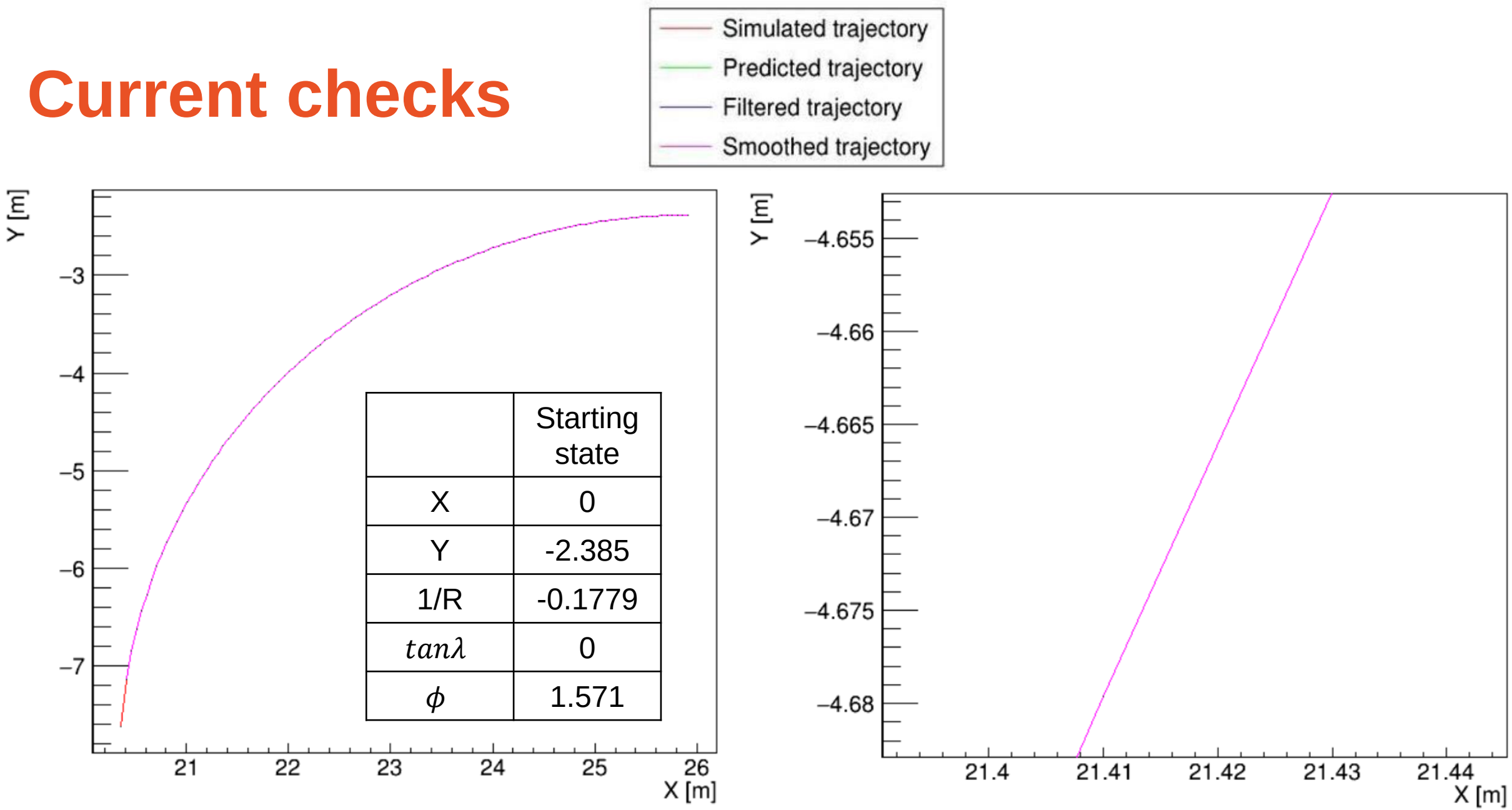
Current checks:

- Everything else

How:

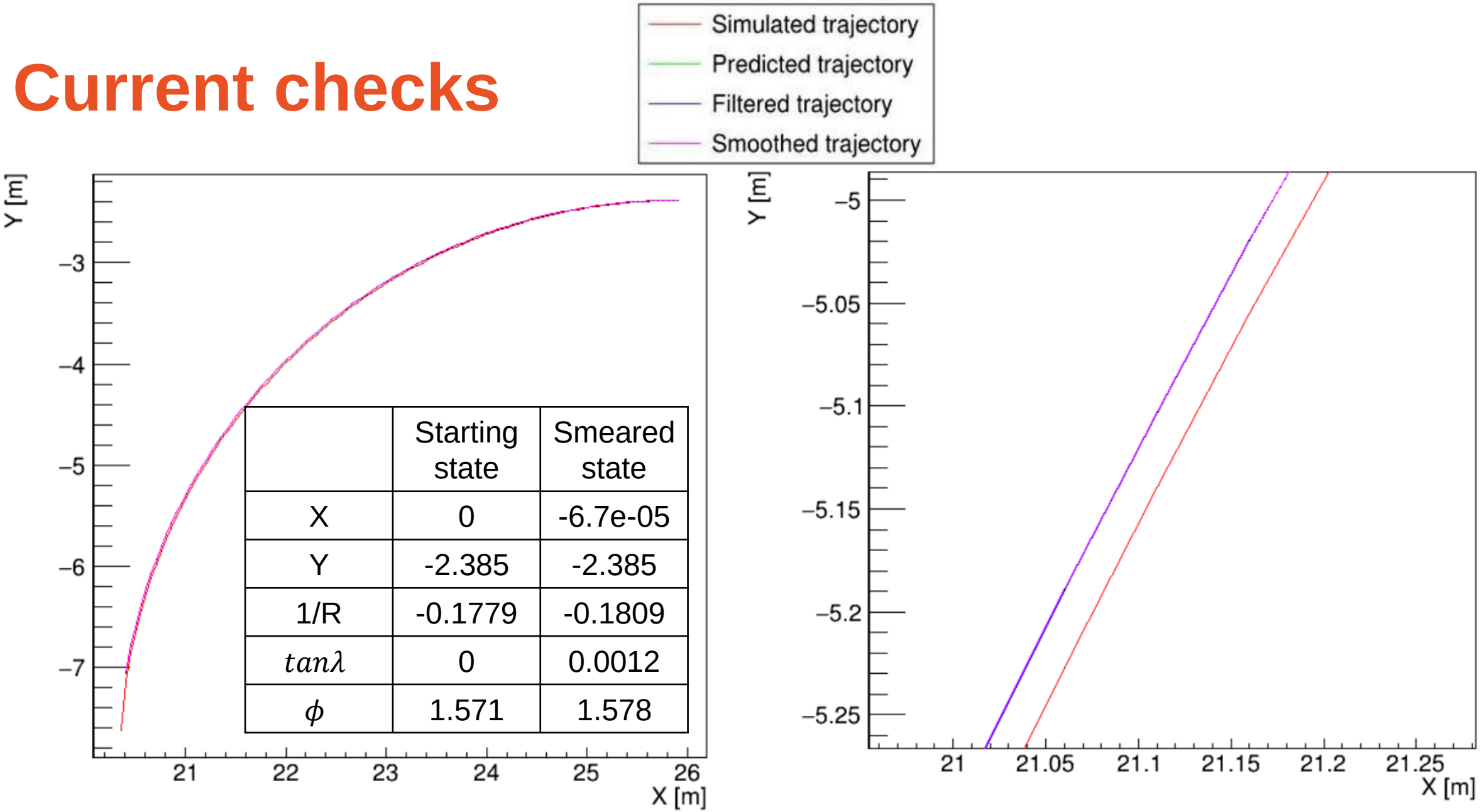
- Consider a particle propagating in STT with no Energy Loss nor Multiple Scattering
- Compute particle's trajectory analytically step by step along the z direction (true trajectory)
- Smear x and y tracjectory coordinates by $\mathbf{200\ \mu m}$ to simulate STT measurements
- Get Measurement vector of each step from the smeared points (no digitization nor clustering applied)

