LCLS-II Tunnel Magnetic Fields

ED0006582 Rev -

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Summary

The magnetic fields in the SLAC LCLS-II tunnel was measured at the beamline height. The fields varied in magnitude from 160 mG to 735 mG. The longitudinal component of the magnetic field had a maximum of 293 mG, with polarity changing for small sections in 4 of 37 cryomodules.

Introduction

Ambient magnetic field can influence the performance of the SRF cryomodules, due to trapped magnetic fields on the RF surface of the SRF cavities. The cavities are therefore shielded from the ambient fields by using a carbon steel vacuum vessel that is present as the outer most layer, and 2-layer high magnetic permeability magnetic shields that are present on the exterior wall of the cavity helium vessels.

The 2-layer magnetic shields provide excellent transverse component (x and y-axes) shielding, i.e. perpendicular to the beamline. The longitudinal component (z-axis) of the magnetic field may be difficult to shield due to coupling of the adjacent magnetic shields, and therefore knowing the level of ambient magnetic fields at the tunnel could aid in pre-planning.

The longitudinal component of the magnetic fields in the three cryomodules tested so far at Fermilab have had values lower than 2.5 mG. This may be due to the change in the polarity of the ambient longitudinal magnetic field in the test cave (CMTS), as illustrated in Figure 1. The polarity reverses at approximately cavities 1 and 8.

In this report, the magnetic fields measured at beamline height in the SLAC LCLS-II tunnel sections that house the SRF cryomodules are presented. In addition to the magnitude of the magnetic fields, the polarity reversal of the longitudinal component is of interest.

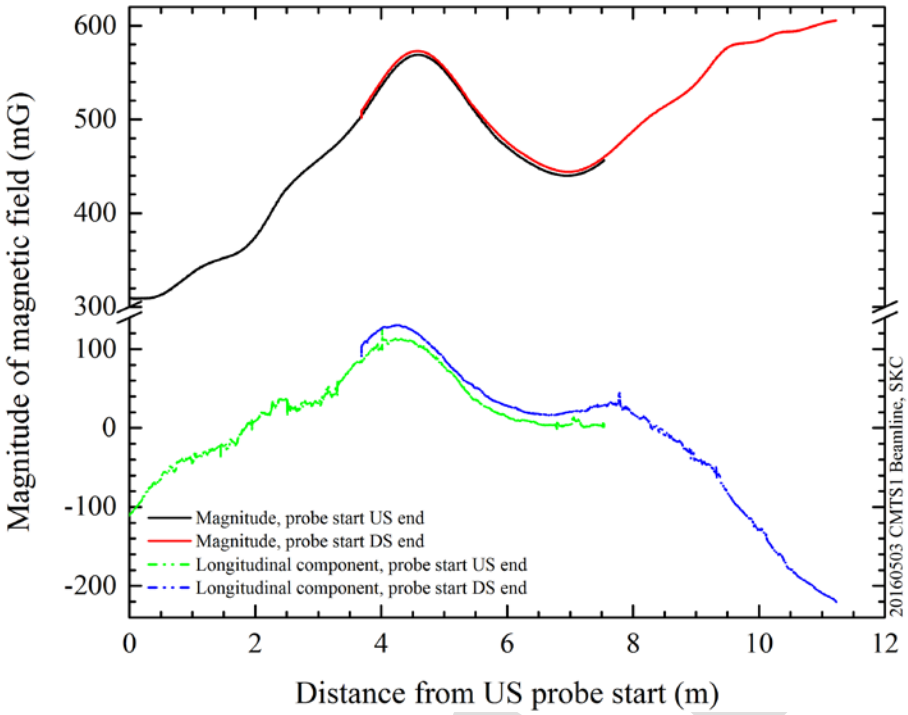


Figure 1: Magnetic fields in the Fermilab CMTS test cave. Red and black curves represent the magnitude, while the green and blue curves represent the longitudinal component.

Measurement apparatus

A custom cart was built to use the south wall of the tunnel as a reference guide. The cart therefore had two points of contact with the south wall. The fields were measured using a Bartington Mag-03MS 3-axis fluxgate. Data from this sensor was sent to a digital multimeter, using a multiplexer for the three signals, and thereafter read into a PC and logged as a function of distance from known monuments in the tunnel using a custom program written by S.D. Anderson. The distance traveled was measured using a measuring wheel that was trailing the cart. A picture of the setup is displayed in Figure 2.

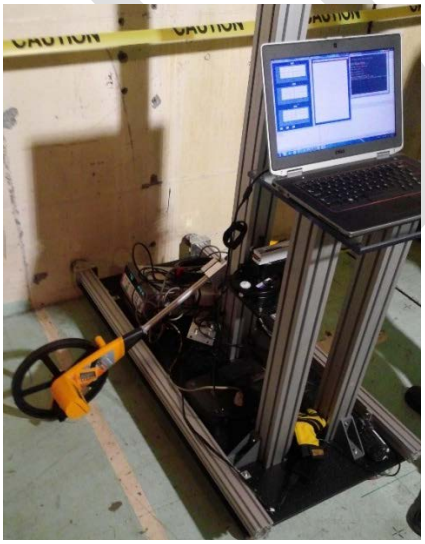


Figure 2: The setup to measure and log the magnetic fields in the tunnel as a function of distance traveled.

Tunnel layout

The distances within the tunnel, and grouping of the cryomodules to form the LINAC sections, were based on the 'MAD Model for LCLS-II Cryomodules' (LCLSII-1.1-IC-0657-R1) released 8 Feb 2017. The cryomodules are broken down into four sections, as illustrated in Figure 3.

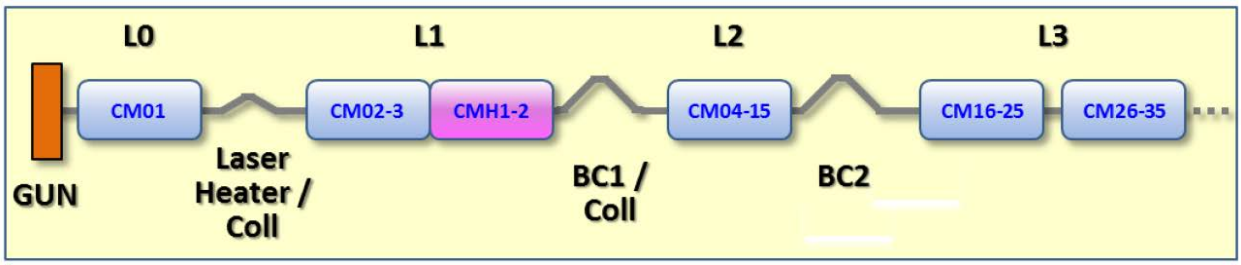


Figure 3: Schematic layout of the LCLS-II Linac (source: LCLSII-1.1-IC-0657-R1).

Magnetic fields

The measured magnetic fields in the tunnel are illustrated as a function of distance in the LINAC coordinate system. The magnitude and components of the magnetic fields in the first 650 m are summarized in Figure 4. The upstream and downstream gate valve locations are identified in the plot with an orange and yellow line, respectively.

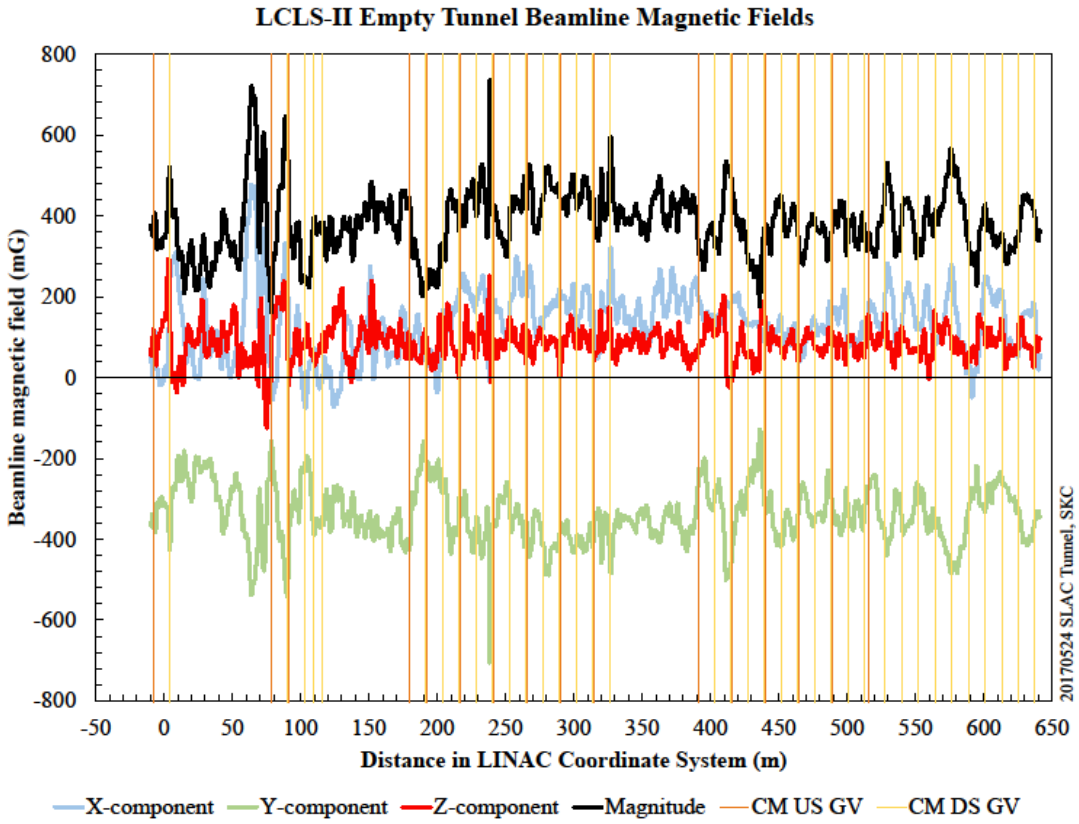
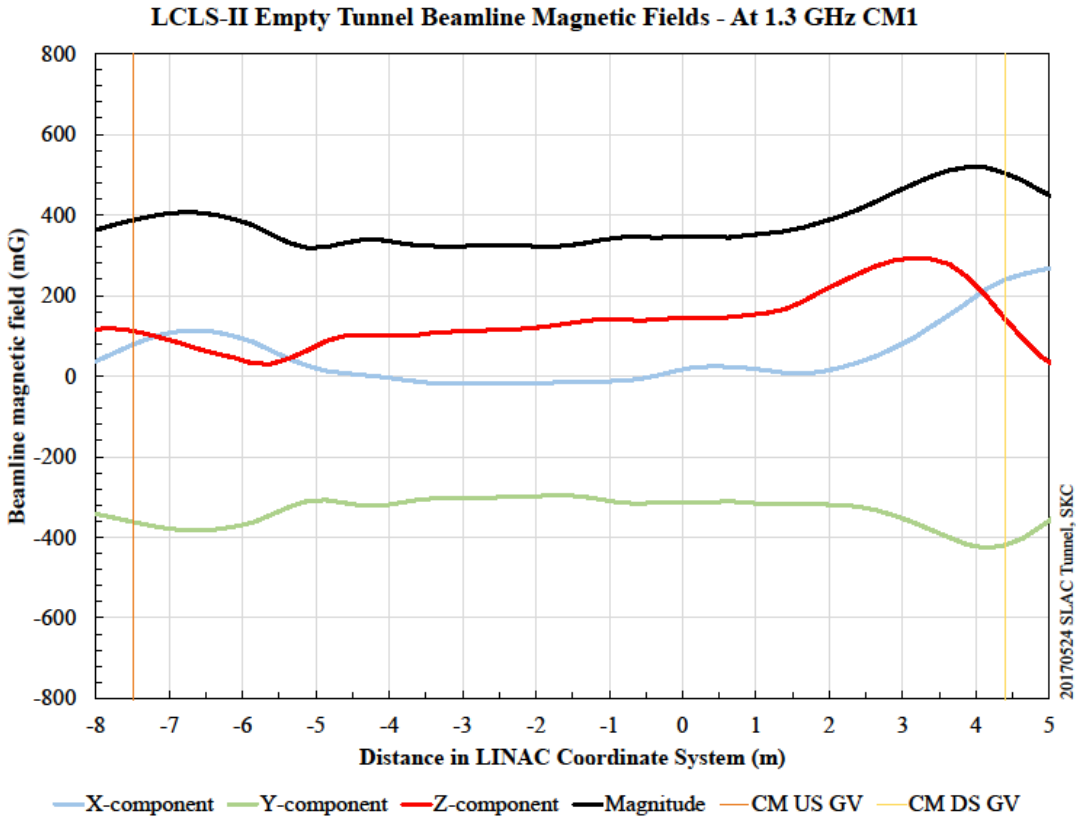
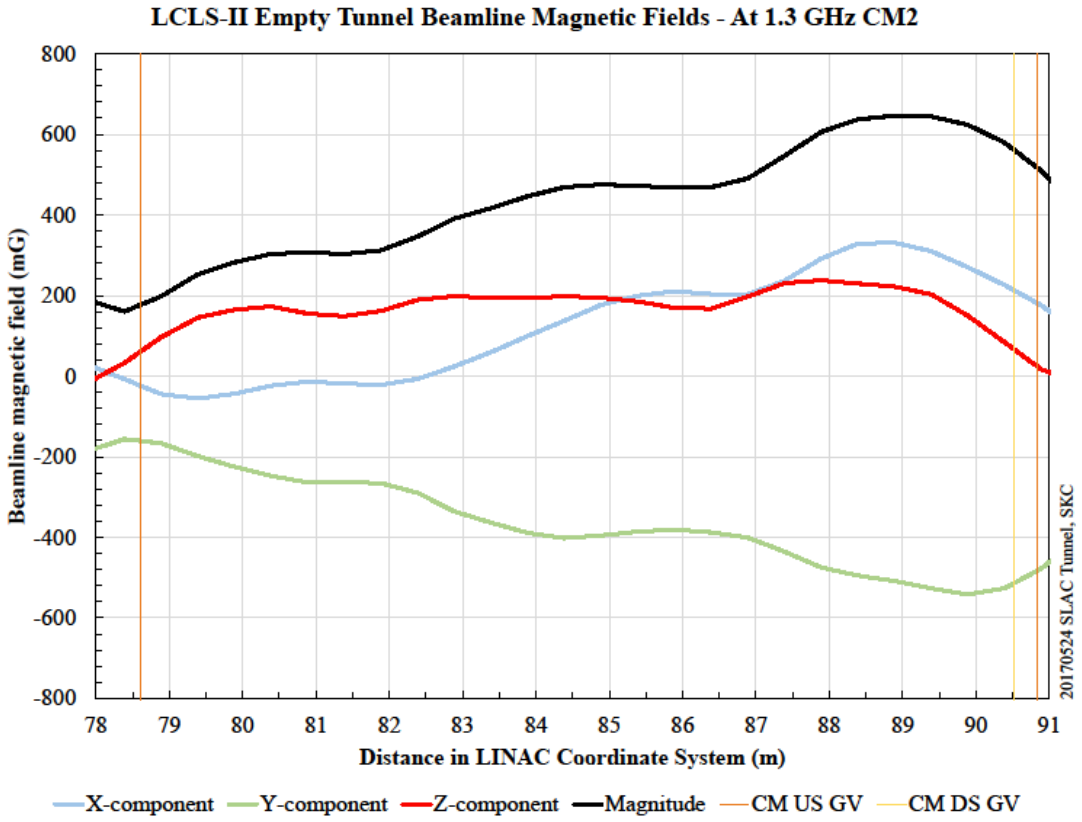


