The current situation of computing resources for accelerator optimization

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CEPC DAY (JUNE 25, 2021)

Content

- The current situation of computing resources
- The status of error correction of collider ring
- Summary and to do list

Computing resources requirement

Key issue

D. H. Ji, CEPC Day, Dec. 28, 2020

Error Correction For Booster Ring

- Shortage of computing resources←→Accuracy/Iteration speed/Seeds
  - Memory
    - ((1408(HC)+1408(VC))*2816(BPM)*2*2816(Q))*8/1024/1024/1024=332.75GB
    - ((100(HC)+100(VC))*2816(BPM)*2*2816(Q))*8/1024/1024/1024=23.63GB
  - Matlab
- 1 loop: 2~3 weeks…

Error Correction For Collider Ring

- ~3600 correctors, ~3600 BPMs, and ~3690 Quadrupole magnets
- 1000 lattice seeds for correction
- Few Matlab licenses
  - Requirement: Both cpu cores and matlab licenses are urgently needed, the more the better.

Computing resources requirement

- Software: SAD and Matlab (AT)

✓ COD correction **--- SAD, 5 ~ 10 h/seed**

✓ Dispersion correction (DFS) --- **SAD, 2~4 h/seed**

☐ Beta beating correction (LOCO) **--- Matlab, 1~2 h/seed**

✓ Coupling and vertical dispersion correction (Local coupling parameter correction）--- SAD, < 1 h/seed

Run matlab in parallel on Slurm cluster - **status**

Provided by Ran Du, Jun 18, 2021

- Status
  - matlab-slurm interface has been provided to cepcmpi users.
  - Parallel degree : 511
  - Five more tempoary matlab client to be added
  - one left bug to get fixed by matlab : non-zero exit code

```
wangbin 611380        accap[057-058]  COMPLETED
        611380.batch        accap057  COMPLETED
        611380.0      accap[057-058]     FAILED
```

Caused by matlab non-zero exit code

- Issues solved
  - Architecture discussed & fixed : to integrate with Slurm cluster
  - Install matlab on /cvmfs
  - Install matlab license manager on a dedicated server
  - Debug matlab-slurm interface

Run matlab in parallel on Slurm cluster - **interface**

Provided by Ran Du, Jun 18, 2021

- Matlab-slurm interface scripts

```
[wangbin@lxslc712 job_script]$ pwd
/scratchfs/bes/wangbin/AC/matlab/job_script
[wangbin@lxslc712 job_script]$ ll
total 32
-rw-r--r-- 1 wangbin physics  216 Jun 17 16:44 customerMLScript.m
-rw-r--r-- 1 wangbin physics  305 Jun 18 18:12 LogFile.txt
-rwxr-xr-x 1 wangbin physics 1537 Jun 18 18:26 matlabSlurmConf_large_mem.m
-rwxr-xr-x 1 wangbin physics 1444 Jun 18 17:50 matlabSlurmConf.m
-rw-r--r-- 1 wangbin physics 5248 Jun 17 14:54 SlurmProfile_512.mlsettings
-rwxr-xr-x 1 wangbin physics  217 Jun 18 18:07 submitMATLABJob_large_mem.sh
-rwxr-xr-x 1 wangbin physics  207 Jun 18 17:47 submitMATLABJob.sh
[wangbin@lxslc712 job_script]$
```

Interface scripts

```
[wangbin@lxslc713 job_script]$ ./submitMATLABJob.sh
```

Run interface scripts

```
[wangbin@lxslc713 ~]$ squeue -u wangbin
             JOBID PARTITION     NAME     USER ST       TIME  NODES NODELIST(REASON)
            611477      spub matlabte  wangbin  R       0:13      2 spub[003-004]
[wangbin@lxslc713 ~]$
```

