The 15-th International Workshop on heavy Quarkonium
ROUND TABLE: Status, challenges and prospects of SDC calculations for quarkonium production

Automatic calculation on heavy Quarkonium Physics

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FDC --- automatic calculation processes up to one-loop level
with all NRQCD operator implemented

FDCHQHP: A Fortran package on heavy Quarkonium Physics,
including heavy quarkonium polarization calculation
generated by using FDC
with automatic parallization and final precision control tool built in.
published at Comput. Phys. Commun. 185, 2939(2014) (arXiv:1405.2143)

$$\lambda_\theta = \frac{d\sigma_{11} - d\sigma_{00}}{d\sigma_{11} + d\sigma_{00}}, \lambda_{\theta\phi} = \frac{\sqrt{2} Re d\sigma_{10}}{d\sigma_{11} + d\sigma_{00}}, \lambda_\phi = \frac{d\sigma_{1,-1}}{d\sigma_{11} + d\sigma_{00}}, \quad \frac{d\sigma^H_{\lambda\lambda'}}{dy}\Big|_{y=a} = n_{\lambda\lambda'} \frac{d\sigma^H_{\lambda\lambda'}}{dy}\Big|_{y=-a}, \; n_{\lambda\lambda'} = \begin{cases} 1 & \lambda=\pm\lambda' \\ -1 & \lambda=\pm1,\lambda'=0 \end{cases}$$

FDCHQHP： A Fortran Package generated by using FDC package

This package includes

- 6 channels
- 76 sub-processes
- Almost 2 millions lines Fortran codes in total.

STATES	LO sub-process	Number of Feynman diagrams	NLO sub-process	Number of Feynman diagrams
${}^3S_1^{[1]}$	$g+g \to (Q\bar{Q})_n + g$	6	$g+g \to (Q\bar{Q})_n + g(one-loop)$	128
			$g+g \to (Q\bar{Q})_n + g + g$	60
			$g+g \to (Q\bar{Q})_n + Q + \bar{Q}$	42
			$g+g \to (Q\bar{Q})_n + q + \bar{q}$	6
			$g+q(\bar{q}) \to (Q\bar{Q})_n + g + q(\bar{q})$	6
${}^1S_0^{[8]}$ $({}^3P_J^{[8]})$	$g+g \to (Q\bar{Q})_n + g$	(12, 16, 12)	$g+g \to (Q\bar{Q})_n + g(one-loop)$	(369, 644, 390)
	$g+q(\bar{q}) \to (Q\bar{Q})_n + q(\bar{q})$	(2, 5, 2)	$g+q(\bar{q}) \to (Q\bar{Q})_n + q(\bar{q})(one-loop)$	(61, 156, 65)
or	$q+\bar{q} \to (Q\bar{Q})_n + g$	(2, 5, 2)	$q+\bar{q} \to (Q\bar{Q})_n + g\ (one-loop)$	(61, 156, 65)
${}^3S_1^{[8]}$			$g+g \to (Q\bar{Q})_n + g + g$	(98, 123, 98)
			$g+g \to (Q\bar{Q})_n + q + \bar{q}$	(20, 36, 20)
or			$g+q(\bar{q}) \to (Q\bar{Q})_n + g + q(\bar{q})$	(20, 36, 20)
${}^3P_J^{[1]}$			$q+\bar{q} \to (QQ)_n + g + g$	(20, 36, 20)
			$q+\bar{q} \to (Q\bar{Q})_n + q + \bar{q}$	(4, 14, 4)
			$q+\bar{q} \to (Q\bar{Q})_n + q' + \bar{q}'$	(2, 7, 2)
			$q+q \to (QQ)_n + q + q$	(4, 14, 4)
			$q+q' \to (Q\bar{Q})_n + q + q'$	(2, 7, 2)

Table: The sub-processes for heavy quarkonium $c\bar{c}$ and $b\bar{b}$ prompt production at the LO and NLO.