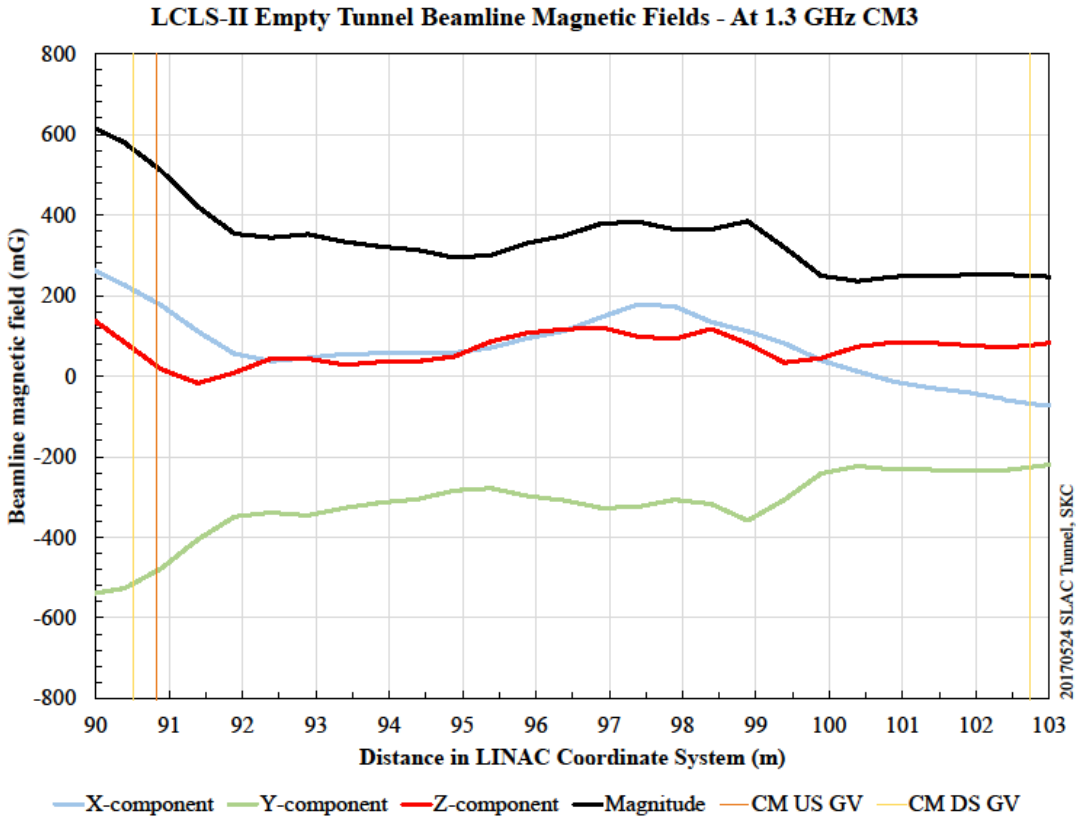
Figure 4: Summary of the magnitude and components of the magnetic fields in the SLAC tunnel, measured at beamline height.

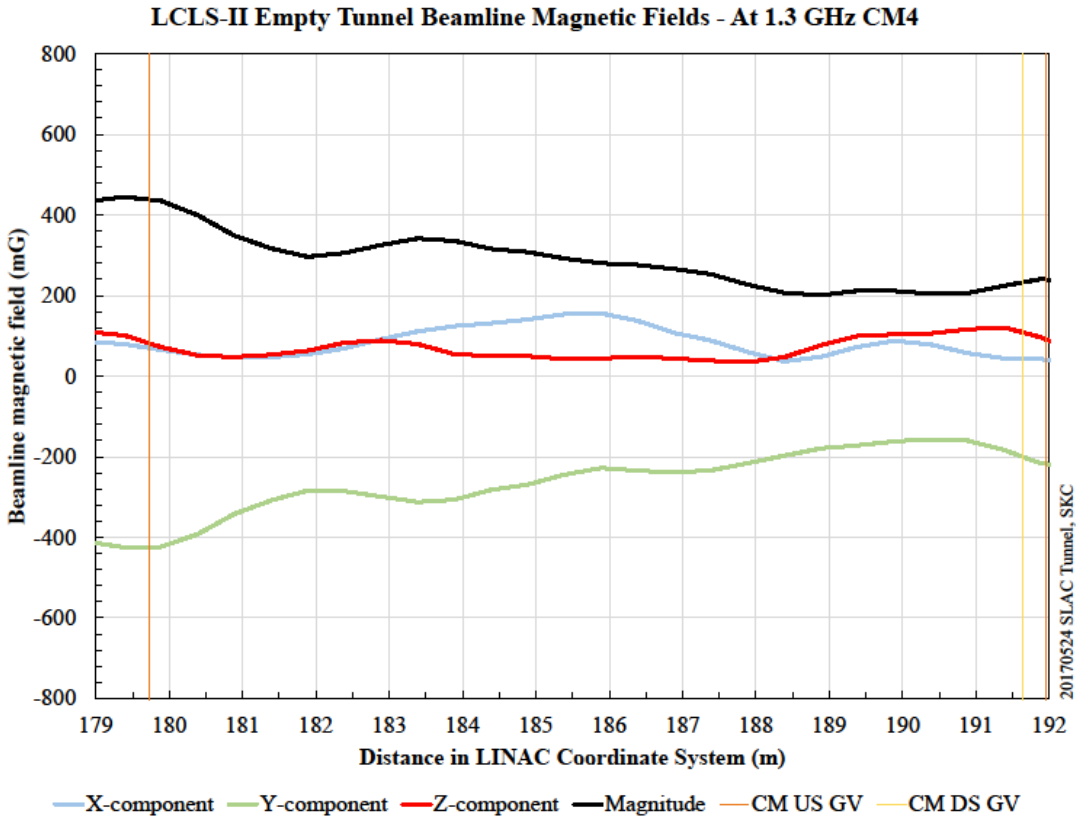
The fields for each individual cryomodule is illustrated in the following 37 plots. The first 35 plots are for each of the 35 1.3 GHz cryomodules (CMxx) in the tunnel, and the last two are for the two 3.9 GHz cryomodules (CMHx). The cryomodule type and number are identified in the plot title.

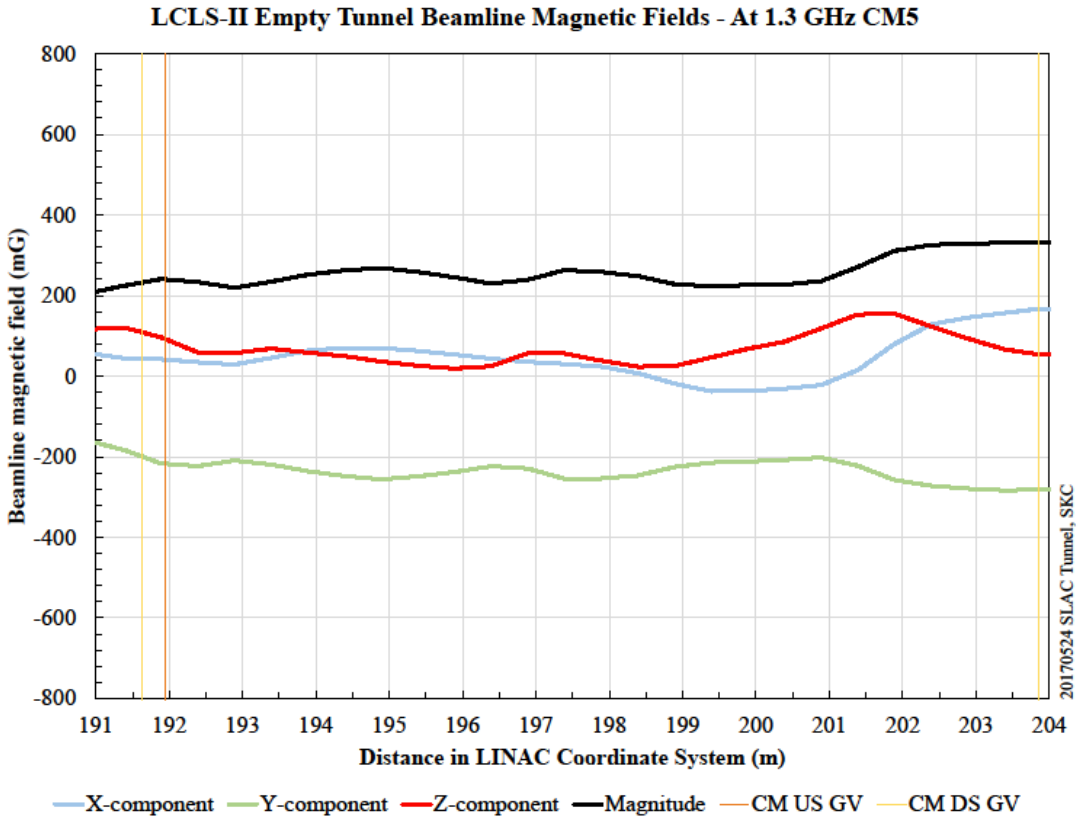
Polarity changes are noted for CM3, CM17, CM18, and CM29, although these reversals are for very short lengths.

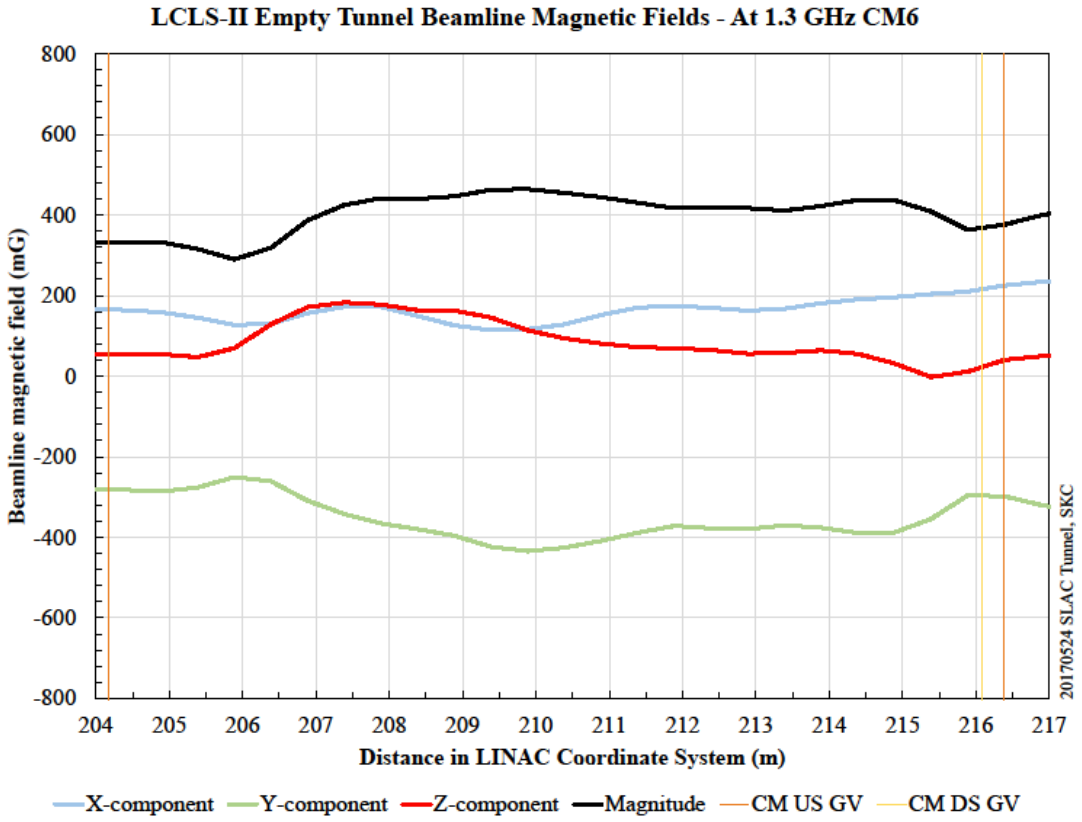

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM1
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

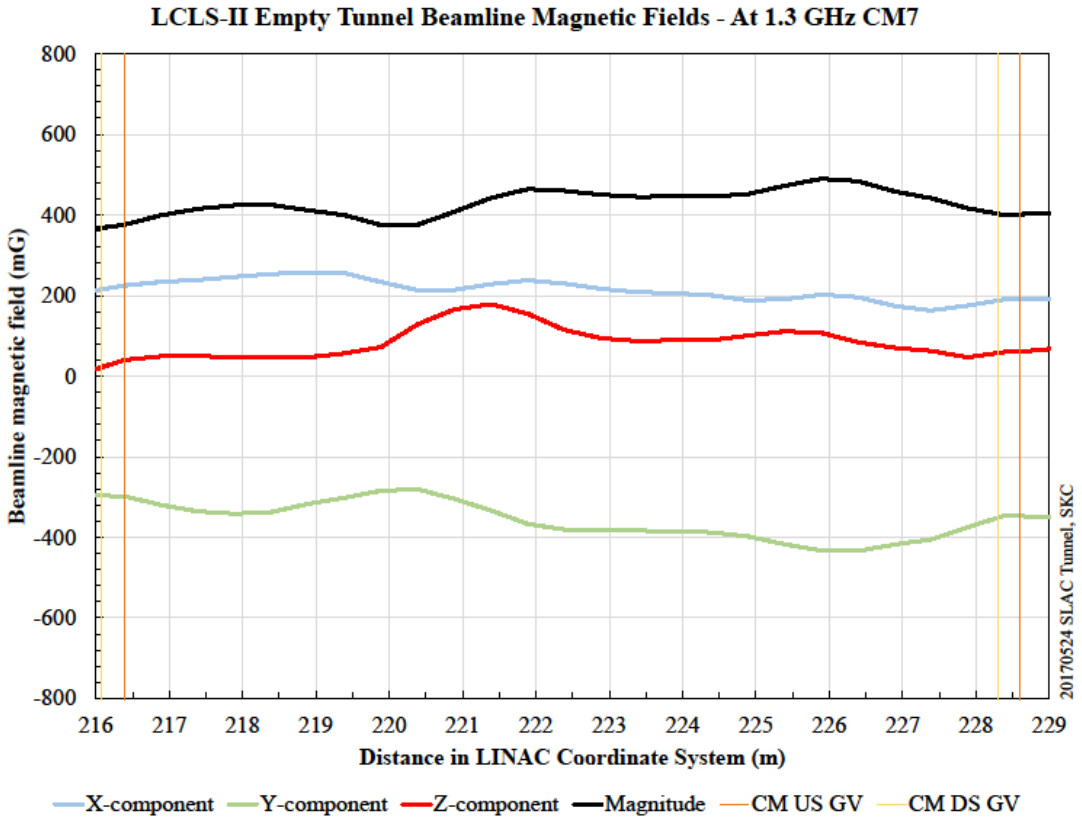

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM2
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
78
79
80
81
82
83
84
85
86
87
88
89
90
91
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