Matlab job on Slurm cluster

Content

- The current situation of computing resources
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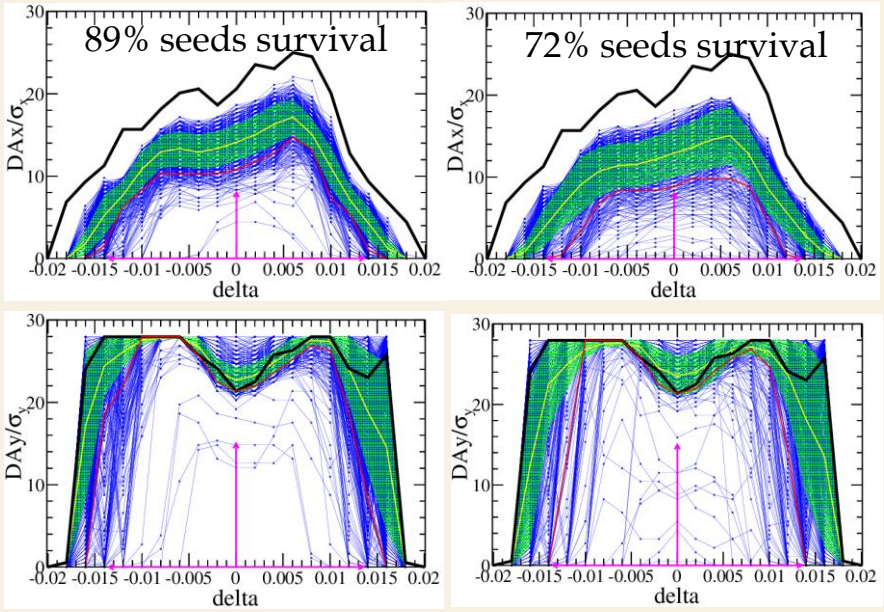
The status of error correction

The CDR lattice [Done]



—DA of bare lattice —mean value —lower limits at 90%

—DA of each seed —statistic errors

The high luminosity lattice [Ongoing]

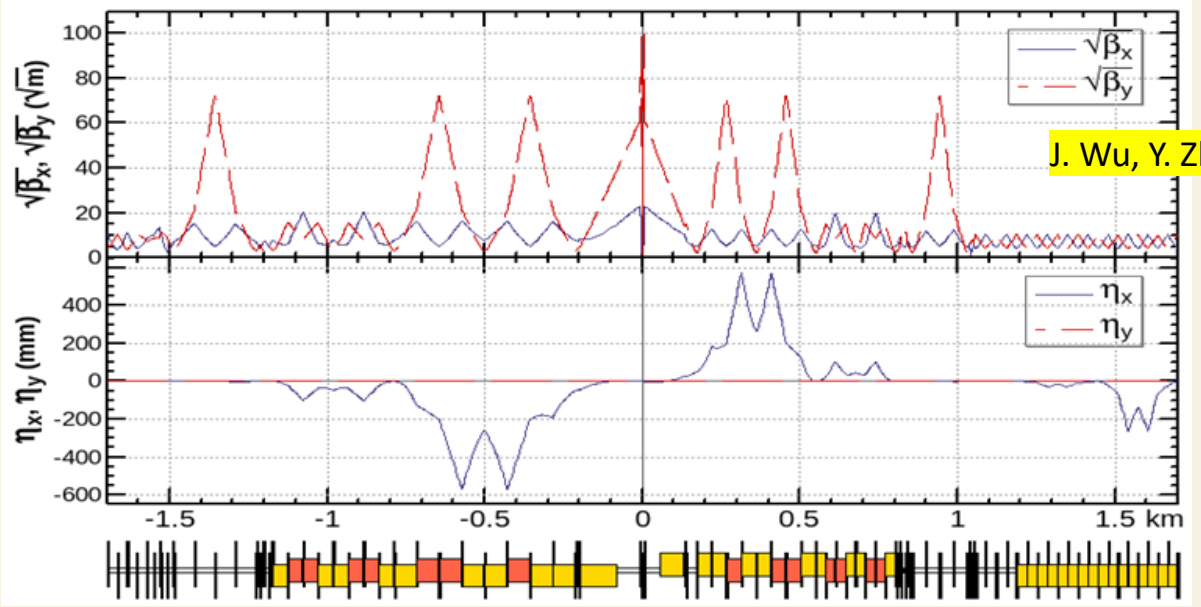
- We need to update and optimize the correction code for this more limited lattice.
- Partial of correction are initially completed.
- Matlab licenses are necessary for the important beta beating correction.