Current checks



	Starting state
X	0
Y	-2.385
1/R	-0.1779
$tan\lambda$	0
ϕ	1.571

Current checks

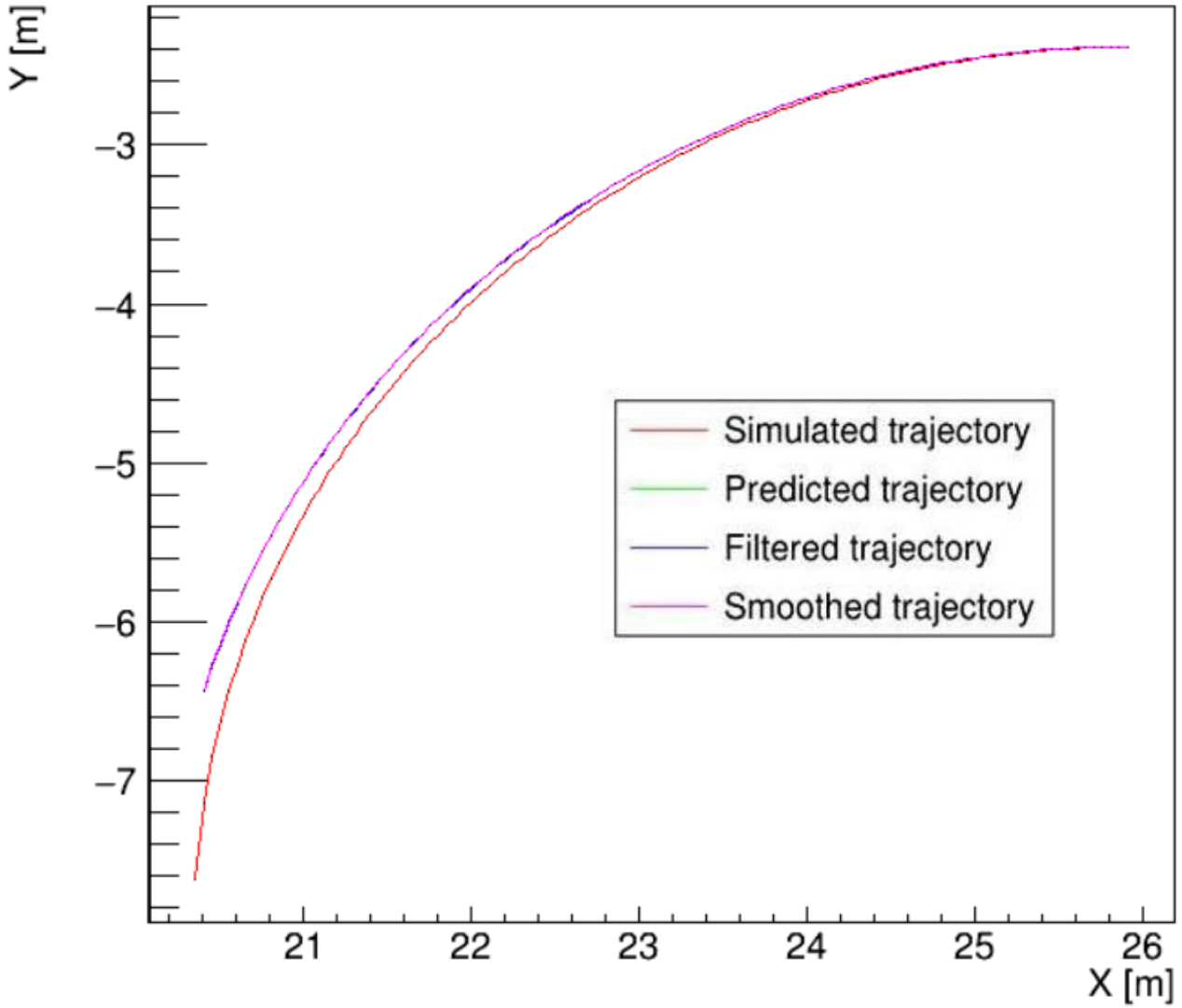


	Starting state	Smeared state
X	0	-6.7e-05
Y	-2.385	-2.385
1/R	-0.1779	-0.1809
$tan\lambda$	0	0.0012
ϕ	1.571	1.578

Current checks