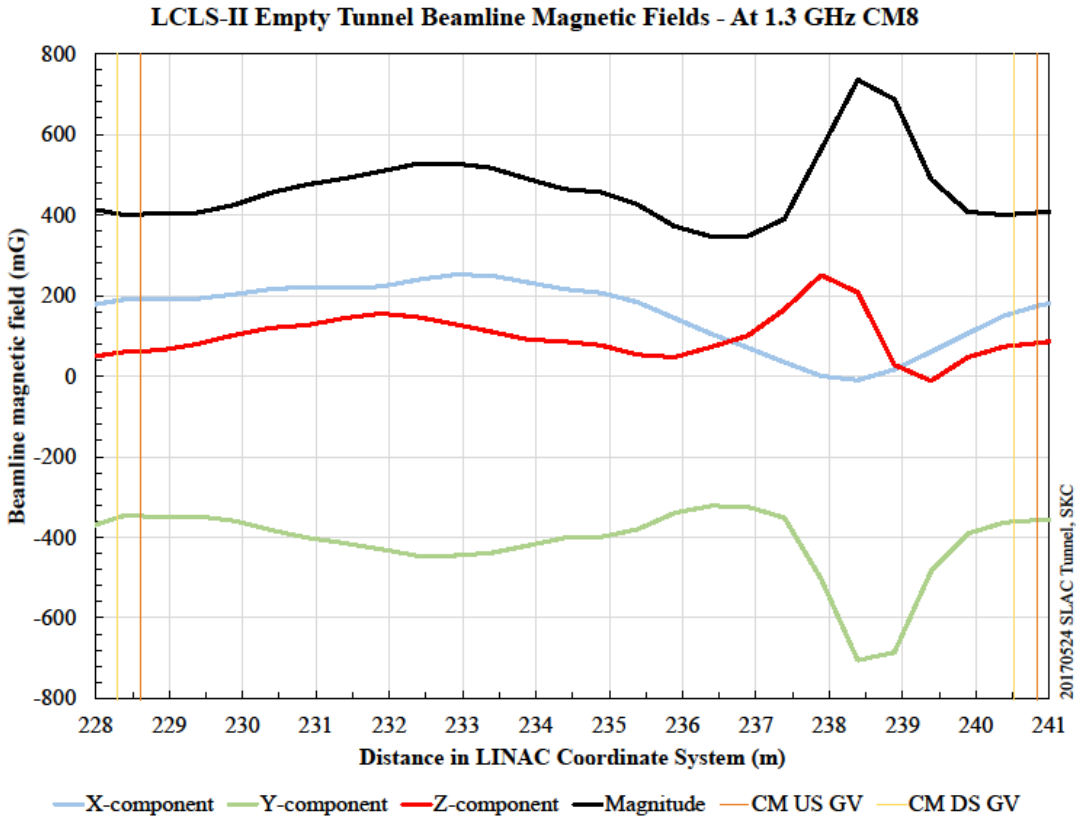

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM3
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
90
91
92
93
94
95
96
97
98
99
100
101
102
103
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

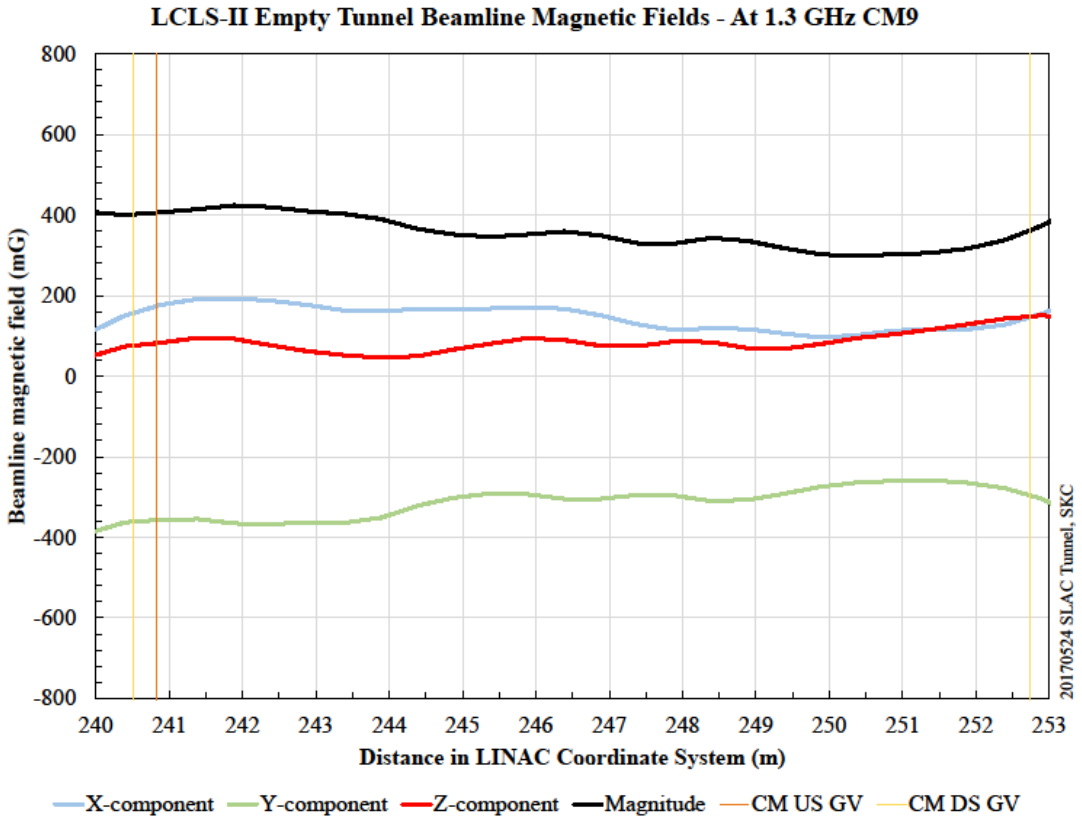

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM4
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
179
180
181
182
183
184
185
186
187
188
189
190
191
192
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

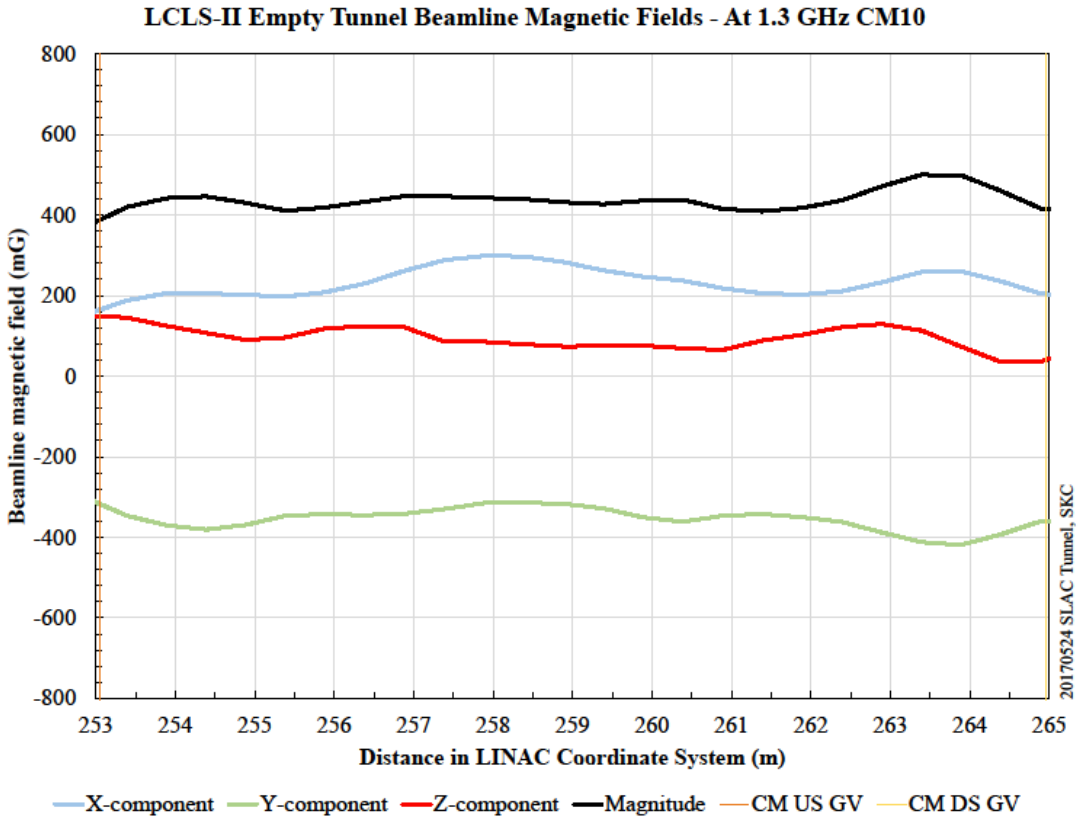

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM5
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
191
192
193
194
195
196
197
198
199
200
201
202
203
204
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

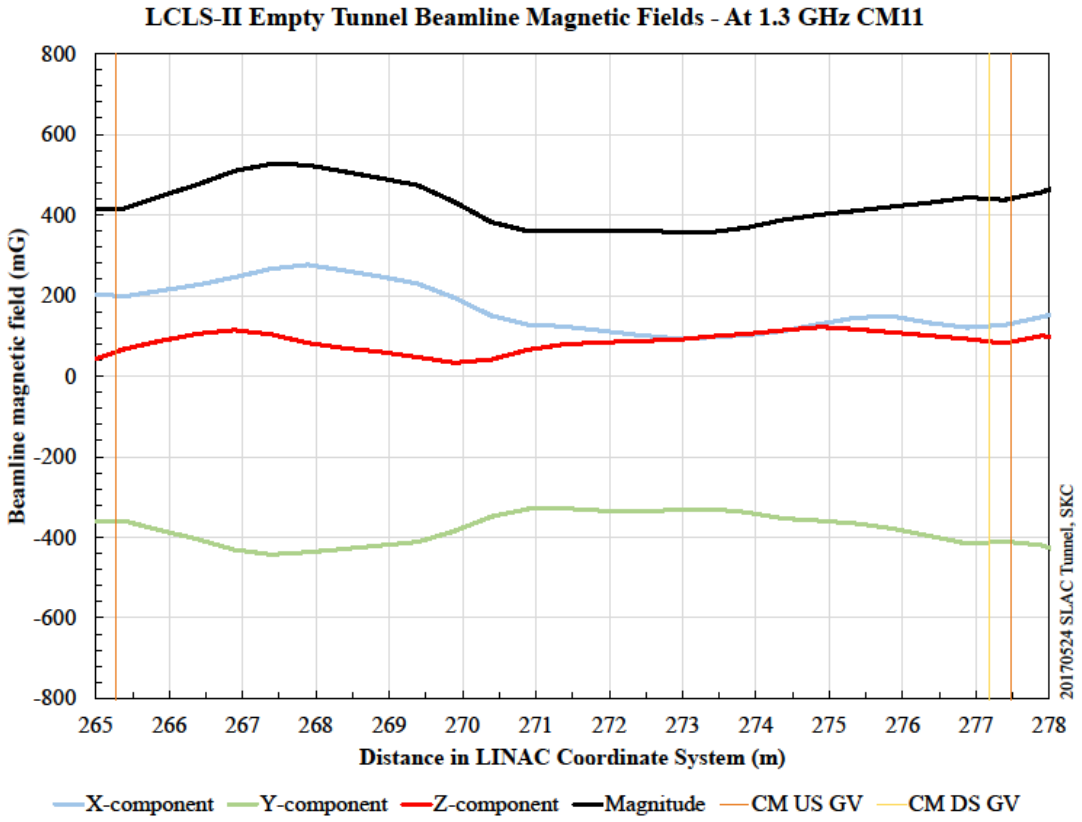

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM6
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
204
205
206
207
208
209
210
211
212
213
214
215
216
217
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