Beam parameters

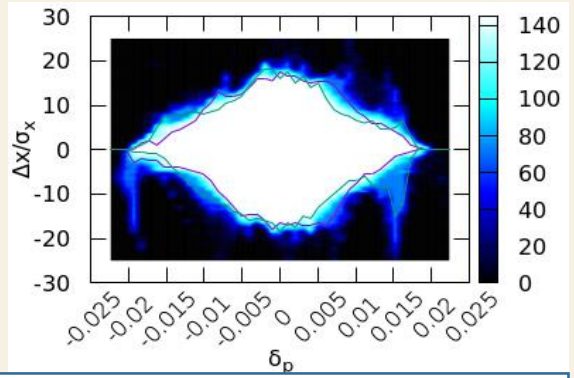
Y. W. Wang, D. Wang, Y. Zhang, J. Y. zhai et al

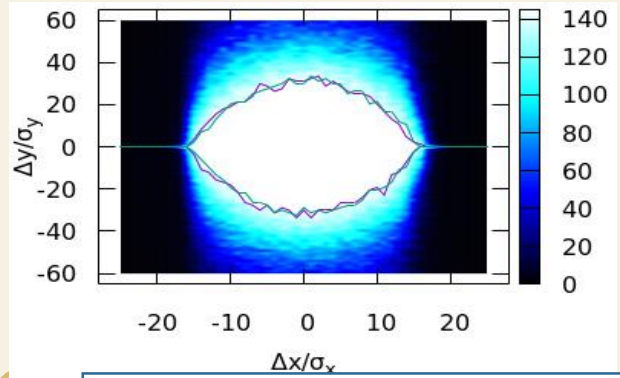
	ttbar	Higgs	W	Z
Number of IPs	2			
Circumference [km]	100.0			
SR power per beam [MW]	30			
Half crossing angle at IP [mrad]	16.5			
Bending radius [km]	10.7			
Energy [GeV]	180	**120**	80	45.5
Energy loss per turn [GeV]	9.1	**1.8**	0.357	0.037
Piwinski angle	1.21	**5.94**	6.08	24.68
Bunch number	35	**249**	1297	11951
Bunch population [10^10]	20	**14**	13.5	14
Beam current [mA]	3.3	**16.7**	84.1	803.5
Momentum compaction [10^-5]	0.71	**0.71**	1.43	1.43
Beta functions at IP (bx/by) [m/mm]	1.04/2.7	**0.33/1**	0.21/1	0.13/0.9
Emittance (ex/ey) [nm/pm]	1.4/4.7	**0.64/1.3**	0.87/1.7	0.27/1.4
Beam size at IP (sigx/sigy) [um/nm]	39/113	**15/36**	13/42	6/35
Bunch length (SR/total) [mm]	2.2/2.9	**2.3/3.9**	2.5/4.9	2.5/8.7
Energy spread (SR/total) [%]	0.15/0.20	**0.10/0.17**	0.07/0.14	0.04/0.13
Energy acceptance (DA/RF) [%]	2.3/2.6	**1.6/2.2**	1.2/2.5	1.3/1.7
Beam-beam parameters (ksix/ksiy)	0.071/0.1	**0.015/0.11**	0.012/0.113	0.004/0.127
RF voltage [GV]	10	**2.2**	0.7	0.12
RF frequency [MHz]	650	**650**	650	650
HOM power per cavity (5/2/1cell)[kw]	0.4/0.2/0.1	**1/0.4/0.2**	-/1.8/0.9	-/-/5.8
Longitudinal tune Qs	0.078	**0.049**	0.062	0.035
Beam lifetime (bhabha/beamstrahlung)[min]	81/23	**39/18**	60/717	80/182202
Beam lifetime [min]	18	**12.3**	55	80
Hour glass Factor	0.89	**0.9**	0.9	0.97
Luminosity per IP[1e34/cm^2/s]	0.5	**5.0**	16	115

