ePump
(error PDF Update Method Package)

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- PRD98 (2018) 9, 094005 – CS, J. Pumplin, C.-P. Yuan
- PRD99 (2019) 5, 054004 – C. Willis, R. Brock, D. Hayden, T.-J.Hou, CS, C.-P. Yuan
- PRD100 (2019) 11, 114024 – T.-J.Hou, Z. Yu, S. Dulat, CS, C.-P. Yuan
- Others…

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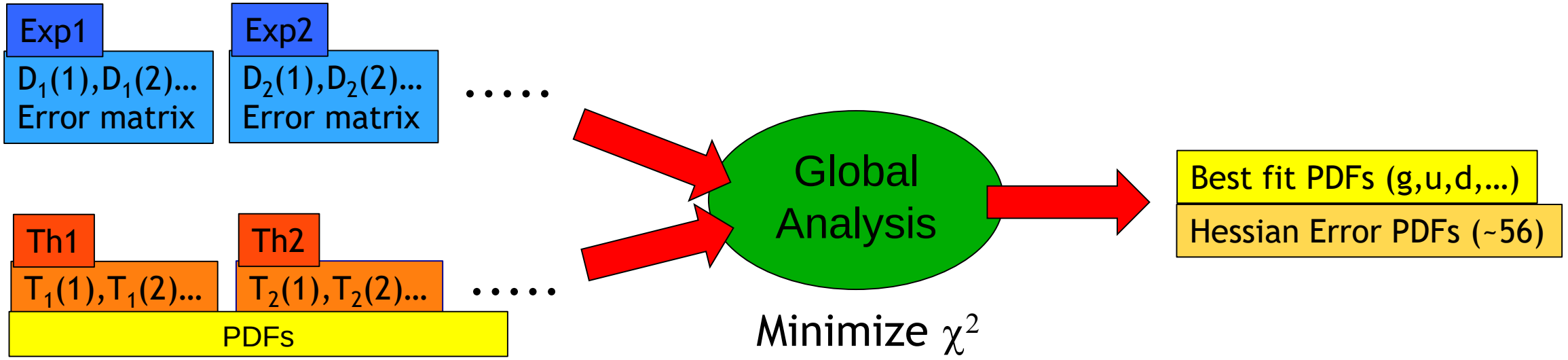
Why ePump?

Global Analysis:

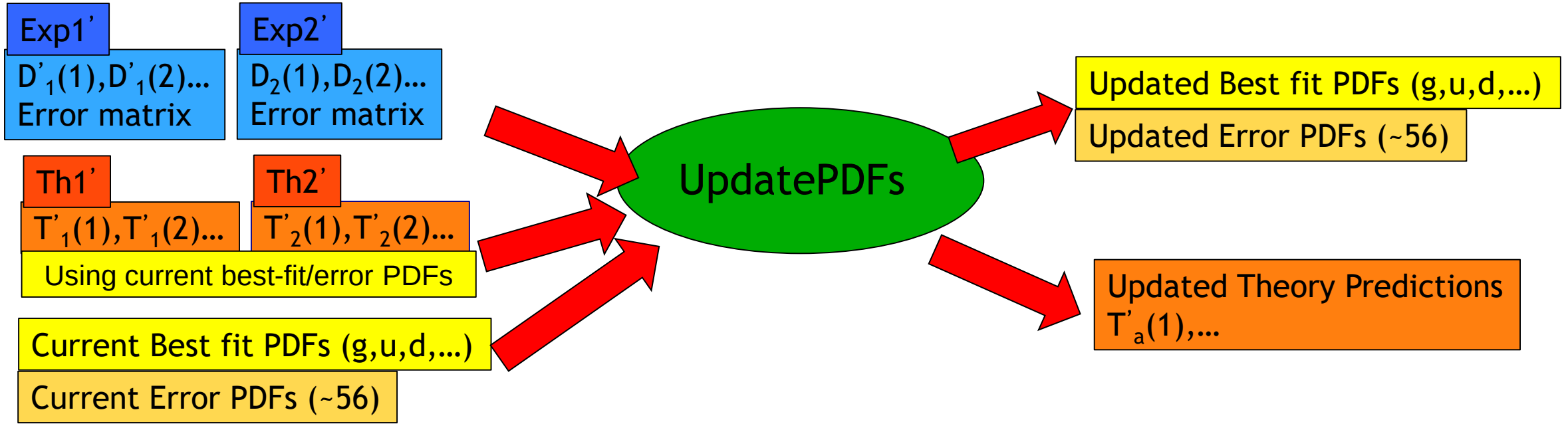


What if we want to see the effects of new experiments Exp1', Exp2',…?