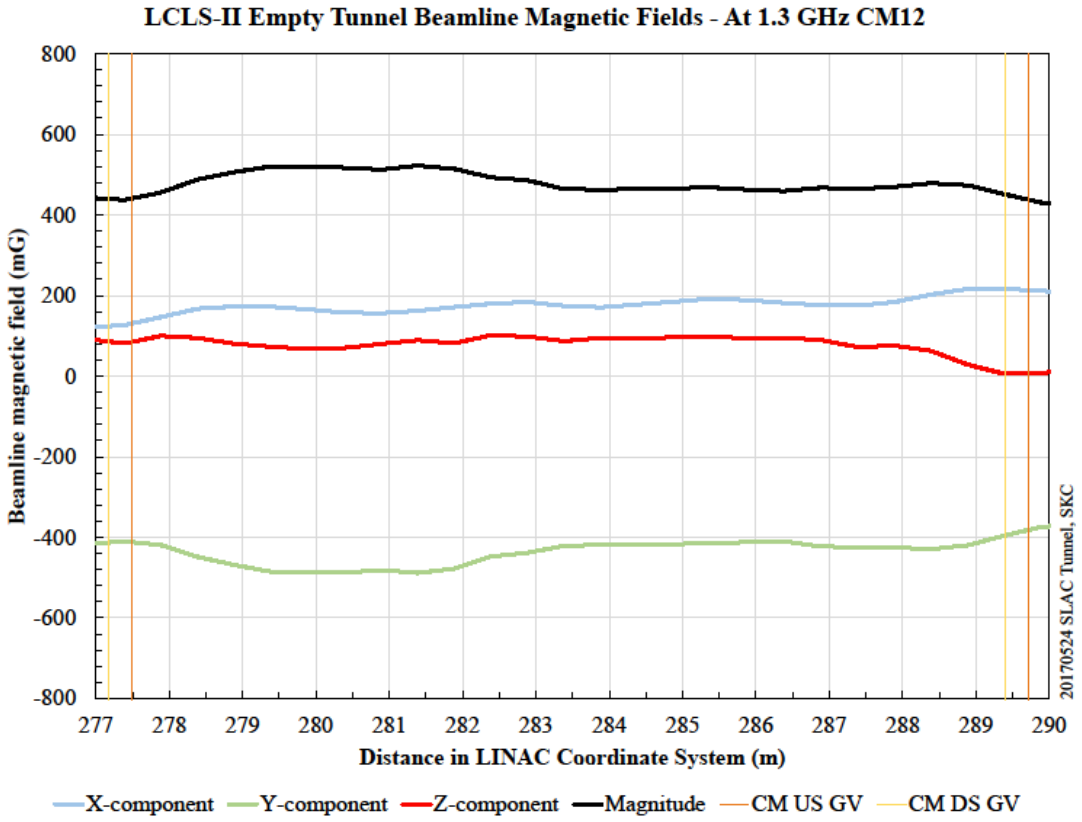

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM7
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
216
217
218
219
220
221
222
223
224
225
226
227
228
229
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

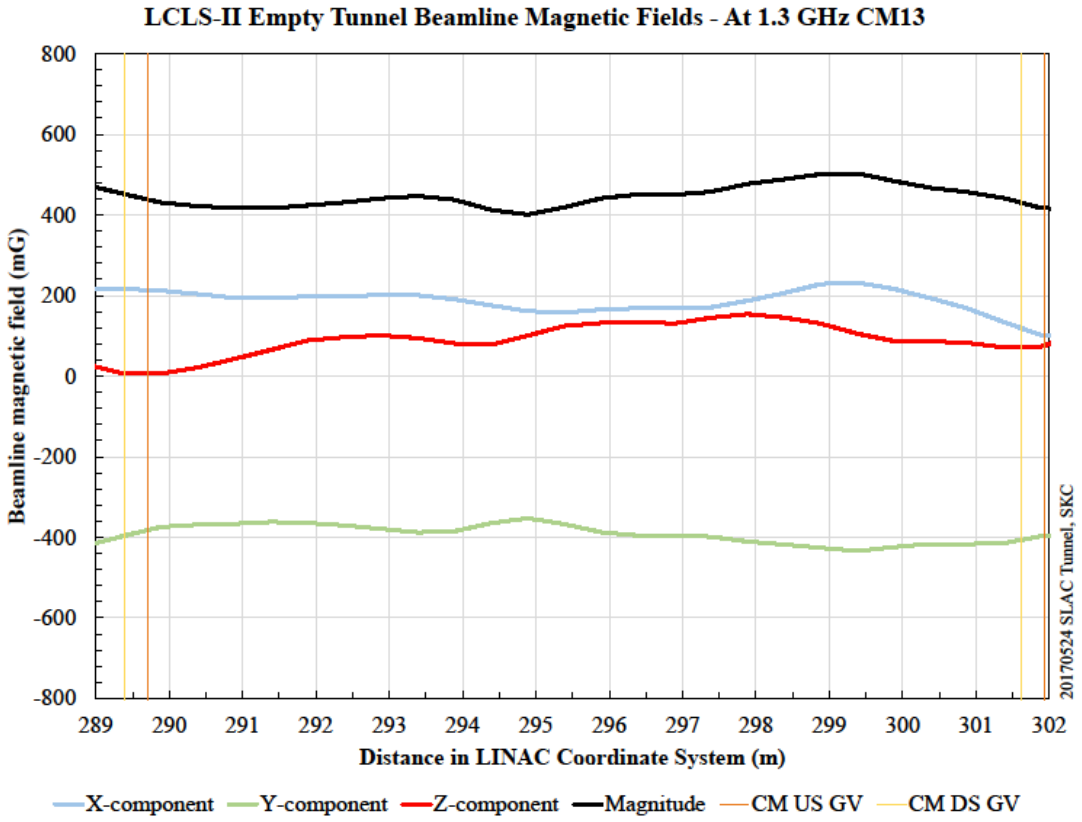

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM8
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
228
229
230
231
232
233
234
235
236
237
238
239
240
241
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

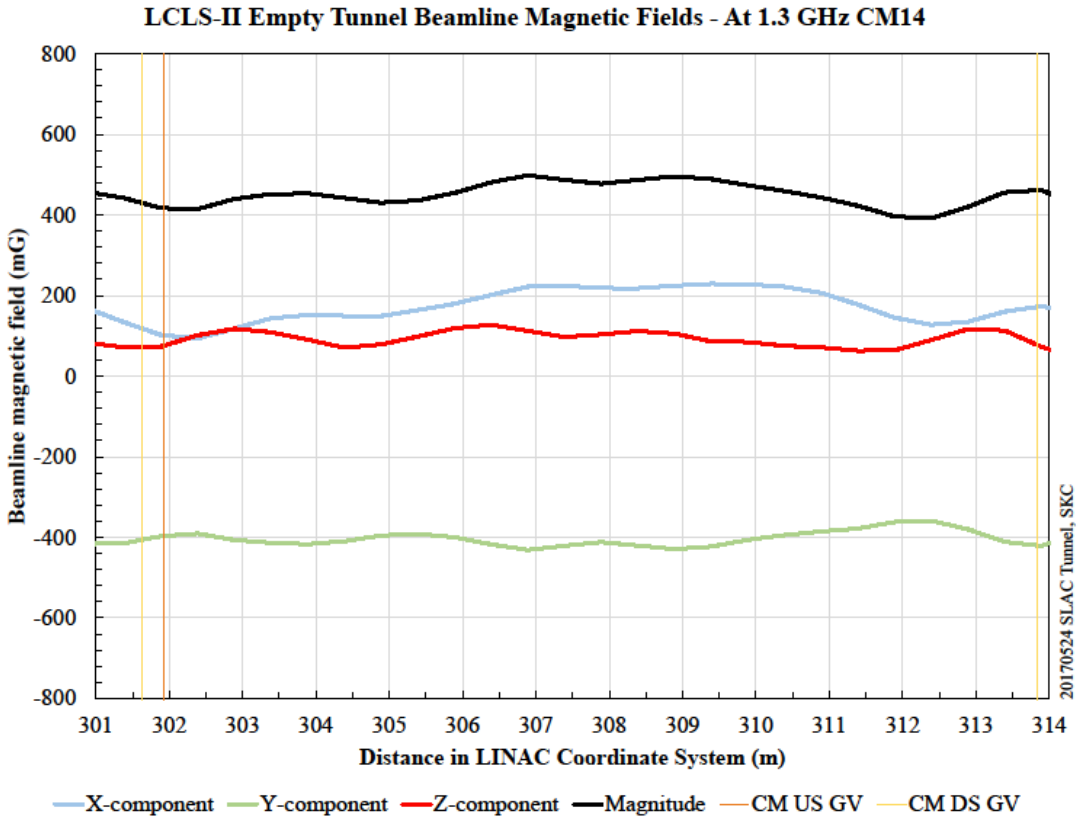

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM9
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
240
241
242
243
244
245
246
247
248
249
250
251
252
253
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

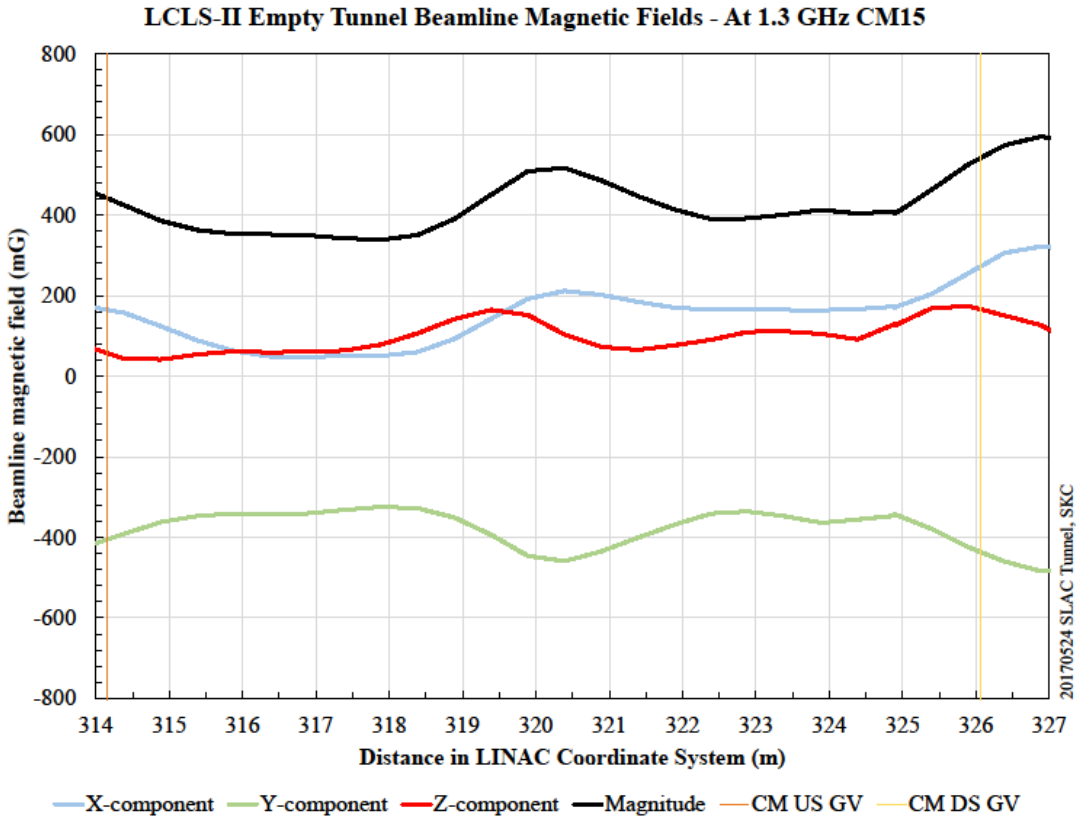

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM10
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
253
254
255
256
257
258
259
260
261
262
263
264
265
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

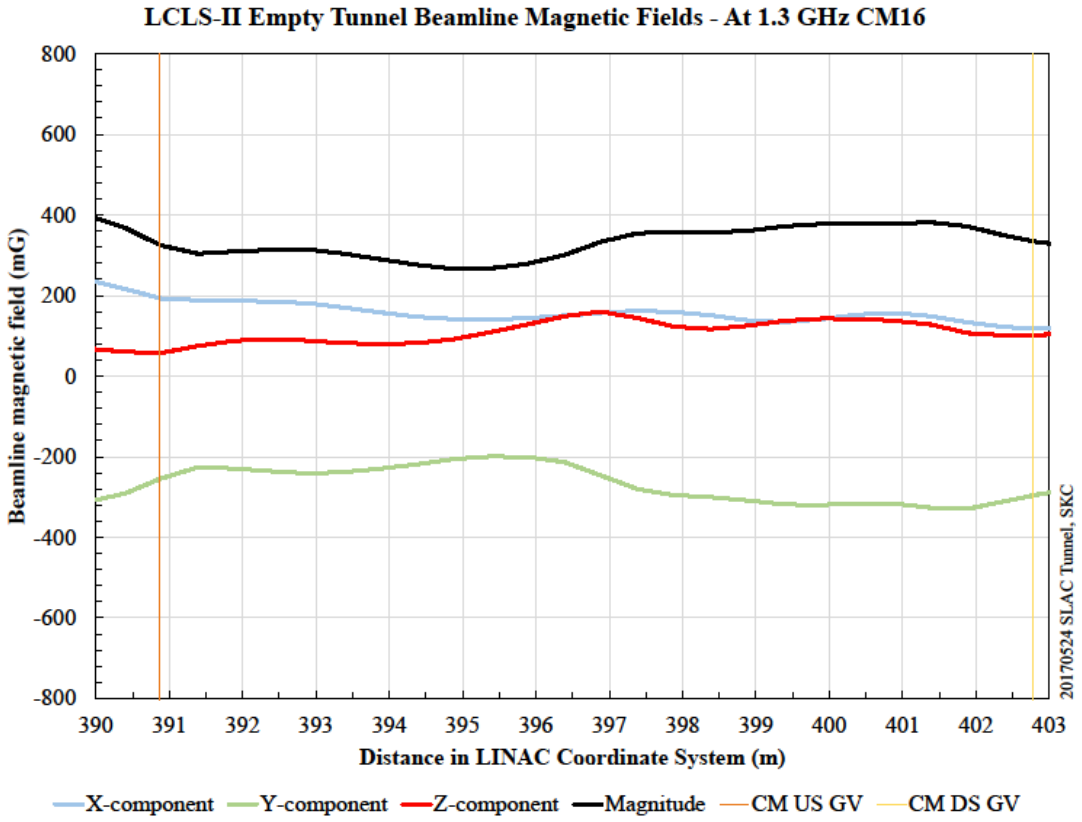

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM11
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
265
266
267
268
269
270
271
272
273
274
275
276
277
278
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