Lattice and requirements



J. Wu, Y. Zhang, Y. W. Wang





Achieved (w/o error): $16\sigma_x \times 32\sigma_y \times 1.9\%$

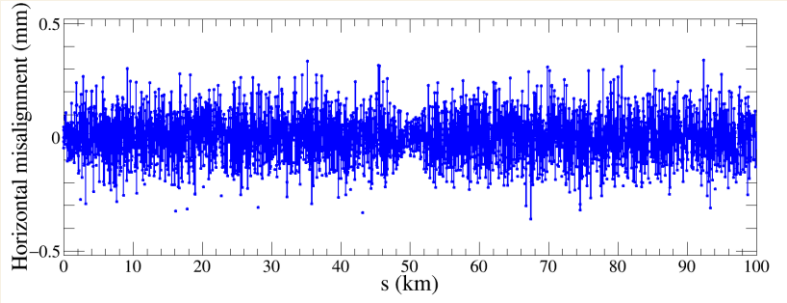
Goal (w/ error): $8\sigma_x \times 15\sigma_y \times 1.6\%$

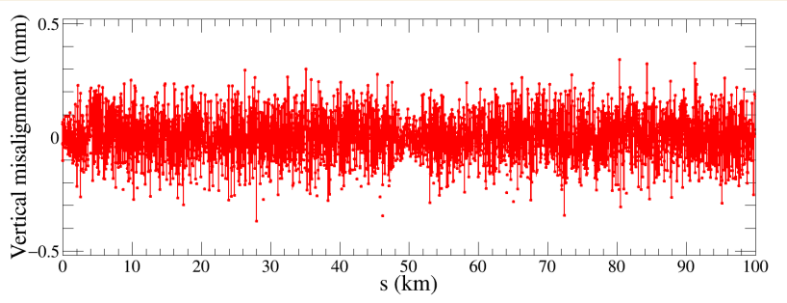
The correction scheme

- Correction steps:
  - Optimize the correction scheme step by step;
  - Optimize the correction scheme by using few lattice seeds (20 ~ 100 seeds);
  - Perform the correction for all 1000 seeds and calculate the passing rate;
  - Repeat above steps for increasing the passing rate.

Errors definition and challenges

Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)	Field error
Dipole	0.10	0.10	0.1	0.01%
Arc Quadrupole	0.10	0.10	0.1	0.02%
IR Quadrupole	**0.05**	**0.05**	**0.05**	
Sextupole	0.10	0.10	0.1	

