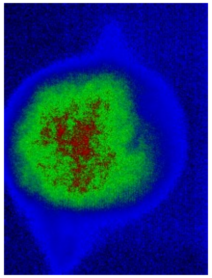
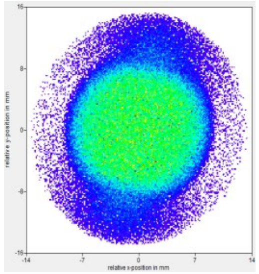
Beam imperfection studies with rotated quads model (continue)

- Motivation
- Previously results and questions
- Idea and method
- Preliminary simulation results
- Summary and conclusions
- Further steps





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PITZ physics Seminar
Zeuthen, 08.09.2016

HELMHOLTZ ASSOCIATION

PITZ Photo Injector Test Facility Zeuthen

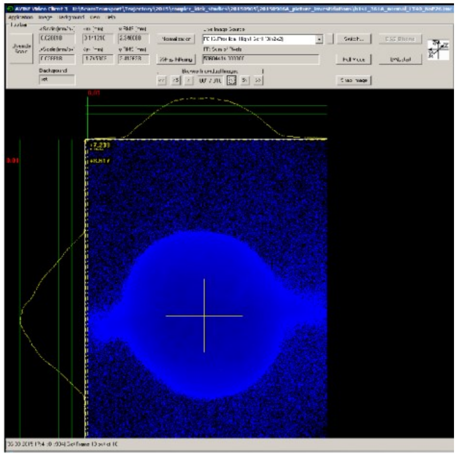
DESY

Motivation

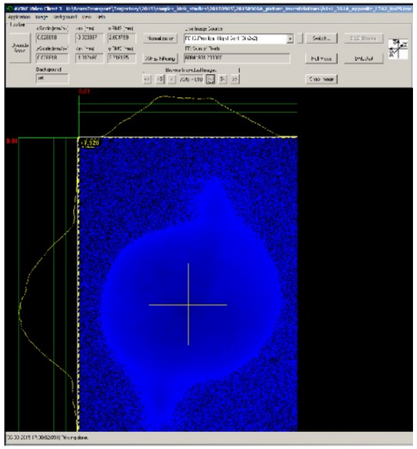
- The asymmetry beam transverse profile was found in the experiment.

beam at High1.Scr1 Imain=361A; Ibucking in compensation NoP=9; LT=42% (~480pC); Gain=12 ,Pgun=5MW , 6.178 MeV/c, **no booster** 05.09A-06.09N.2015.

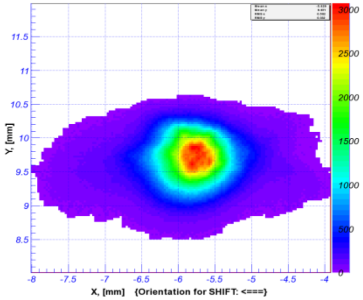
Normal solenoid polarity

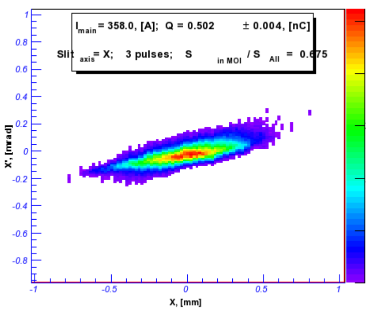


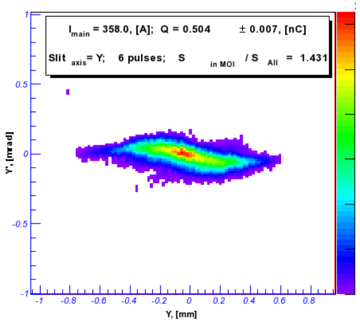
opposite solenoid polarity



- The electron beam asymmetry was observed during emittance measurements.