- Full global analysis code takes a long time to run.
- Requires detailed info of all other included experiments.

ePump provides two tools: UpdatePDFs, OptimizePDFs

ePump: UpdatePDFs



- Only requires new experiments Exp1', Exp2' (or pseudo-data).
  - Old experimental info is contained in Error PDFs
- Only requires theory predictions calculated with current best-fit/error PDFs
  - With these input, it runs fast, ~few seconds on MacBook Pro

Hessian Updating

- PDF parametrization $f(x,Q;\mathbf{z})$: (parameters $\mathbf{z}$)

  best-fit: $f^0 = f(x,Q;\mathbf{0})$, error PDFs: $f^{\pm i} = f(x,Q;\pm\mathbf{e}^i)$

- Updated Chi-square function :

$$\Delta\chi^2(\mathbf{z}) = \Delta\chi^2_{\text{old}}(\mathbf{z}) + \left(X_a^E - X_a(\mathbf{z})\right) C^{-1}_{ab} \left(X_b^E - X_b(\mathbf{z})\right)$$

- Hessian approximation :

$$\Delta\chi^2_{\text{old}}(\mathbf{z}) = T^2\mathbf{z}^2 \quad (T = \text{tolerance parameter})$$

$$X_\alpha(\mathbf{z}) = X_\alpha(\mathbf{0}) + \Delta X_\alpha \cdot \mathbf{z} \quad \text{with} \quad \Delta X_a^i = \tfrac{1}{2}\left(X_a(+\mathbf{e}^i) - X_a(-\mathbf{e}^i)\right)$$

- Minimize to find new best fit:

$$\mathbf{z}^0_{\text{new}} = (\mathbf{1}+\mathbf{M})^{-1}\mathbf{A} \quad \text{with}$$

$$A^i = \tfrac{1}{T^2}\left(X_a^E - X_a(\mathbf{0})\right) C^{-1}_{ab} \Delta X_b^i$$

$$M^{ij} = \tfrac{1}{T^2} \Delta X_a^i C^{-1}_{ab} \Delta X_b^j$$

Paukkunen and Zurita, JHEP 1412 (2014) 100

Updated PDF set

- New best-fit PDF : $f^0_{\text{new}} = f^0 + \Delta \boldsymbol{f} \cdot \mathbf{z}$
- New error PDFs : $f^{\pm(r)} = f^0_{\text{new}} \pm \frac{1}{\sqrt{1+\lambda^{(r)}}} \Delta \boldsymbol{f} \cdot \mathbf{U}^{(r)}$

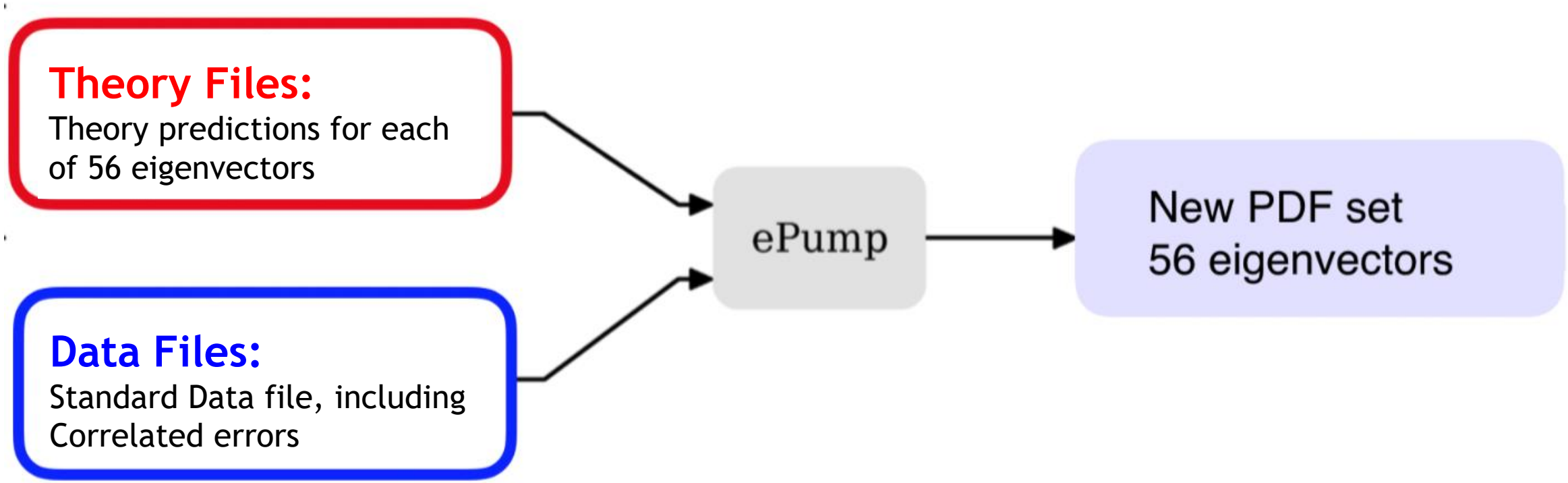
  where $\boldsymbol{/}^{(r)}$ and $\mathbf{U}^{(r)}$ are the eigenvalues and eigenvectors of matrix $\mathbf{M}$