The reconstructed trajectory diverge even for small smearing of the initial state, suggesting the existence of a wrong implementation of the code.

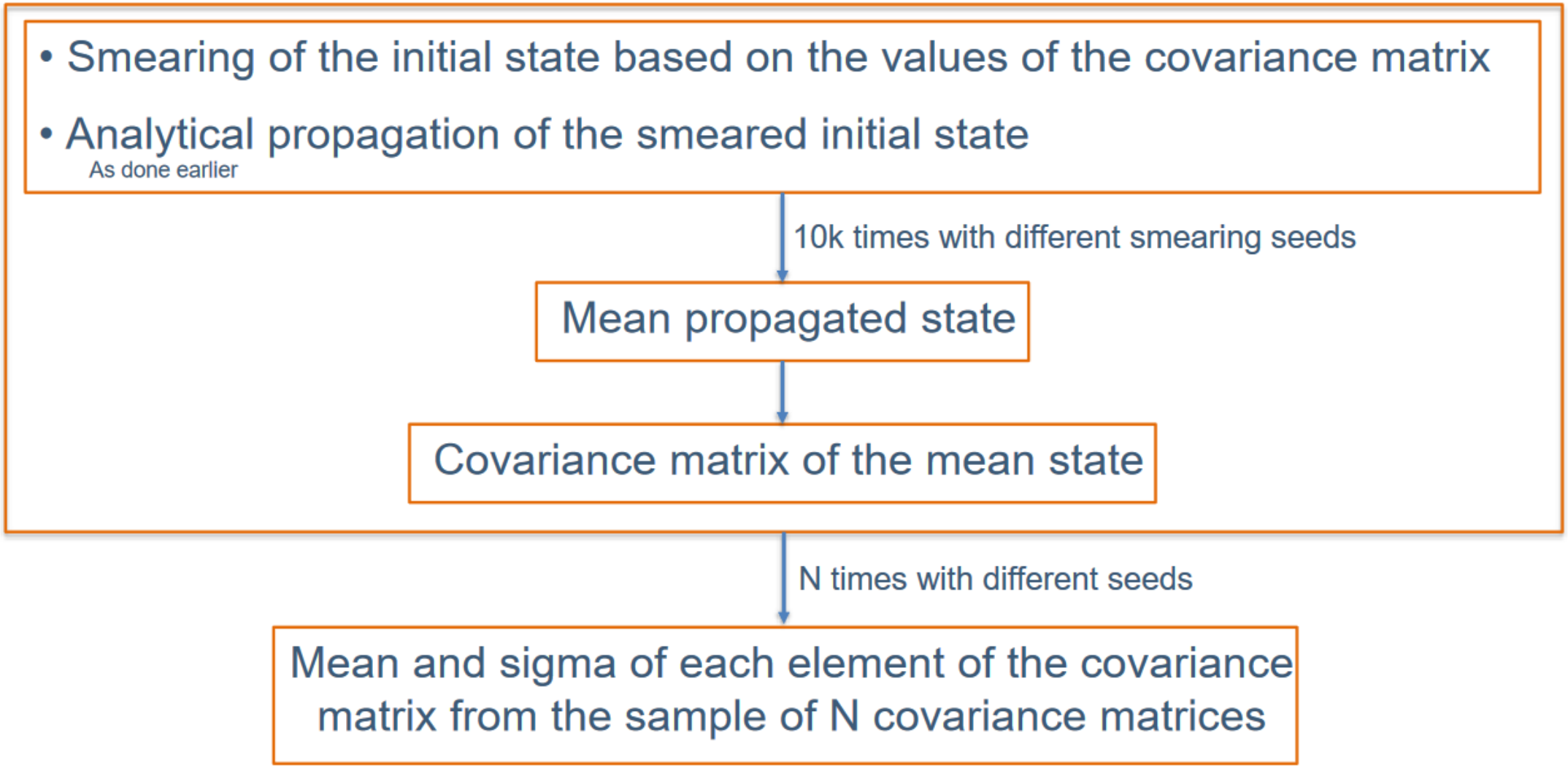
	Starting state	Smeared state
X	0	0.00027
Y	-2.385	-2.384
1/R	-0.1779	-0.175
$tan\lambda$	0	0.0092
ϕ	1.571	1.576