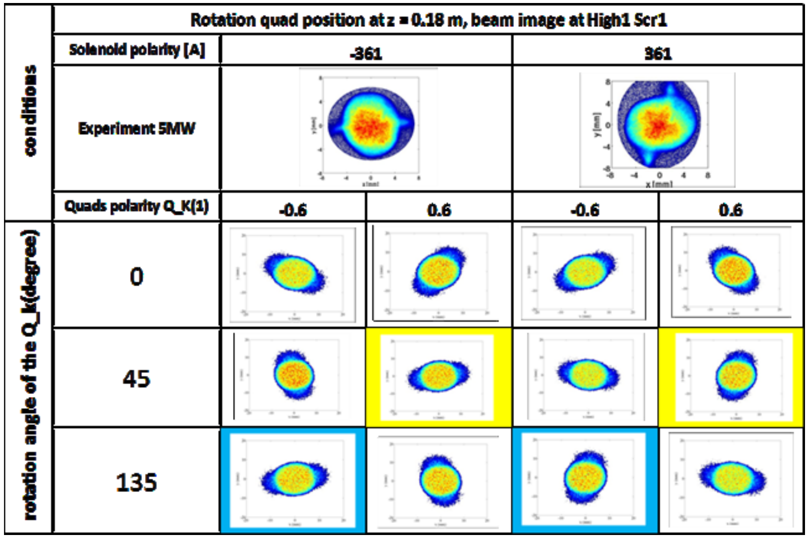


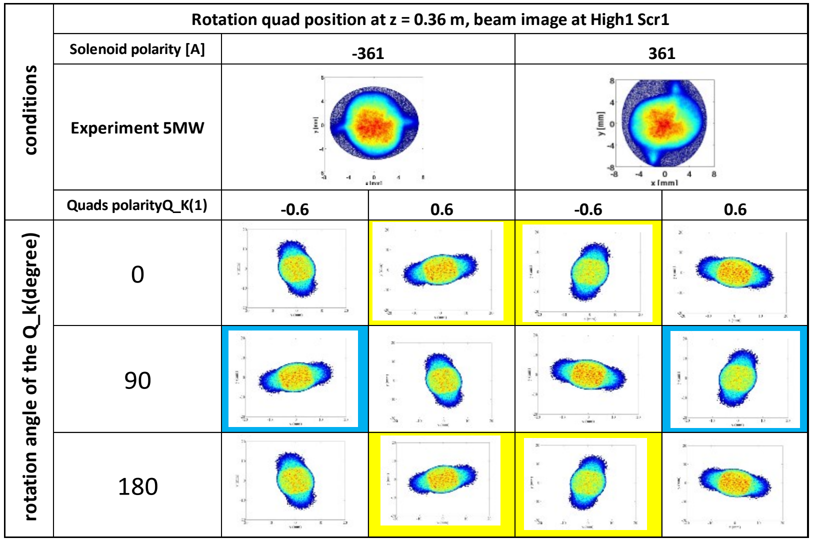


Example: Imain = 358A , BSA1.2mm, 500 pC, beam spot size and phase space, data from 20N.10.2015

Previous results and questions

#Previous results:





- ➢ The rotation quads position and rotation angle were estimated by ASTRA simulation:
- ✓ Position: around z=0.18m, **at the transition region of coupler to gun cavity**
  - > Rotation angle: Skew quads[45 degree(negative polarity) or ~135 degree(positive polarity)].
  - > Polarity: same, not effected by solenoid field polarity.
- ✓ Position: around z=0.36m, **near the exit region of the solenoid**
  - > Rotation angle: normal quads.
  - > Polarity: when change the solenoid polarity, the quads polarity also changed.

Question: How to estimate the strength of these kinds of rotated quads like field?

Coupled beam dynamics*

1. Two source of beam transverse coupling: solenoid and rotated quads.

For solenoid:

$$x'' - S(z)\,y' - \tfrac{1}{2}S'(z)\,y = 0,$$

$$y'' + S(z)\,x' + \tfrac{1}{2}S'(z)\,x = 0\,.$$

$$S(z) = \frac{e}{p}B_s(z)\,.$$

In solenoid induced coordinate:

$$v'' + \tfrac{1}{4}S^2(z)\,v = 0,$$

$$w'' + \tfrac{1}{4}S^2(z)\,w = 0\,.$$

For skew quads:

$$x'' + \underline{k}\,y = 0,$$

$$y'' + \underline{k}\,x = 0\,.$$

- In solenoid induced coordinate, the coupling due to beam rotation induced by solenoid can be canceled.