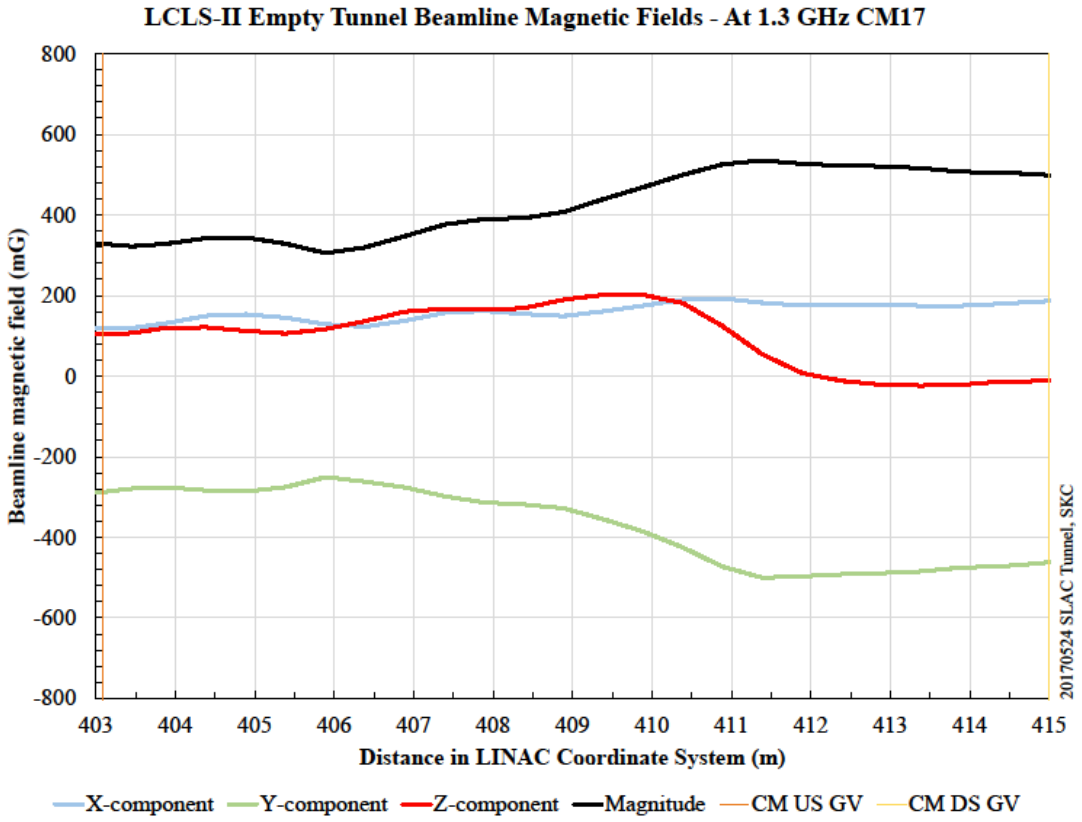

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM12
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
277
278
279
280
281
282
283
284
285
286
287
288
289
290
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

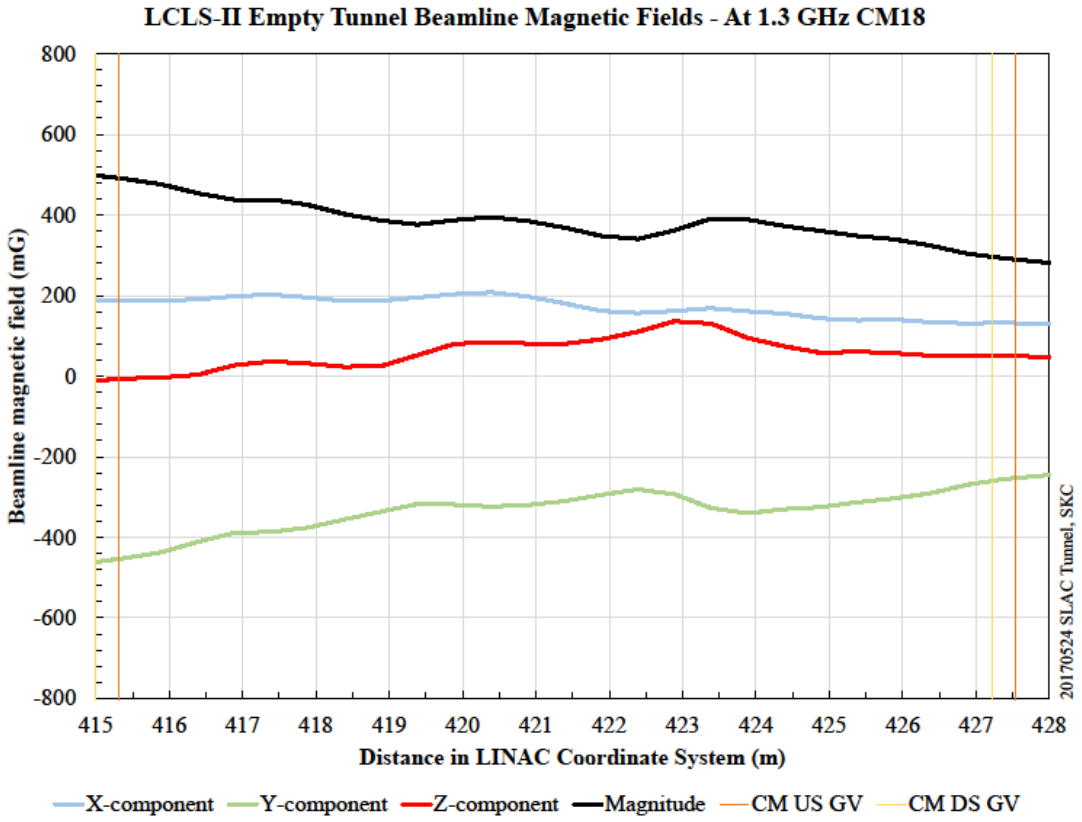

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM13
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
289
290
291
292
293
294
295
296
297
298
299
300
301
302
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

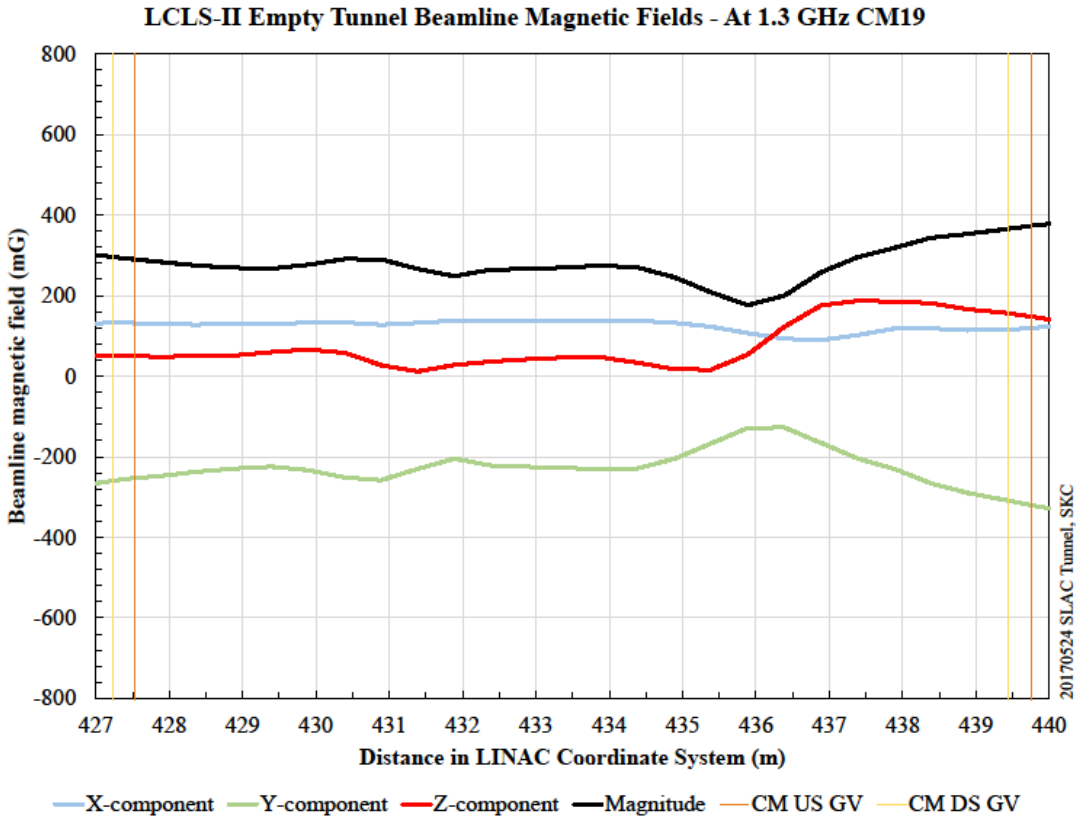

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM14
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
301
302
303
304
305
306
307
308
309
310
311
312
313
314
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

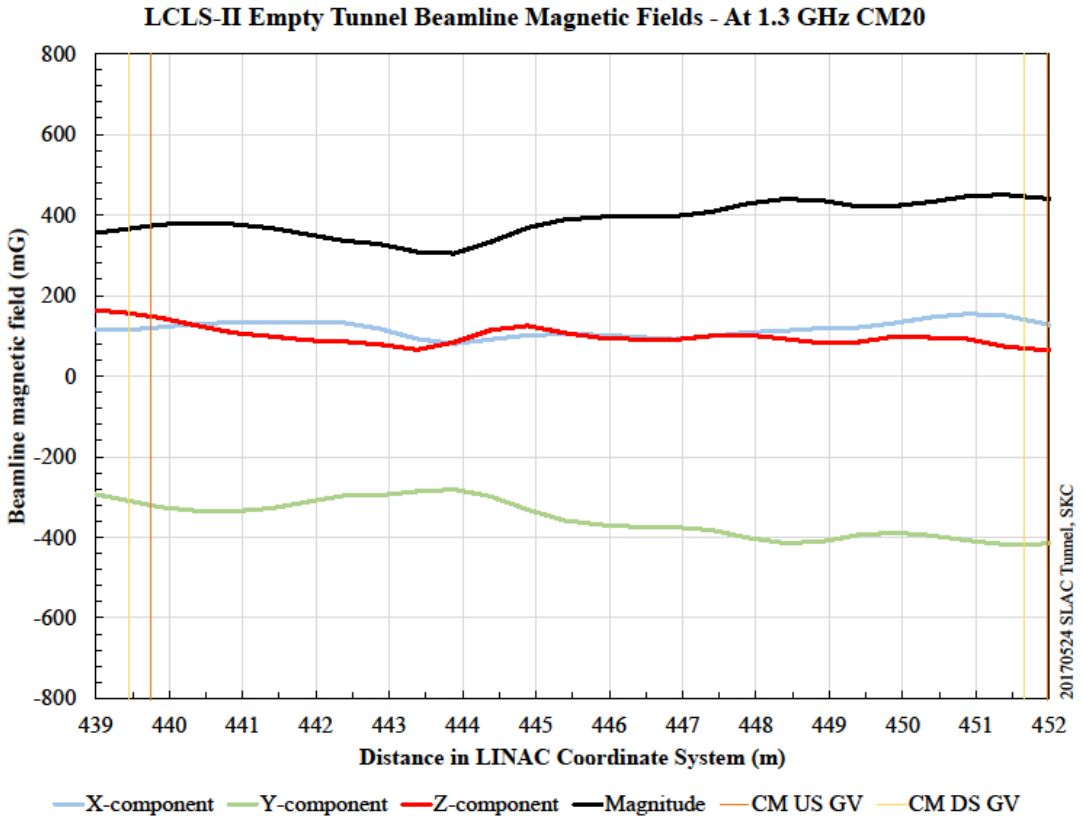

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM15
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
314
315
316
317
318
319
320
321
322
323
324
325
326
327
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

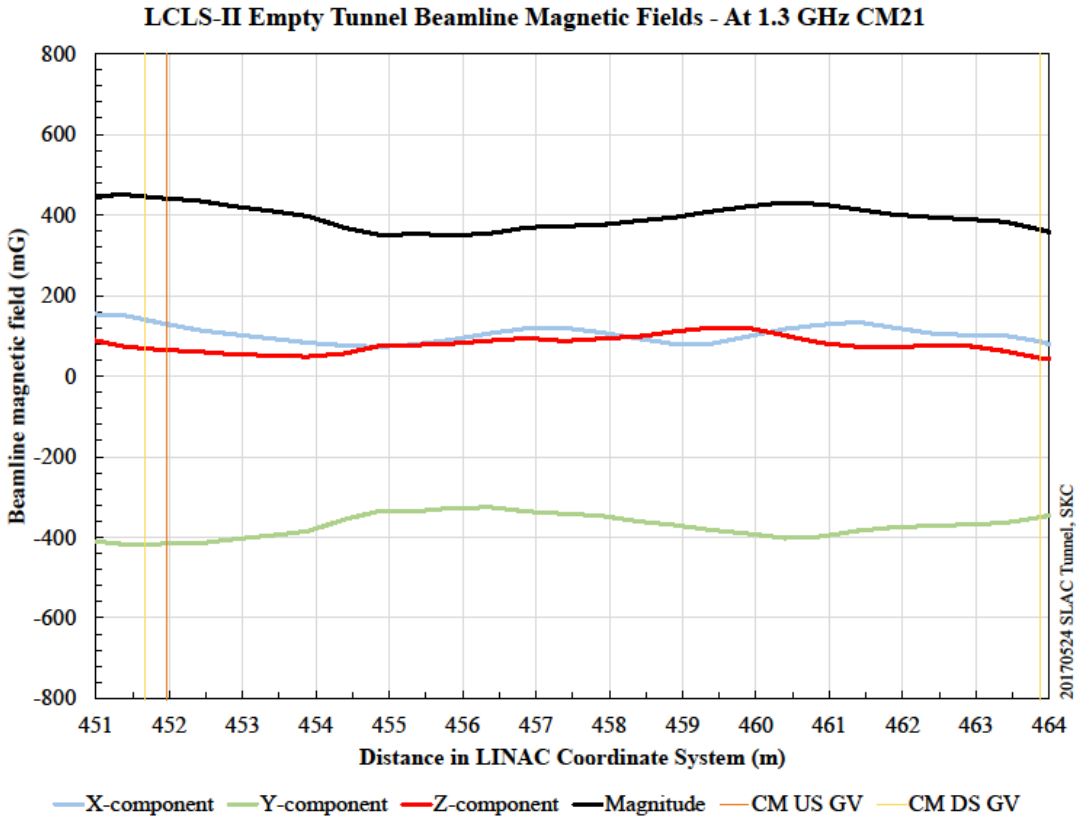

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM16
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
390
391
392
393
394
395
396
397
398
399
400
401
402
403
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