- L.-P. Wan and J.-X.Wang, Comput. Phys. Commun. 185, 2939(2014) (arXiv:1405.2143)

Automatic Parallization, control precision and submitt jobs

- Parallization on numerical calculation:

  N (for example 21 points) p_t point for theoretical plots

  76 sub-processes

  there are 21 X 76 = 1596 indepental jobs

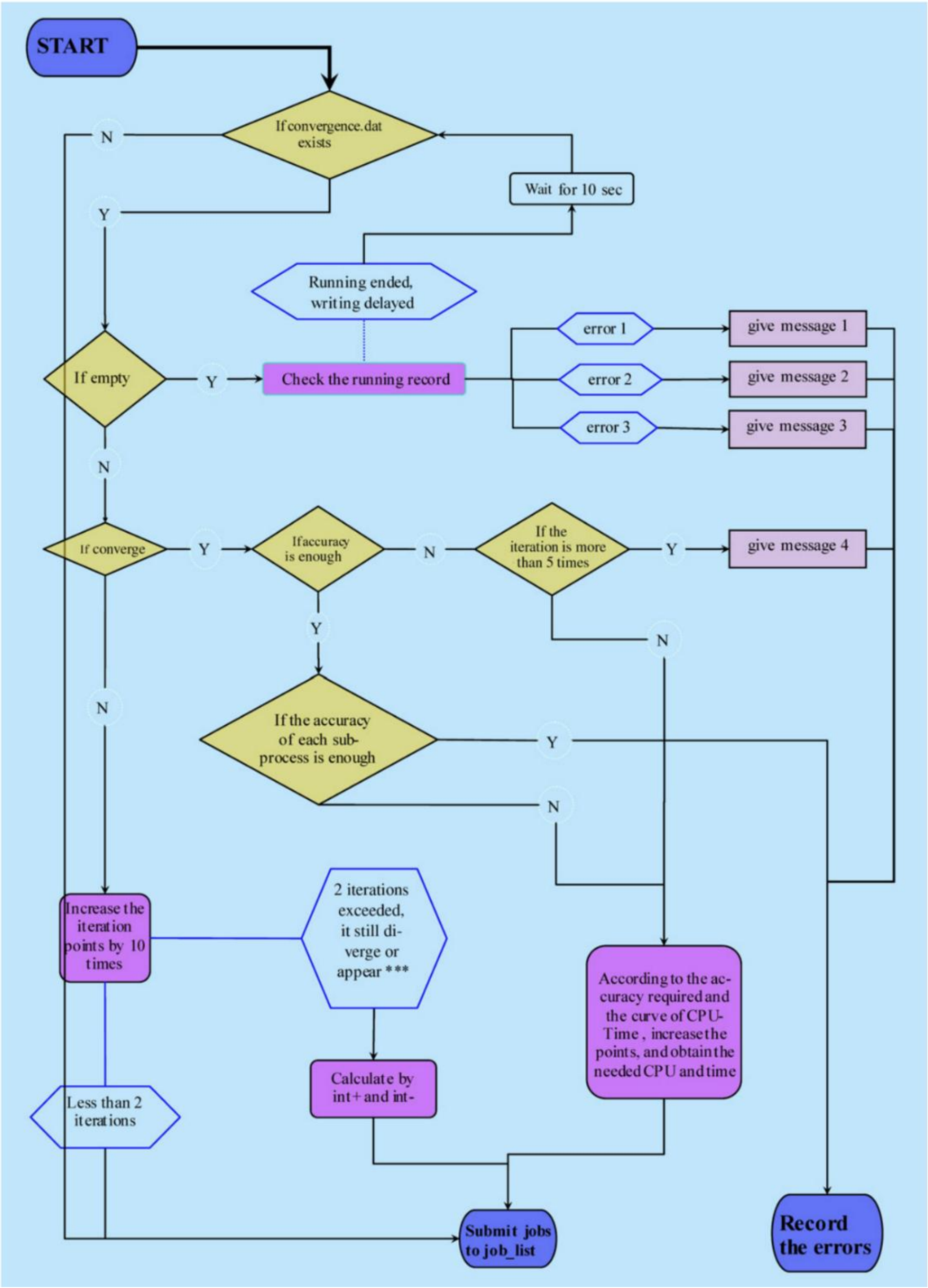
- To control the final results precision for 6 channels