2. If we can separate solenoid and rotated quads coupling or cancel one of them, the coupling problem becomes easier to solve.

Clues: The parameters can be measured for estimating the rotated quads strength:
➔ beam transverse position (x,y) without solenoid coupling.
➔ beam position shift only (or dominated) due to rotated quads coupling.

➔ Possible method: move laser positions at the cathode.

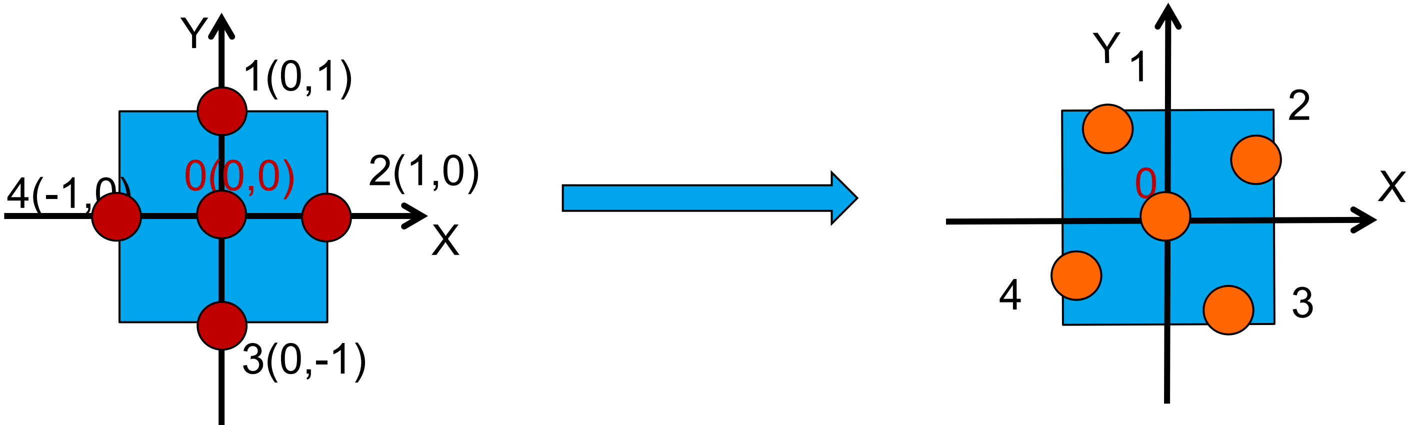
*Helmut Wiedemann, Particle Accelerator Physics, Third Edition, pp 605-620.

One possible method*

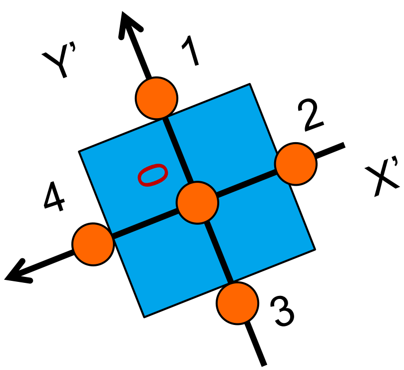
- Move the laser position on the cathode and get the beam relative positions (0-0,1-0,2-0,3-0,4-0) in the solenoid rotation induced coordinate system.

Laser relative positions on the VC2 in lab coordinate

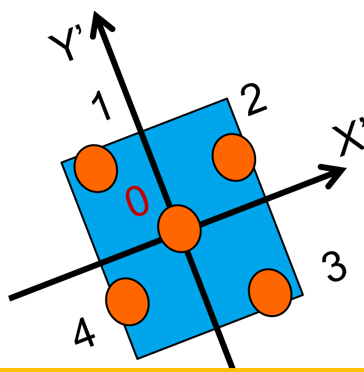
Beam relative positions at low screens in lab coordinate.



Beam relavitve positions at low screens in solenoid induced rotation coordinate (X',Y')



Without any other x-y coupling



With other (rotated quads, et al.) x-y coupling

* H. Qian private communication.