- Extensions :
  - Best choices for $\Delta \boldsymbol{f}$ within the linear approximation
  - Dynamical tolerances : $\pm\mathbf{e}^i \text{ Þ } \pm\left(T^{\pm i}/T\right)\mathbf{e}^i$
  - Inclusion of diagonal quadratic terms in expansion of $X_a\left(\mathbf{z}\right)$
  - Direct update of other observables :

$$Y^0_{\text{new}} = Y^0 + \Delta \boldsymbol{Y} \cdot \mathbf{z} \quad , \quad \left|\Delta Y\right| = \Delta \boldsymbol{Y} \cdot \left(\mathbf{1}+\mathbf{M}\right)^{-1} \cdot \Delta \boldsymbol{Y}$$

Xfitter “Hessian profiling” has similar functionality, but less flexible in choice of tolerances (as used by CT, MMHT)

How to use ePump



(Auxiliary Theory Files may also be included to update predictions for observables not included in fit.)

Enhancements of ePump (in progress)

- Simultaneously update PDFs + α_s
  - Use CT-provided $(\alpha_s^0 \pm \delta\alpha_s)$ PDF sets $(0.118 \pm .002)$ as $(N+1)^{\text{th}}$ error set pair
  - (with theory predictions calculated using $\alpha_s = 0.118 \pm .002$)
    - ➢ New best-fit and error PDFs corresponding to updated α_s
    - ➢ Some theoretical work left to sort this out – in progress
- Simultaneously update PDFs + SMEFT parameters
  - "SM Effective Field Theory" parameters
  - Implemented by Keping Xie and Yao Fu

ePump website

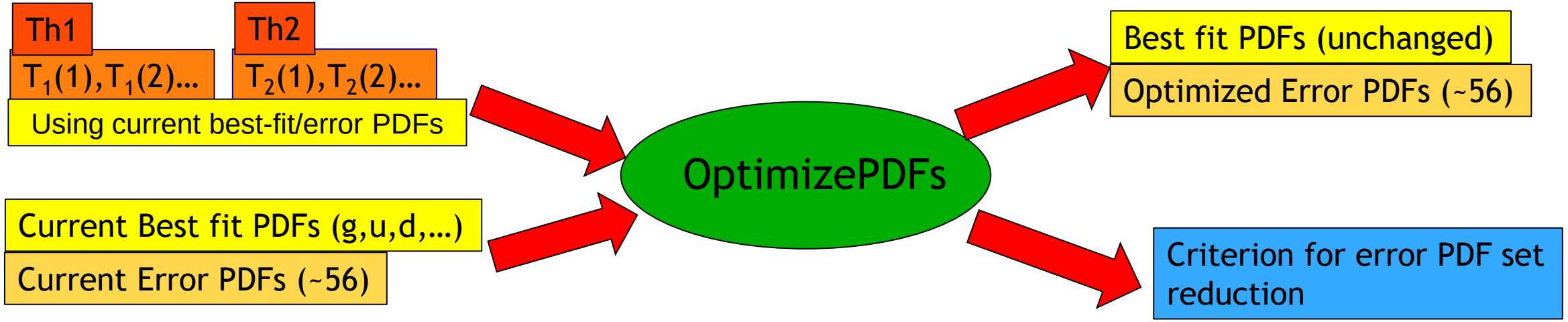
https://epump.hepforge.org/

- Carl Schmidt (MSU)
- C.-P. Yuan (MSU)
- *Keping Xie (U.Pitt)
- *Yao Fu (USTC)

Backups

ePump: OptimizePDFs

- Exp analysis may require great many runs with Error PDFs (~56)
  - But may be insensitive to certain flavors or combinations



- OptimizePDFs
  - creates an optimized set of error PDFs for the relevant observables
  - gives a criterion for choosing a reduced set (~6-10) which contains most of the relevant dependence for the observables.