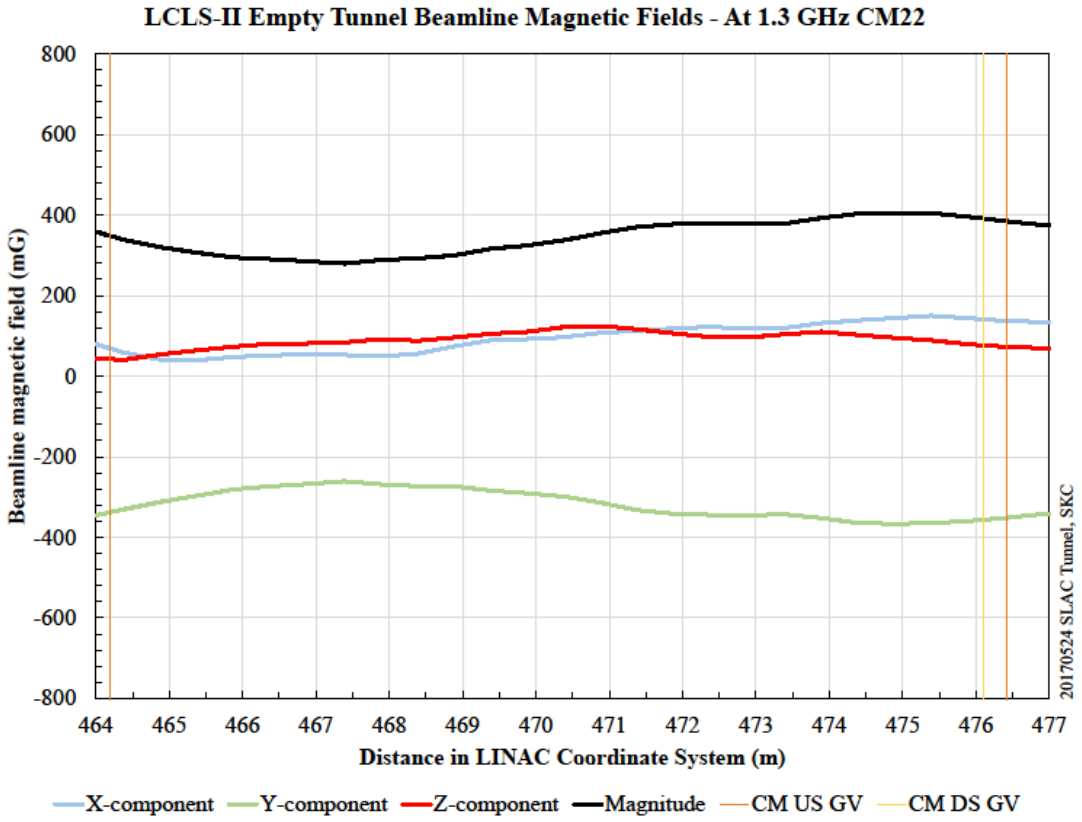

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM17
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
403
404
405
406
407
408
409
410
411
412
413
414
415
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

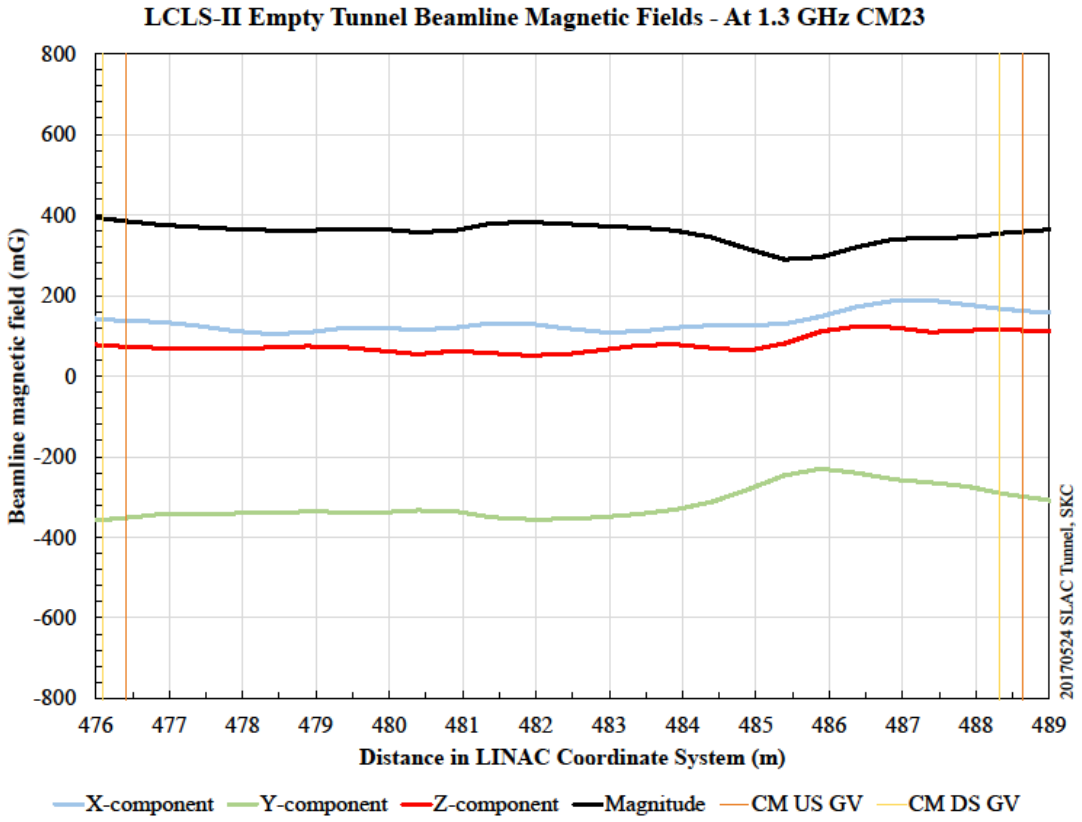

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM18
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
415
416
417
418
419
420
421
422
423
424
425
426
427
428
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

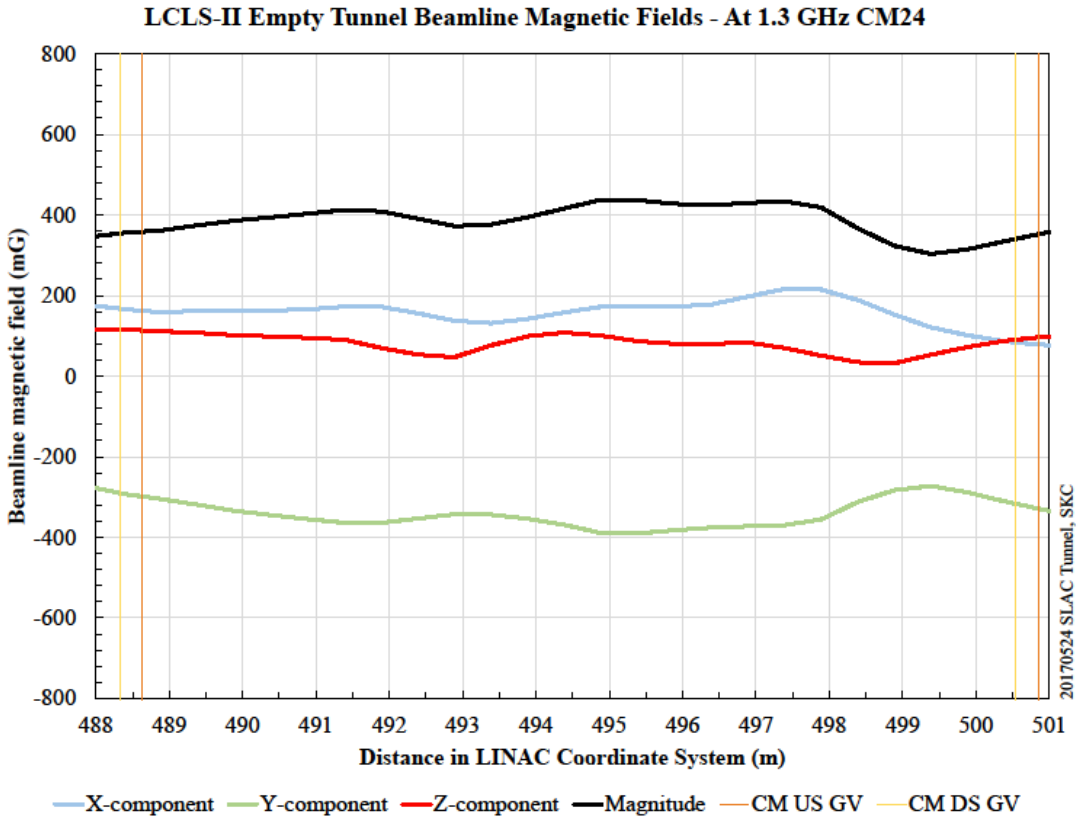

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM19
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
427
428
429
430
431
432
433
434
435
436
437
438
439
440
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

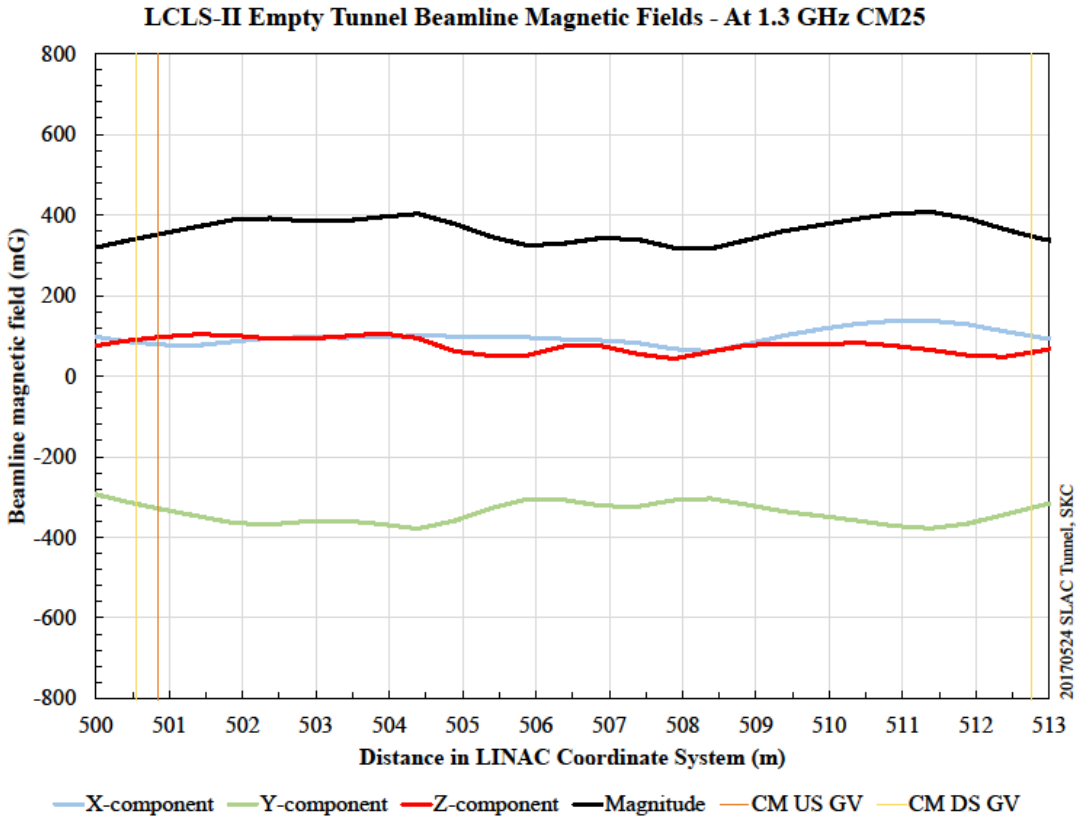

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM20
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
439
440
441
442
443
444
445
446
447
448
449
450
451
452
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

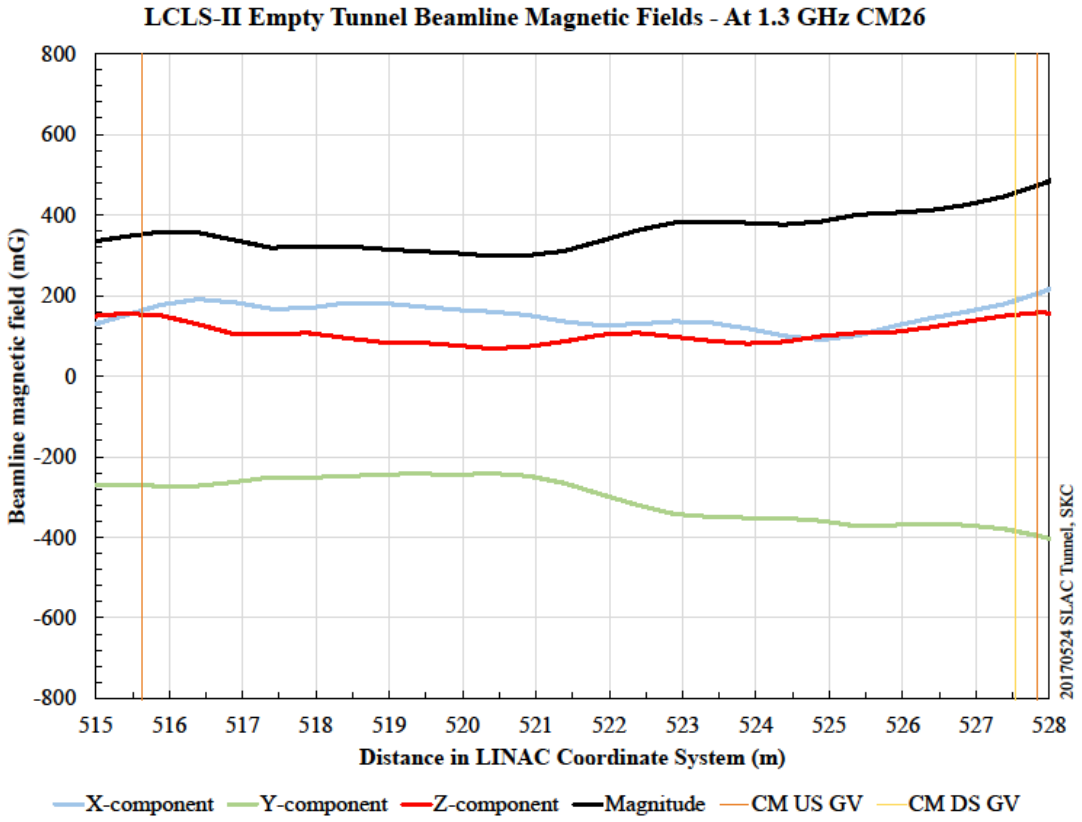

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM21
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
451
452
453
454
455
456
457
458
459
460
461
462
463
464
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