Simulation results of the coordinate transform using ASTRA

Lsub_Larmor : If true, a rotation of the transverse coordinate system induced by solenoid will be taken into account.

Lsub_Larmor =False

Laser coordinate(mm)	Beam coordinate(mm)	Relative beam position(mm)	Relative beam position(mm) In solenoid coordinate(by coordinate transform)
0(0,0)	0(0,0)	**(1,2,3,4)-0**	
1(0,1)	1(-1.979,-0.523)	**10(-1.979,-0.523)**	**10(0.001, -2.0469)**
2(1,0)	2(-0.523,1.979)	**20(-0.523,1.979)**	**20(2.0469,-0.0001)**
3(0,-1)	3(1.979,0.523)	**30(1.979,0.523)**	**30(-0.001,2.0469)**
4(-1,0)	4(0.523,-1.979)	**40(0.523,-1.979)**	**40 (2.0469,0.0001)**

Lsub_Larmor =True

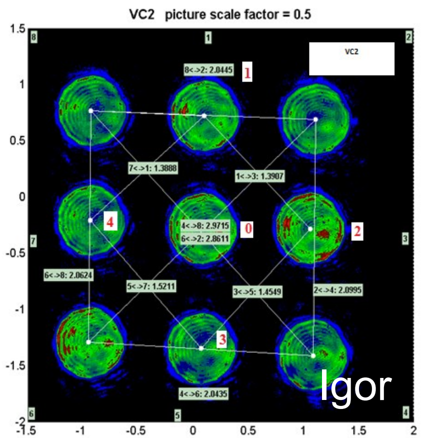
Laser coordinate(mm)	Beam coordinate(mm)	Relative beam position(mm)
0(0,0)	0(0,0)	**(1,2,3,4)-0**
1(0,1)	1(0.004,-2.047)	**10(0.004,-2.047)**
2(1,0)	2(-2.046,-0.004)	**20(-2.046,-0.004)**
3(0,-1)	3(-0.004,2.047)	**30(-0.004,2.047)**
4(-1,0)	4(2.047,0.004)	**40(2.047,0.004)**

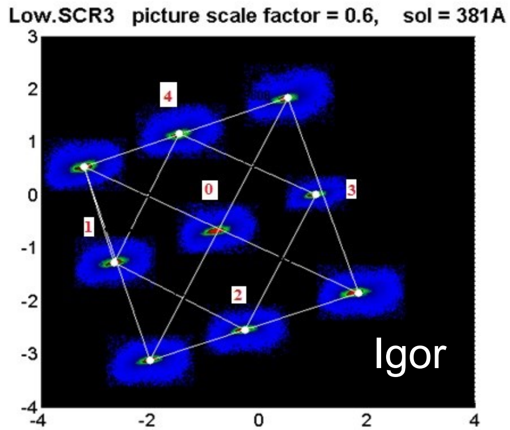
Simulation set up:
BSA 1.2mm
Charge 502 pC
Momentum after gun 6.144 MeV/c
Solenoid current: -381A

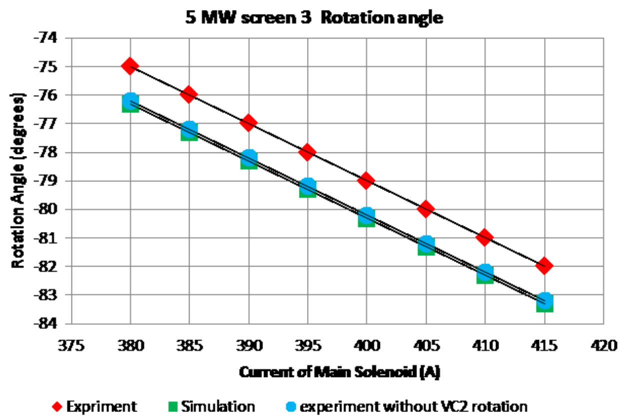
- The simulation result confirms this method is possible.

One of previous experiment results (2015)

> Laser move on the cathode and beam position at low scr3, BSA 1.2mm, Charge 502 pC, Momentum after gun 6.144 MeV/c, Solenoid current 381A.