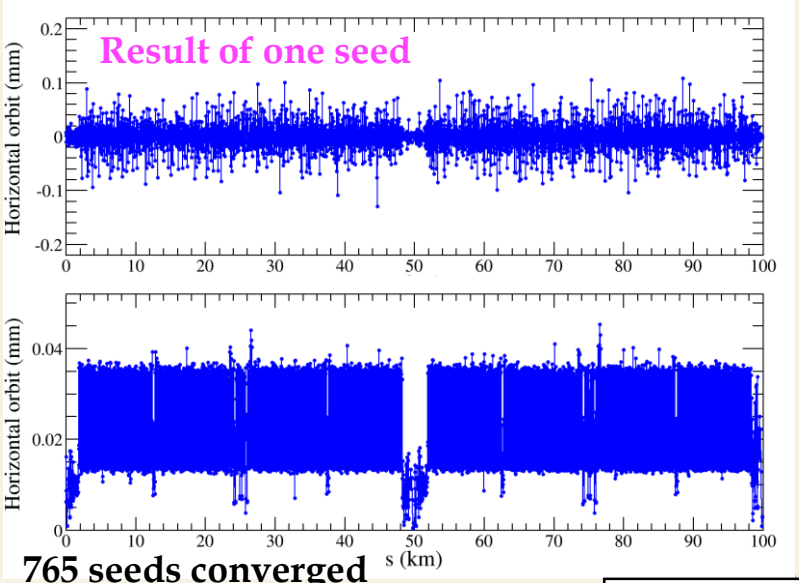




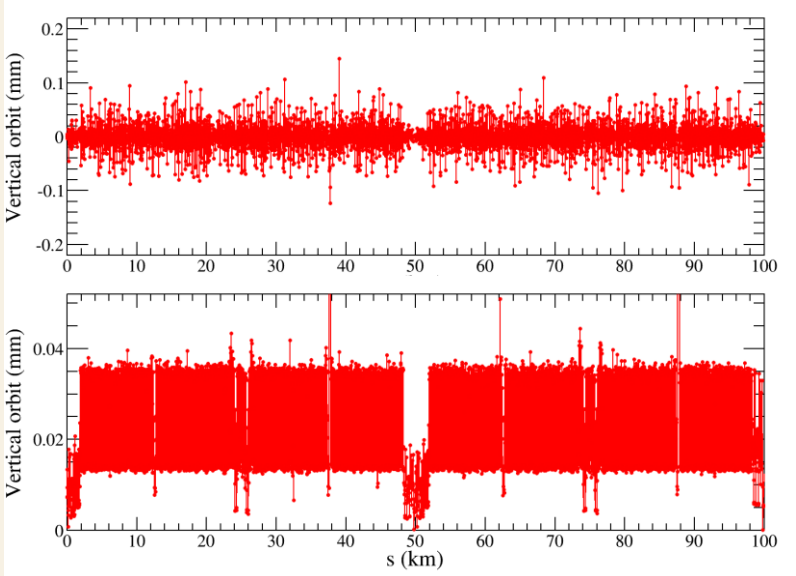
- The high luminosity lattice is much more sensitive to imperfections, the optics correction is very challenging.
- 1000 lattice seeds are generated for further correction.

COD correction

- A new corrector setting is necessary for the more limited lattice.
- BPMs placed at quadrupoles (~1800, 4 per betatron wave) Horizontal correctors placed beside focusing quadrupoles（~1800）
- Vertical correctors placed beside defocusing quadrupoles（~1800）
- Orbit correction is applied using orbit response matrix and SVD method.



765 seeds converged



$RMS_{COD} < 0.05\ mm$

Dispersion correction

Dispersion free steering principle (DFS): θ_c

$$\vec{d} = \begin{pmatrix} (1-\alpha)\vec{u} \\ \alpha\vec{D}_u \end{pmatrix} \quad M = \begin{pmatrix} (1-\alpha)A \\ \alpha B \end{pmatrix} \quad \vec{d} + M\vec{\theta} = 0$$

$\vec{u}$: Orbit vector

$\vec{D}_u$: Dispersion vector

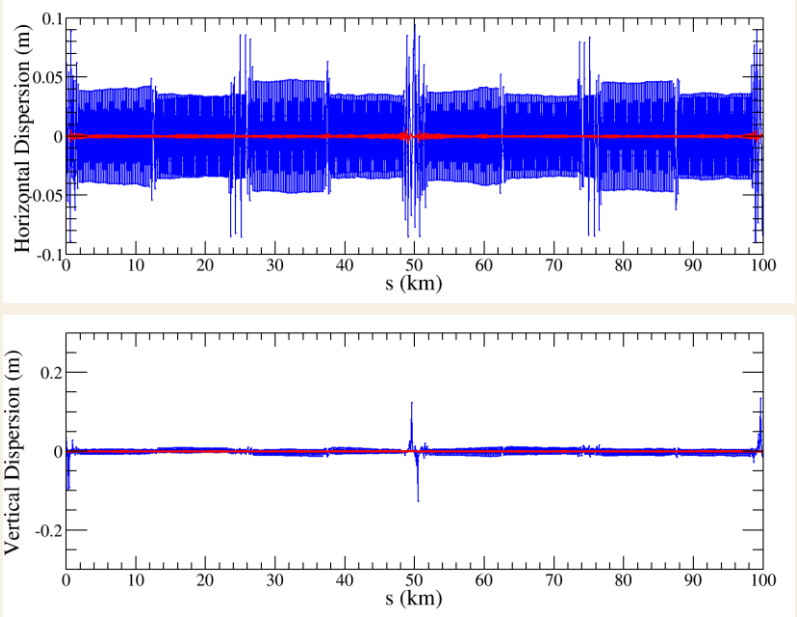
$\vec{\theta}$: Corrector strengths vector