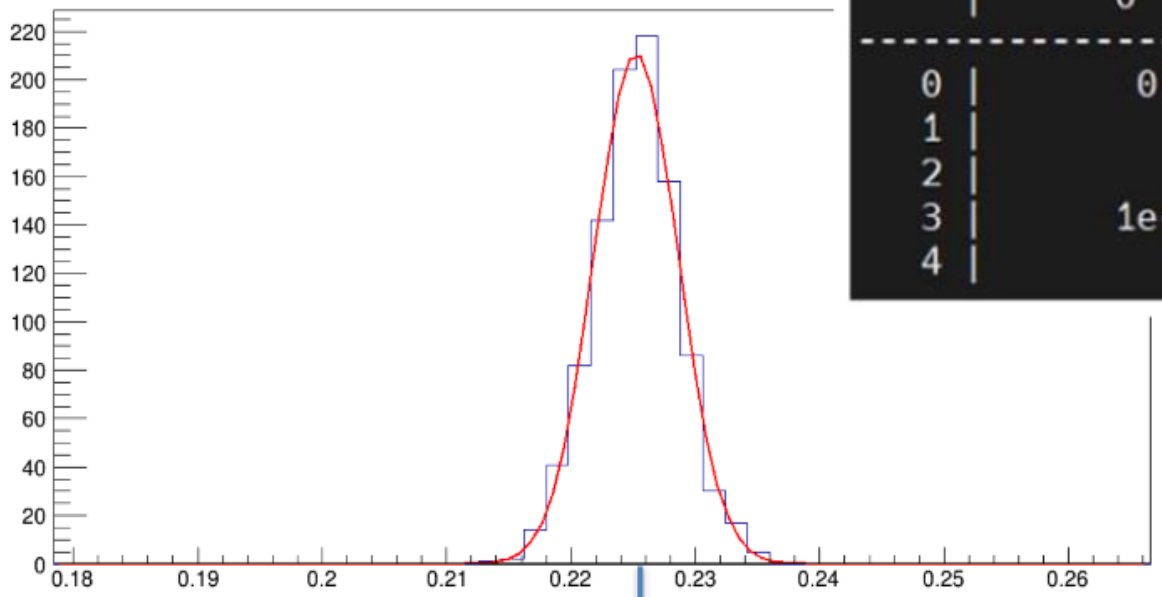
Conclusions

- Small progress were made
- Checks are ongoing to verify everything is working as wanted
  - State propagation works as intended
  - Covariance matrix propagation works as intended
  - Checks on the other algorithm steps are ongoing