Move laser position on the cathode:

Four postions 0(0,0), 1(0,1),2(1,0), 3(0,-1),4(-1,0)

Corresponding **beam mean position** at Low.scr3, solenoid current 381A (after focus), the rotation angle is -76.5 degree(from imaging studies)

0(-1.259,-0.756)
1(-2.667,-1.27)
2(-0.248,-2.542)
3(1.065,0.016)
4(-1.454,1.165)

Coordinate transform →

0(-0.4412,-1.4007)
1(-0.6123,-2.8898)
2(-2.4139,-0.8346)
3(-0.2331,1.0393)
4(1.4722, -1.1419)

→

Experiment beam relative coordinate(mm)	*Relative beam position(mm) Without solenoid coupling
10 (-0.1711, -1.4891)	10(0.004,-2.047)
20(-1.9727, 0.5661)	20(-2.046,-0.004)
30 (0.2081, 2.4400)	30(-0.004,2.047)
40(1.9134, 0.2588)	40(2.047,0.004)

Simulation results compared with experiment results(1)

Rotated quads parameters uesd in ASTRA:
Only skew Quads at z =0.18 m.

BSA 1.2mm
Charge 502 pC
Momentum after gun 6.144 MeV/c
Solenoid current: 381A

```
 Lquad=TRUE
Q_type(1)= 'skew'
Q_length(1)=0.0100
Q_grad(1)=-0.15
Q_pos(1)=0.1800
Q_xoff(1)=0.0000
Q_yoff(1)=0.0000
Q_zrot(1)=0.0000
/
```

Laser coordinate(mm)	Experiment beam relative coordinate(mm)	Only with skew quads Relative beam position(mm)
0(0,0)	(1,2,3,4)-0	(1,2,3,4)-0
1(0,1)	10 (-0.1711, -1.4891)	10(-0.209,-2.217)
2(1,0)	20(-1.9727, 0.5661)	20(-1.969,-0.210)
3(0,-1)	30 (0.2081, 2.4400)	30(0.209,2.217)
4(-1,0)	40(1.9134, 0.2588)	40(1.969,0.210)

➔With only skew quads, the integral strength ~ -0.0015 T, for the 5 MW in the gun.

Simulation results compared with experiment results(2)

Rotated quads parameters uesd in ASTRA:
Only skew Quads at z =0.18m with same parameters.

```
 Lquad=TRUE
Q_type(1)= 'skew'
Q_length(1)=0.0100
Q_grad(1)=-0.15
Q_pos(1)=0.1800
Q_xoff(1)=0.0000
Q_yoff(1)=0.0000
Q_zrot(1)=0.0000
/
```

- Assumed the skew quads comes from coupler, so at the same gun power, the skew quads should be same when change the solenoid current.

356 A Only skew quads Relative beam position(mm)	356 A Experiment data(mm)	381 A Only skew quads Relative beam position(mm)	381 A Experiment data(mm)
10(-0.229,-1.257)	10(-0.1242,-0.7291)	10(-0.209,-2.217)	10(-0.1711, -1.4891)
20(-1.007,-0.229)	20(-0.9317,0.3512)	20(-1.969,-0.210)	20(-1.9727, 0.5661)
30(0.229,1.257)	30(0.0975,1.1187)	30(0.209,2.217)	30(0.2081, 2.4400)
40(1.007,0.229)	40(1.0163,-0.1253)	40(1.969,0.210)	40(1.9134, 0.2588)

➔ Only skew quads can not fit two solenoid current settings.
➔The normal quads was also existed (at z = 0.36m).

Fit skew quads and normal quads to two solenoid currents

Rotated quads parameters uesd in ASTRA:
skew Quads at z =0.18m and normal quads at z = 0.36m for two solenoid currens.