  test running for all processes and give estimate on integration sample

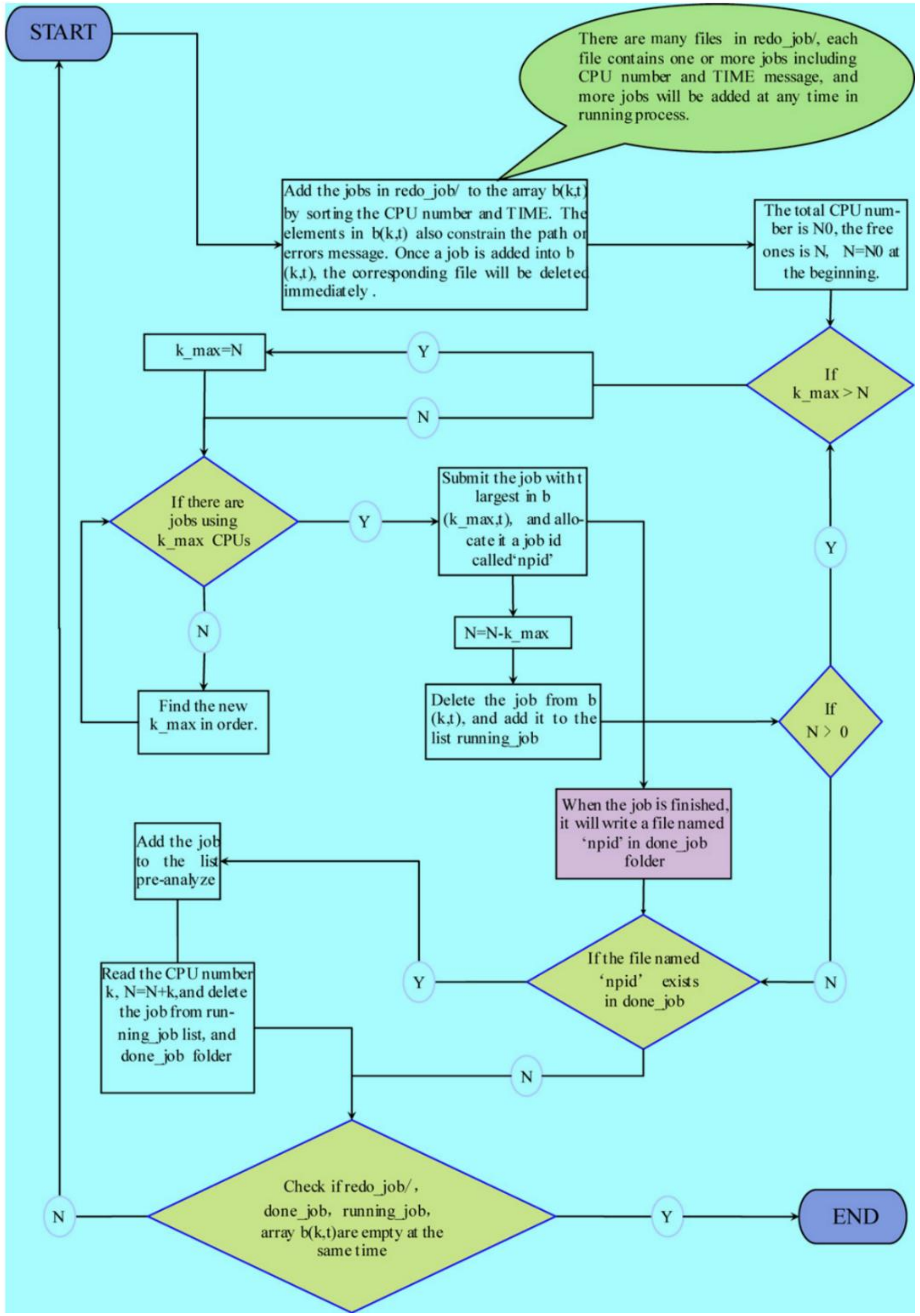
  real calculation for each jobs and check the precision is ok or not

  if not, inrease the sample points in the integration, ...

- It will take about 100,1000 CPU hours on three polarization parameter p_t distributions for prompt J/psi production at LHC



The flow chart for analyzing the precision in WBIN package



The flow chart for submitting jobs on supercomputers in WBIN package

- Aim and applicability of the codes and their deliverables
  - pp, $p\bar{p}$ collisions, Different PDF
  - heavy ions,
  - Production J/ψ, η_c, χ_c, $\Upsilon(ns)$, η_b, $\chi_{bJ}(nP)$
- Theoretical uncertainties
  - Partonic level Acc < 0.1%
  - Channel level Acc < 1 %
- New applications
  - J/ψ production in polarized proton collision
- Main challenges behind numerical computations
  - take times $^3P_J^{[1]} \gg {}^3P_J^{[8]}, {}^3S_1^{[8]}, {}^1S_0^{[8]},$
- Expected improvements in perturbative calculations