Covariance matrix propagation check



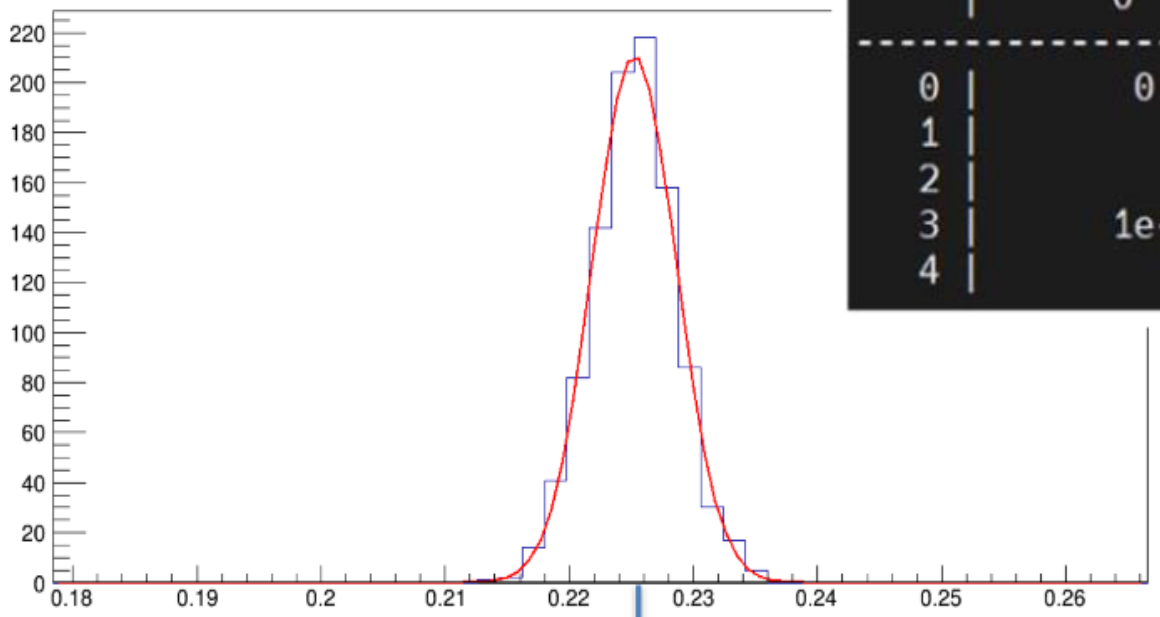
Covariance matrix propagation check



	0	1	2	3	4
0	0.01	0	0	1e-07	0
1	0	0.01	5e-10	0	2e-06
2	0	5e-10	10	0	0.0001
3	1e-07	0	0	0.01	0
4	0	2e-06	0.0001	0	0.2

Mean and sigma of each element of the covariance matrix from the sample of N covariance matrices