Lquad=TRUE
Q_type(1)= 'skew'
Q_length(1)=0.0100
Q_grad(1)=-0.05
Q_pos(1)=0.1800
Q_xoff(1)=0.0000
Q_yoff(1)=0.0000
Q_zrot(1)=0.0000
Q_length(2)=0.0100
Q_grad(2)=X
Q_pos(2)=0.3600
Q_xoff(2)=0.0000
Q_yoff(2)=0.0000
Q_zrot(2)=0.0000
/

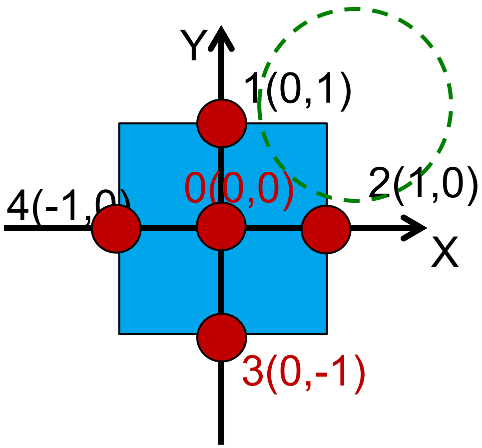
Pgun\Imain	356A	381A
5MW	Skew Q_grad:-0.05 T/m Norm Q_grad:0.01 T/m	Skew Q_grad:-0.05 T/m Norm Q_grad:0.07 T/m

356 A **Relative beam position(mm)**	**356 A** **Experiment data(mm)**	**381 A** **Relative beam position(mm)**	**381 A** **Experiment data(mm)**
10(-0.099,-1.184)	10 (-0.1242,-0.7291)	10(-0.211,-2.221)	10 (-0.1711, -1.4891)
20(-1.080,-0.100)	**20 (-0.9317**,0.3512)	**20(-1.962**, -0.212)	**20(-1.9727**, 0.5661)
30(0.099,1.184)	**30(0.0975,1.1187)**	**30(0.211, 2.221)**	**30 (0.2081, 2.4400)**
40(1.080, 0.100)	**40(1.0163**,-0.1253)	**40(1.962, 0.212)**	**40(1.9134, 0.2588)**

➢ The bold numbers are fit well between simulation and experiment.

Possible source investigation for the asymmetric relative beam position from experiment results → on going

356 A Relative beam position(mm)	356 A Experiment data(mm)	381 A Relative beam position(mm)	381 A Experiment data(mm)
10(-0.099,-1.184)	10 (-0.1242,-0.7291)	10(-0.211,-2.221)	10 (-0.1711, -1.4891)
20(-1.080,-0.100)	20 (-0.9317,0.3512)	20(-1.962, -0.212)	20(-1.9727, 0.5661)
30(0.099,1.184)	30(0.0975,1.1187)	30(0.211, 2.221)	30 (0.2081, 2.4400)
40(1.080, 0.100)	40(1.0163,-0.1253)	40(1.962, 0.212)	40(1.9134, 0.2588)



Laser at VC2

- X relative positions fit better than y except 10.
- Y relative postions has big asymmetry and large discrepancy to simulation except 30.

Possible source:

- ? Solenoid mis-alignment
  - Offset
  - Rot
- ? Rotated quads mis-alignment (irregular)
  - Offset
  - Rot
- ?   Anything else….

Diople fields effect

Rotated quads parameters uesd in ASTRA:
Skew quads at z=0.18m and normal quads at z=0.36m.
Assumed Dipole at z =0.18 m

BSA 1.2mm
Charge 502 pC
Momentum after gun 6.144 MeV/c
Solenoid current: 381A

```
Lquad=TRUE
Q_type(1)= 'skew'
Q_length(1)=0.0100
Q_grad(1)=-0.15
Q_pos(1)=0.1800
Q_xoff(1)=0.0000
Q_yoff(1)=0.0000
Q_zrot(1)=0.0000
Q_length(2)=0.0100
Q_grad(2)=0.08
Q_pos(2)=0.3600
Q_xoff(2)=0.0000
Q_yoff(2)=0.0000
Q_zrot(2)=0.0000
/
&DIPOLE
LDIPOLE = T /F
D_TYPE(1) = 'vertical'
D1(1)=(0.01,0.17)
D2(1)=(-0.01,0.17)
D3(1)=( 0.01,0.19)
D4(1)=(-0.01,0.19)
D_GAP(1,1)=0.0010
D_GAP(2,1)=0.0010
D_strength(1)=-0.002
```