α: Weight factor

A: Orbit response matrix

B: Dispersion response matrix

Result of one seed

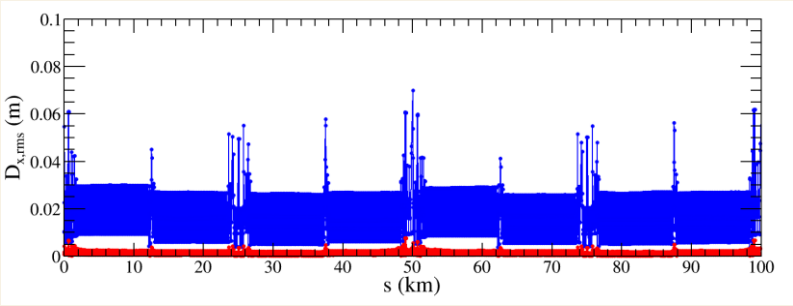


Before DISP correction

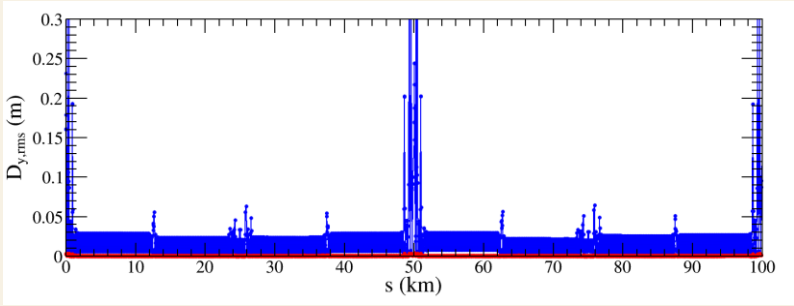
After DISP correction

Dispersion correction

674 seeds converged



$\Delta D_{x,rms}$ decreased from 15.5mm to 1.0mm
Factor 15 improvement



$\Delta D_{x,rms}$ decreased from 18.4mm to 0.4mm
Factor 46 improvement

- The dispersion correction is performed for all selected seeds, 674 seeds are converged.
- The correction effect is comparable to that of CDR lattice.

Beta-beating correction

- Correct the beta functions with sextupoles on.
- Based on AT LOCO: model based correction
  - Establish lattice model M_{mod}, multi-parameter fit to the orbit response matrix M_{meas} to obtain calibrated model:
  - Parameters fitted: K, KS …
  - Use calibrated model to perform correction and apply to machine.
  - Fit the dispersion at the same time.
  - Application to correct beta-beating, dispersion and coupled response matrix.

$$\chi^2 = \sum_{i,j} \frac{(M_{\mathrm{mod},ij} - M_{meas,ij})^2}{\sigma_i^2} \equiv \sum_{i,j} V_{ij}^2$$

- We are working on the beta beating correction.
- More Matlab licenses are necessary.

Summary and to do list

- The imperfection correction to the high luminosity lattice is on going.
- The close orbit correction and dispersion correction are almost finished, the passing rates and the correction effect are comparable to those for CDR lattice.

- Optimize the correction strategy to achieve the beta beating correction.
- Keep working on the optimization of the whole correction scheme.
- Finish the whole correction for high luminosity lattice before October.