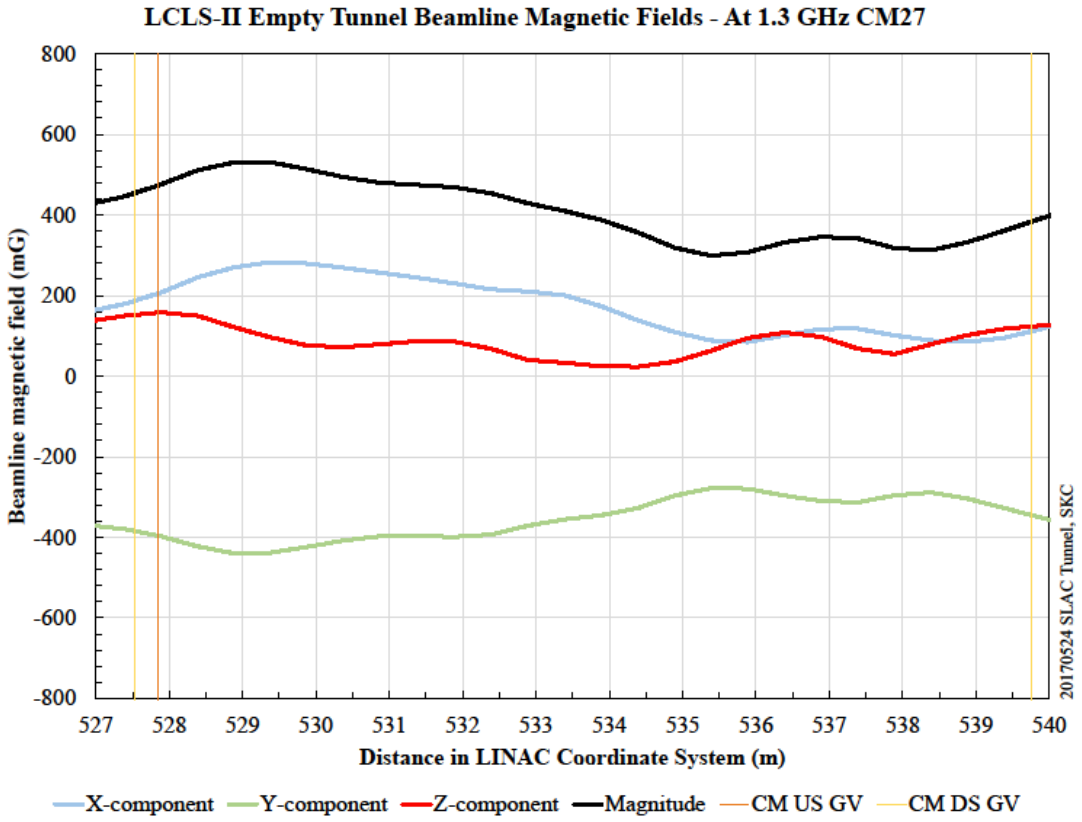

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM22
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
464
465
466
467
468
469
470
471
472
473
474
475
476
477
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

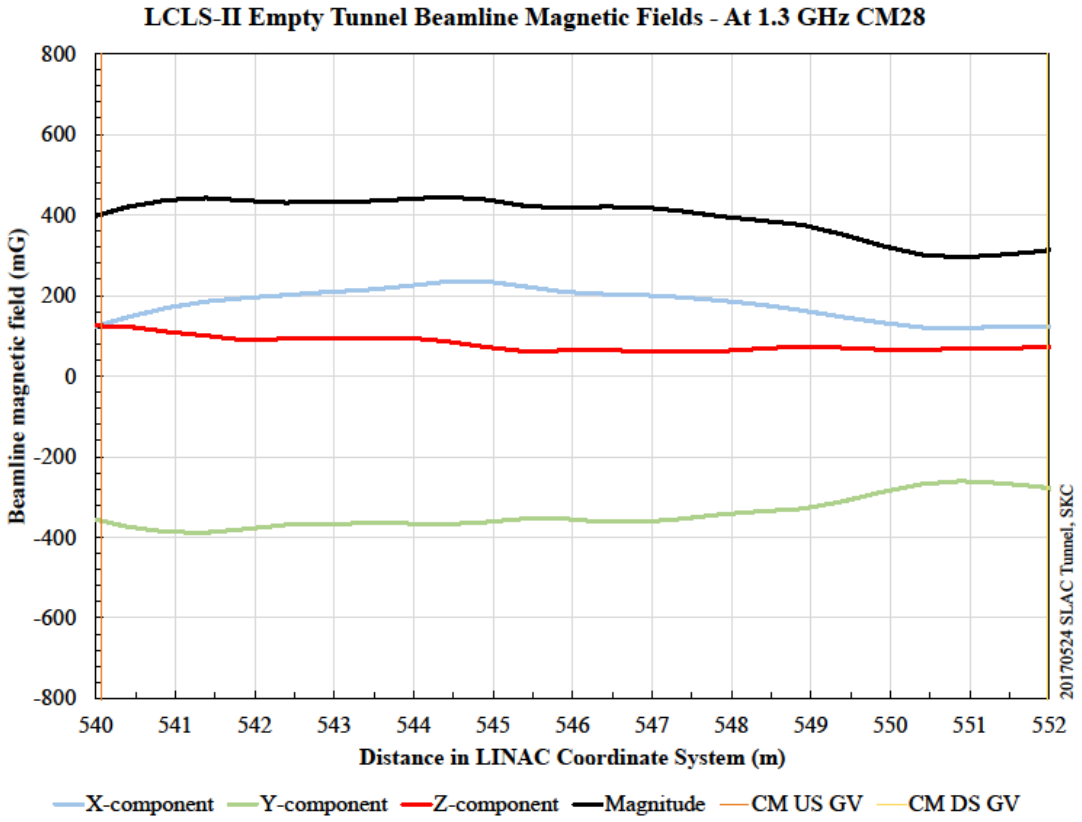

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM23
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
476
477
478
479
480
481
482
483
484
485
486
487
488
489
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

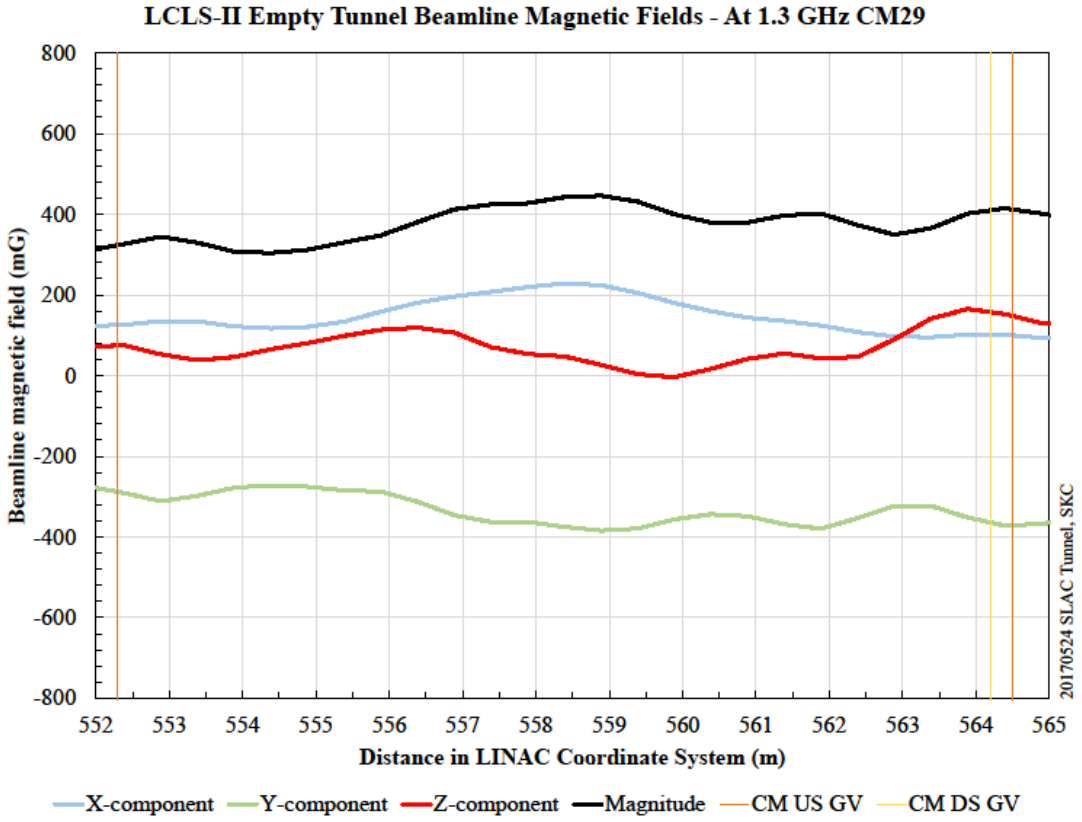

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM24
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
488
489
490
491
492
493
494
495
496
497
498
499
500
501
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

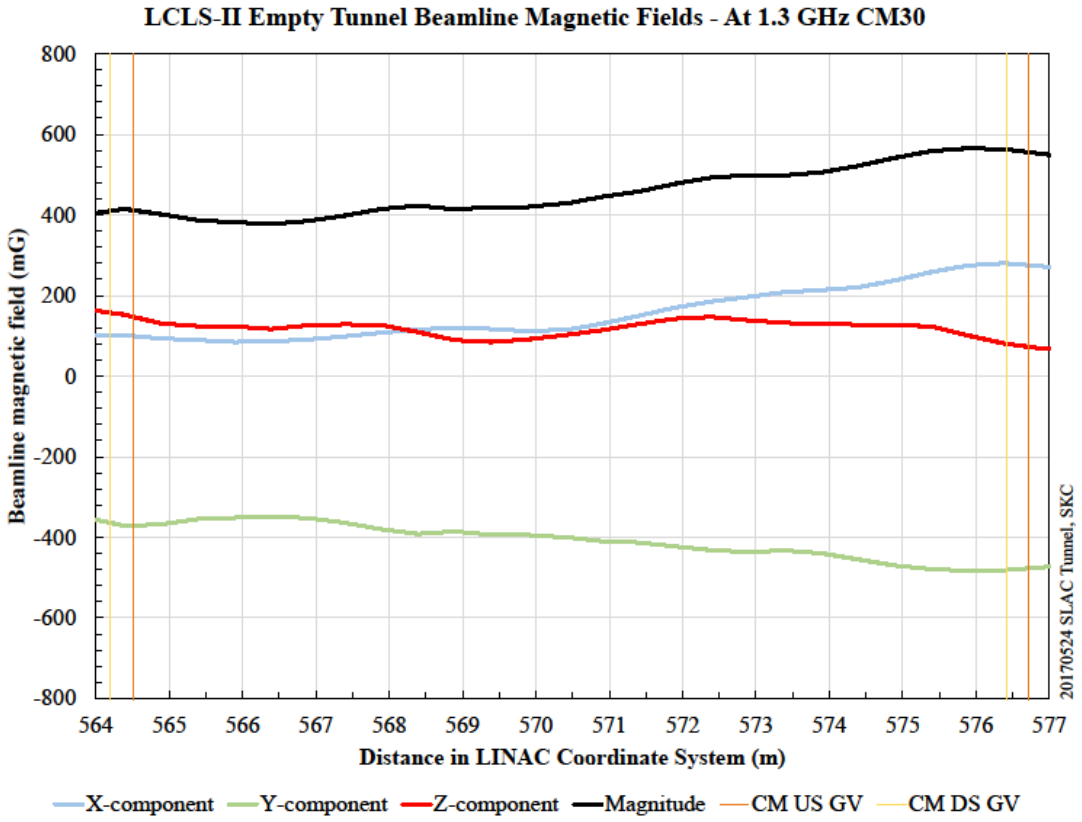

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM25
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
500
501
502
503
504
505
506
507
508
509
510
511
512
513
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

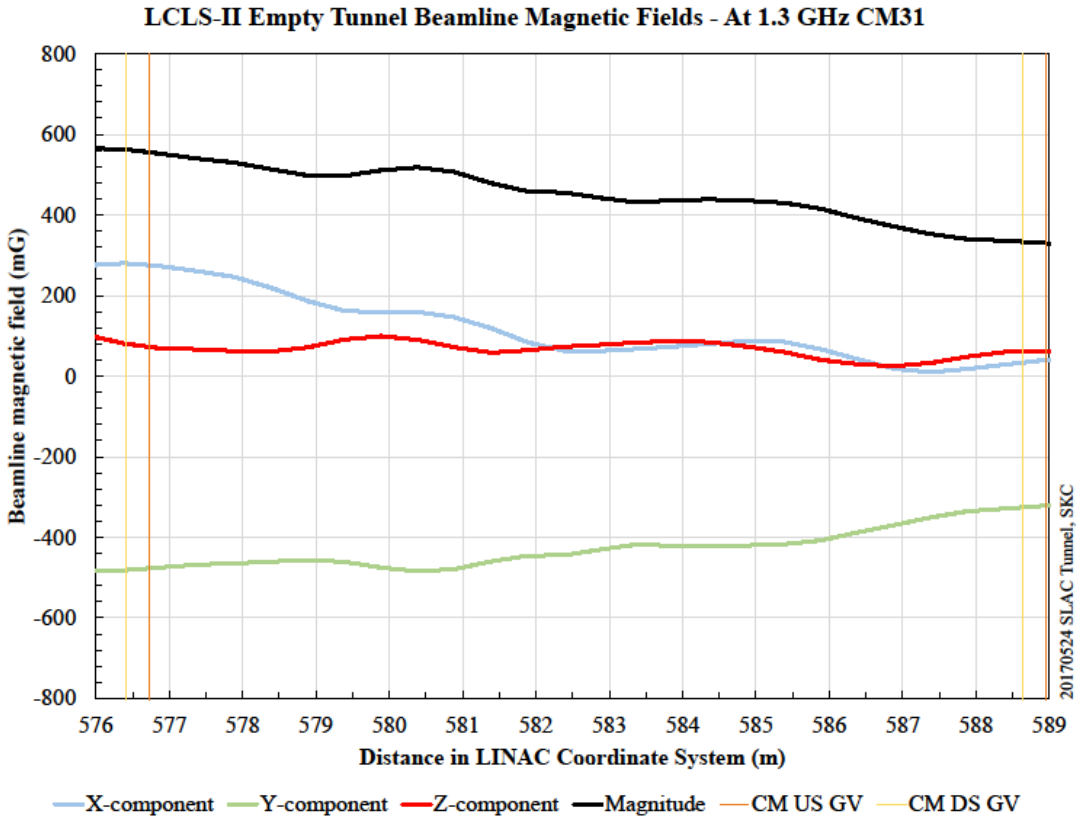

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM26
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
515
516
517
518
519
520
521
522
523
524
525
526
527
528
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