Laser coordinate(mm)	Beam coordinate(mm) Dipole True	Relative beam position(mm) Dipole True	Beam coordinate(mm) Dipole False	Relative beam position(mm) Dipole False
0(0,0)	**0(0.539,-1.824)**	**(1,2,3,4)-0**	**0(0,0)**	**(1,2,3,4)-0**
1(0,1)	1(0.168,-4.136)	**10(-0.371,-2.312)**	1(-0.371,-2.312)	**10(-0.371,-2.312)**
2(1,0)	2(-1.323,-2.197)	**20(-1.862,-0.373)**	2(-1.862,-0.372)	**20(-1.862,-0.372)**
3(0,-1)	3(0.911,0.488)	**30(0.372,2.312)**	3(0.371,2.312)	**30(0.371,2.312)**
4(-1,0)	4(2.401,-1.452)	**40(1.862,0.372)**	4(1.862,0.372)	**40(1.862,0.372)**

- ✓ As expected, the dipole has no effect to the beam relative position in solenoid induced coordinate.
- ✓ But the absolute beam position in solenoid induced coordinate is effected by dipole. From simulation and experiment results, it seems there are still dipole fields, but we do not care here.

Summary and conclusions

- The method is valid for estimating the rotated quads strength, also can confirm both the skew quads and normal quads are really existed.
- Preliminary estimated results:

  For skew quads together with normal quads, the integtal strength estimated:

  skew quads ~ - 0.0005 T for 5MW in the gun;

  nomal quads ~ 0.0007 T for 381A and ~ 0.0001 T for 356A.
- The source for asymmetric relative position(10&30 and 20&40) in the experiment is not understood yet, specially large discrepancy in 10 and 20 y relative position.

Next steps:

1. The source for asymmetric relative beam position(10&30 and 20&40) and large discrepancy in y??
2. Analyze more for the old data (from Igor).
3. Take more experiments for this year set up and do more analysis and simulations.

   1)Solenoid scan at one gun power:

   ➔normal quads, Strength_Qnormal=f(Imain)

   2)Different gun power:

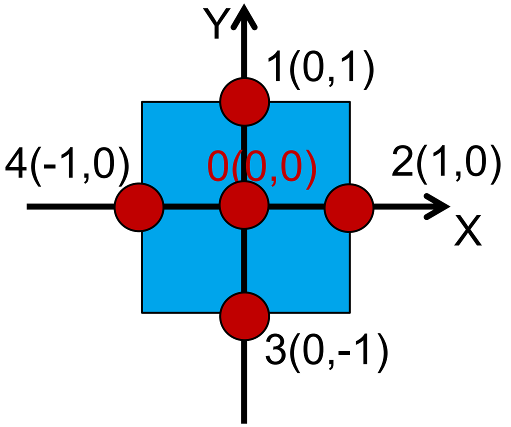
   ➔skew quads, Strength_Qskew=f(Pgun)

Thanks a lot to Houjun helpful discussions!

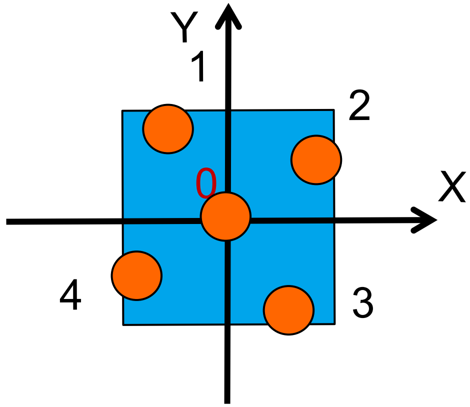
Thanks for your attention!

Experiment data table

Laser relative positions on the VC2 in lab coordinate



Beam relative positions at lower screens in lab coordinate.



Strength_Qnormal=f(Imain)

Strength_Qskew=f(Pgun)

Steps: move laser position at the cathode and record VC2 images; LEDA scan, set Gun MMMG phase; solenoid scan and recording beam images at low scr3.

Pgun\Imain	350A	360A	370A	380A	390A	400A	410A	420A	….
5MW	(Xmean, Ymean)								
3MW									
1.5MW									
….									

Beam images at low scr 3

*If it is possible, record data at one solenoid current(only need one) with different gun power.