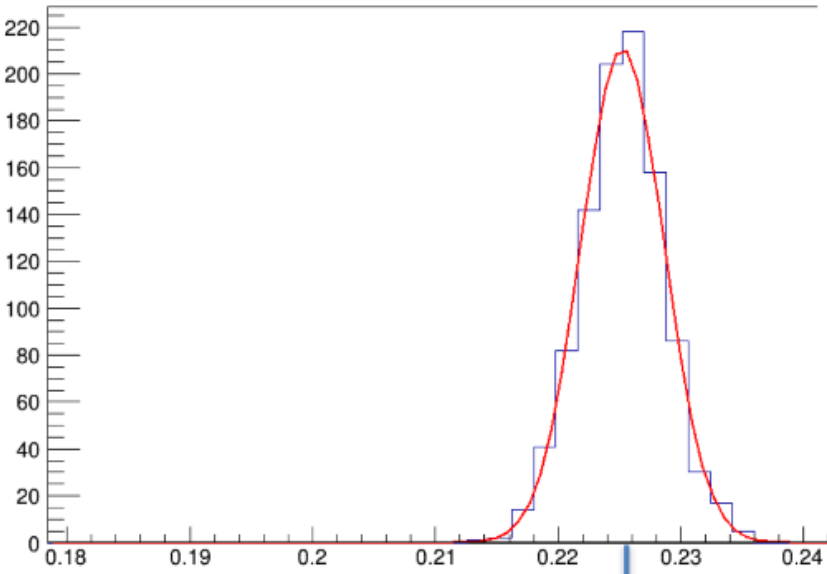
Covariance matrix propagation check



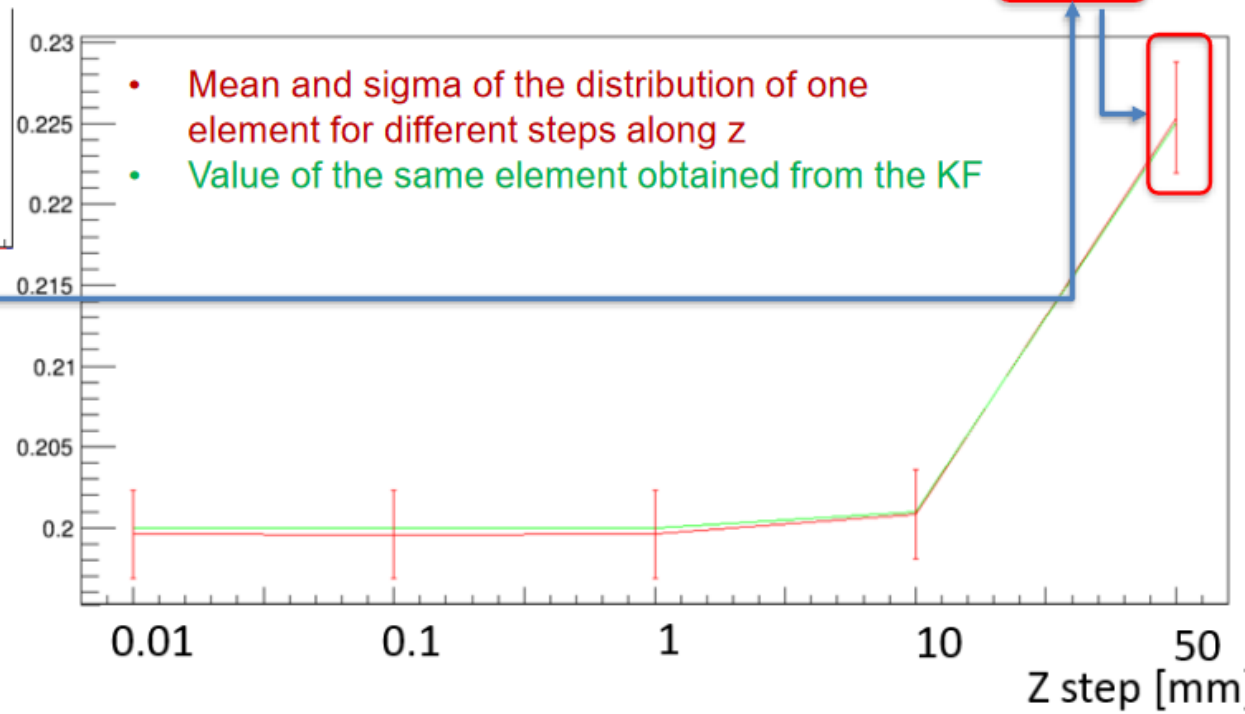
	0	1	2	3	4
0	0.01	0	0	1e-07	0
1	0	0.01	5e-10	0	2e-06
2	0	5e-10	10	0	0.0001
3	1e-07	0	0	0.01	0
4	0	2e-06	0.0001	0	0.2

- Mean and sigma of each element are obtained for different steps along z, from 0.1 to 50 mm
- The results are compared to the values obtained with the KF propagation

Covariance matrix propagation check



	0	1	2	3	4
0	0.01	0	0	1e-07	0
1	0	0.01	5e-10	0	2e-06
2	0	5e-10	10	0	0.0001
3	1e-07	0	0	0.01	0
4	0	2e-06	0.0001	0	0.2



- Mean and sigma of the distribution of one element for different steps along z
- Value of the same element obtained from the KF

- Mean and sigma of each element are obtained for different steps along z, from 0.1 to 50 mm
- The results are compared to the values obtained with the KF propagation