Thank you for your attention

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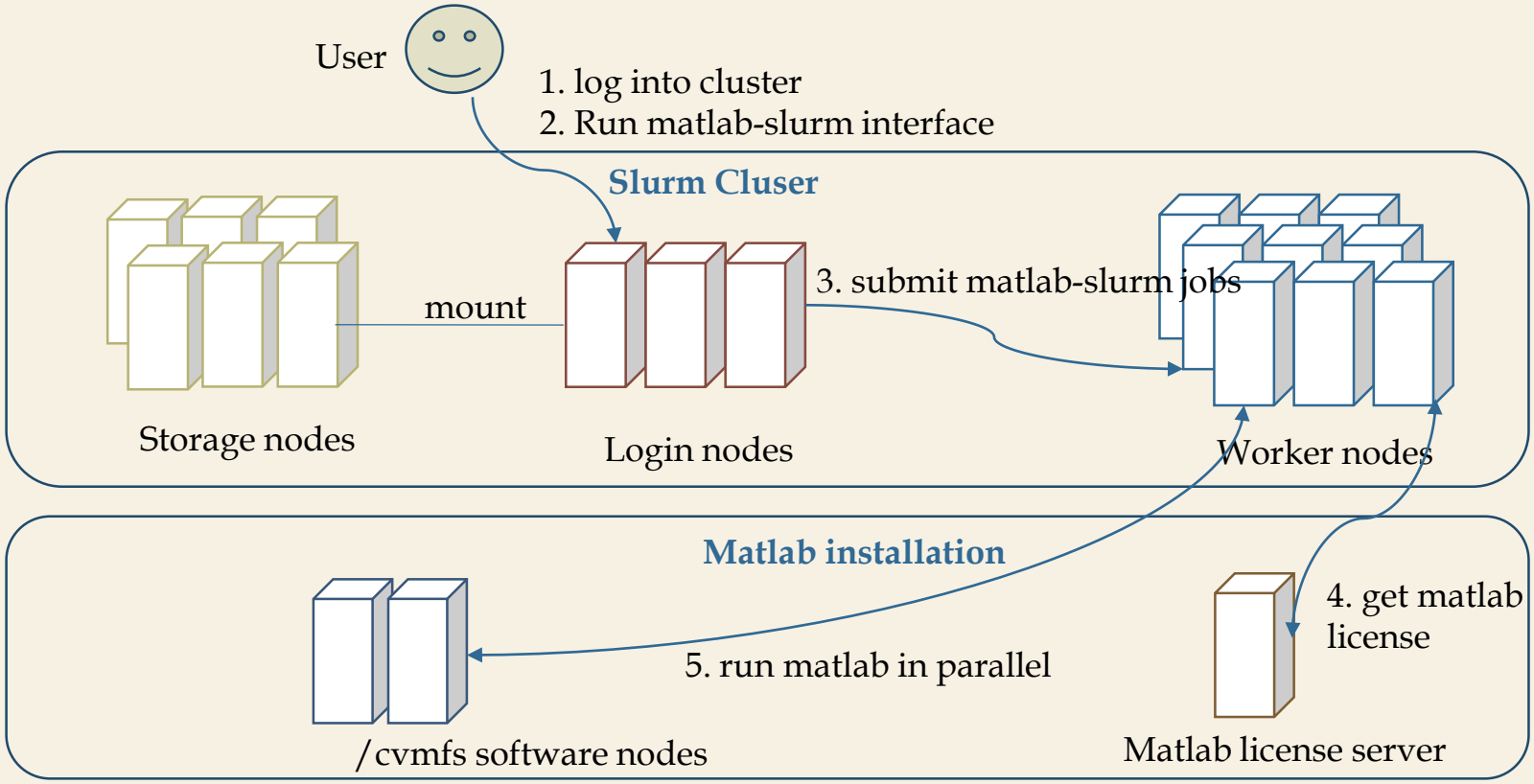
Run matlab in parallel on Slurm cluster - **architectu**



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