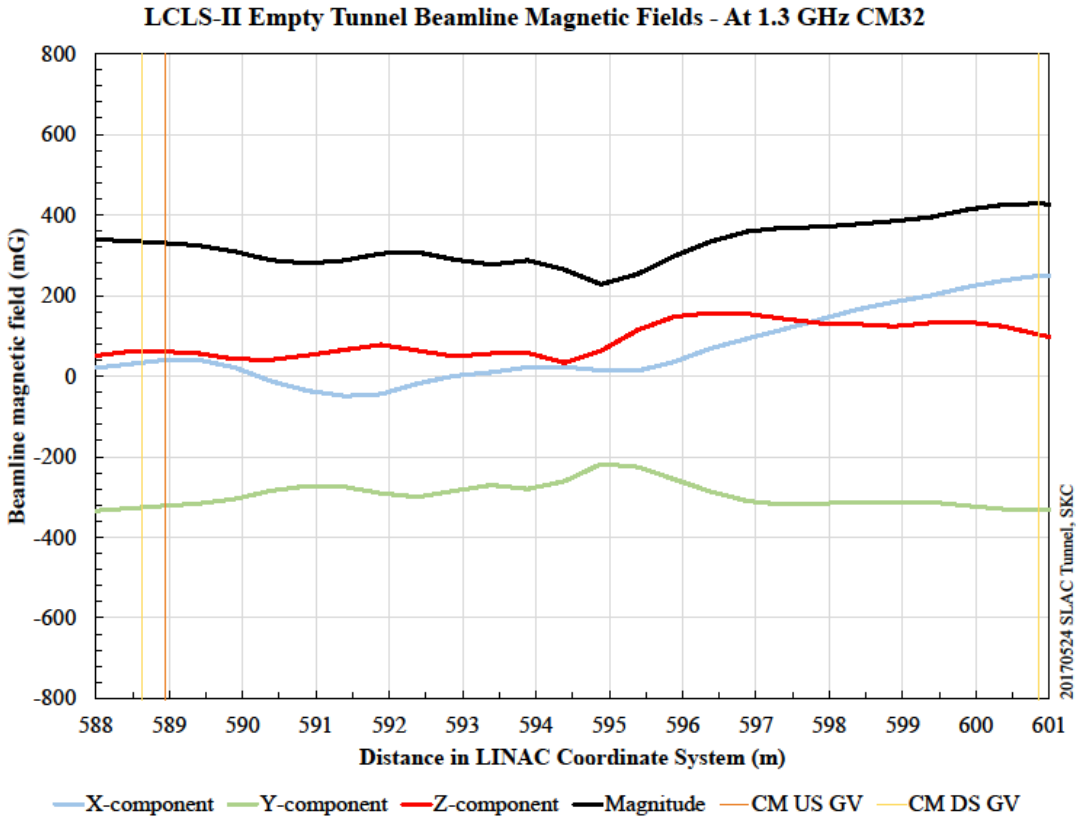

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM27
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
527
528
529
530
531
532
533
534
535
536
537
538
539
540
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

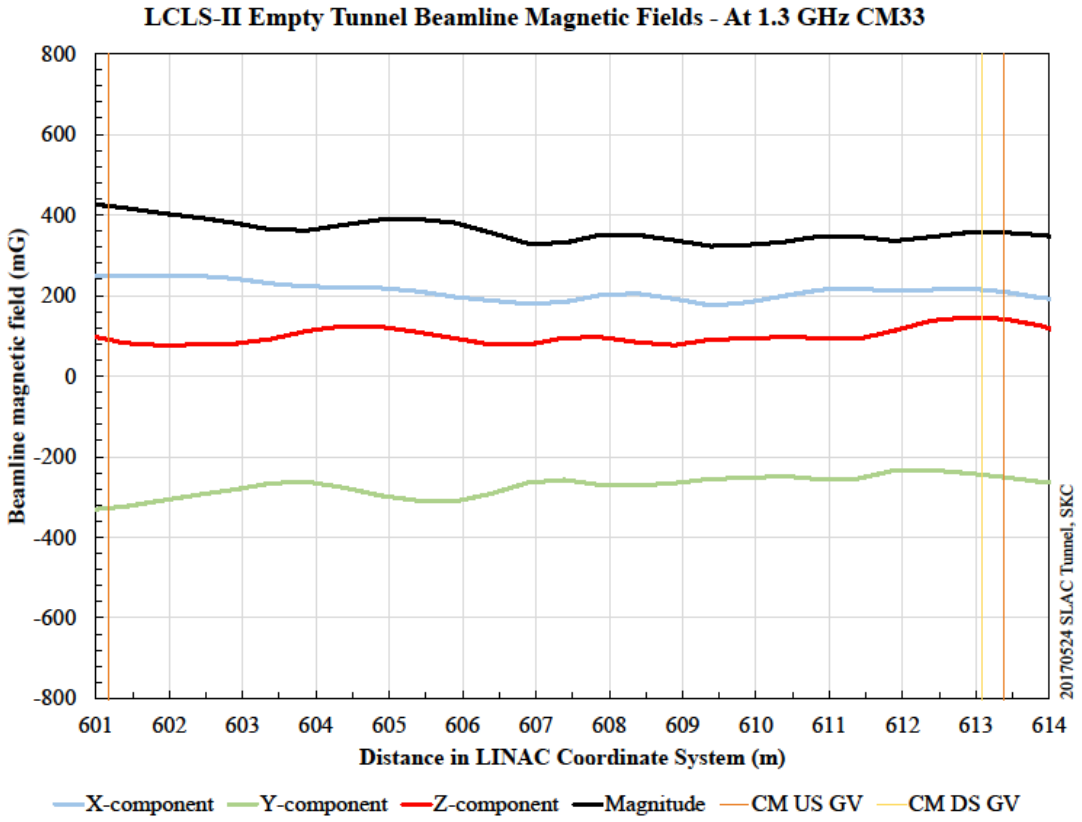

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM28
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
540
541
542
543
544
545
546
547
548
549
550
551
552
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

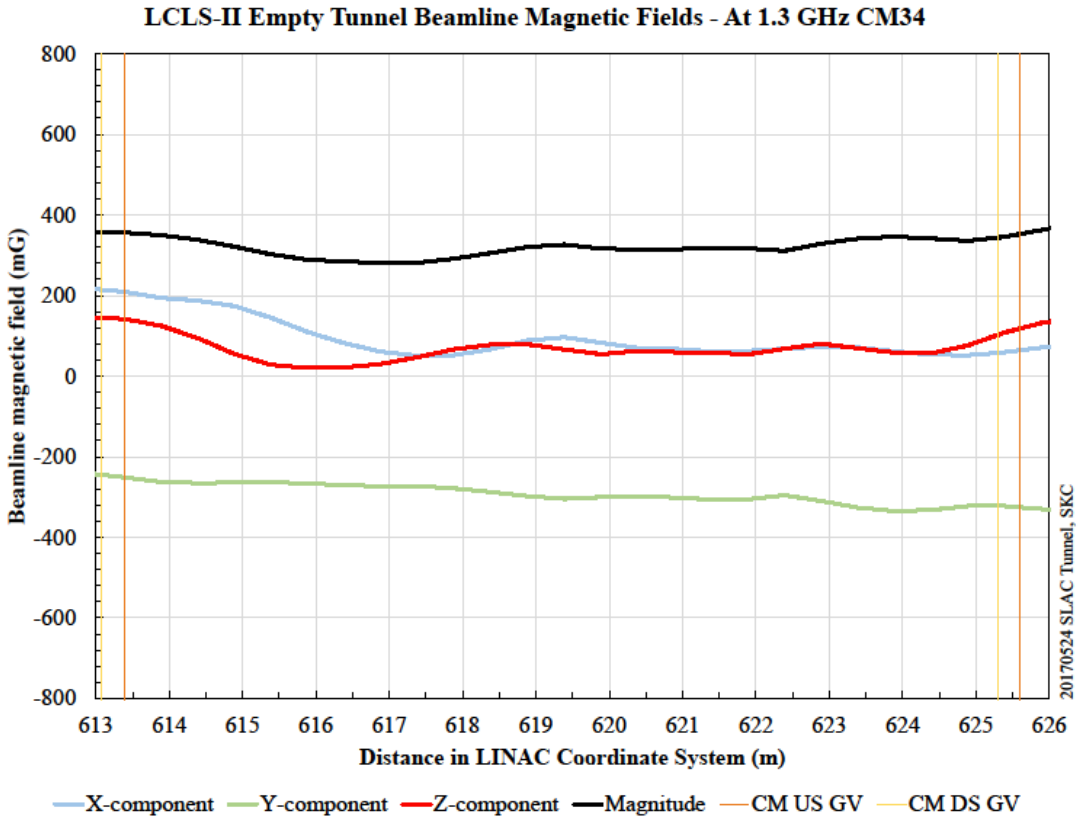

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM29
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
552
553
554
555
556
557
558
559
560
561
562
563
564
565
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

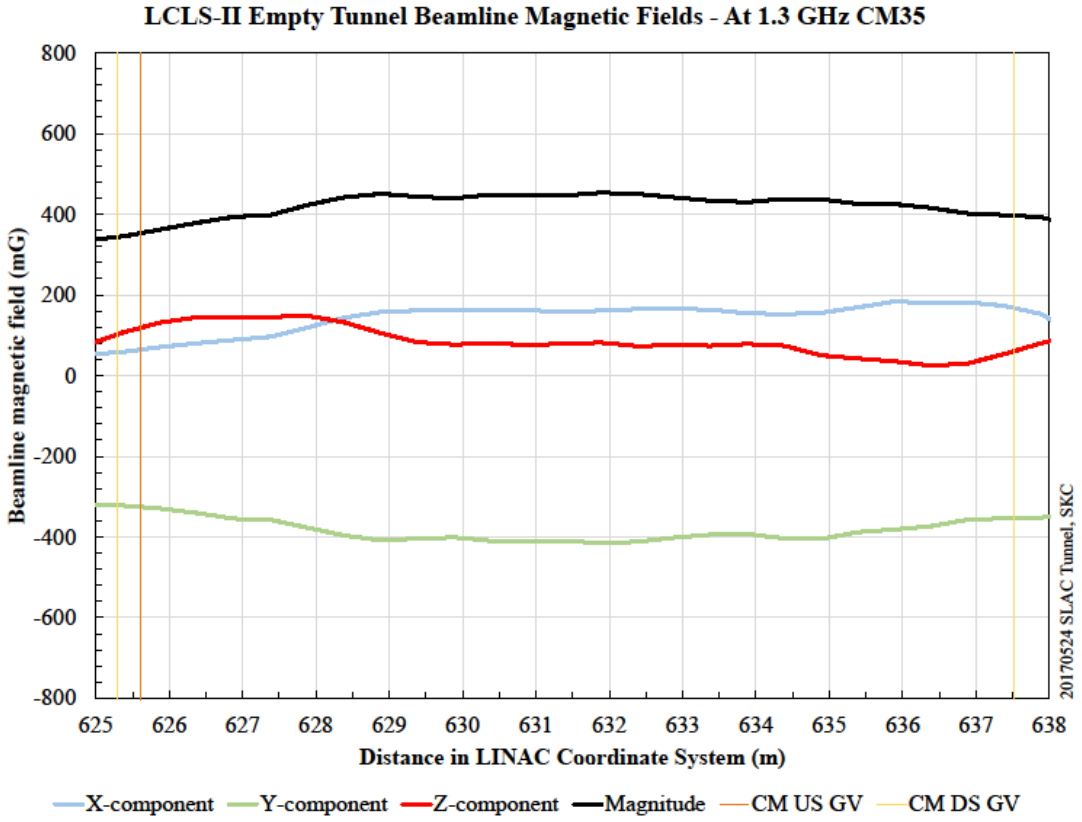

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM30
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
564
565
566
567
568
569
570
571
572
573
574
575
576
577
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

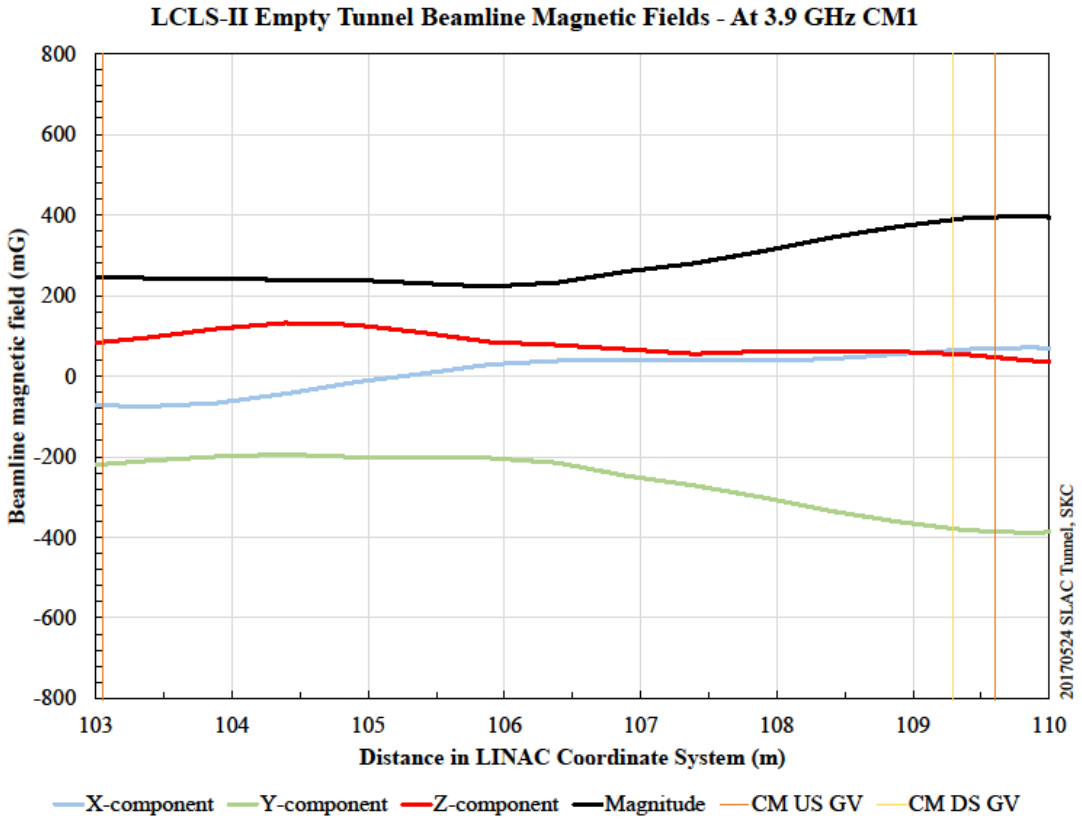

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM31
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
576
577
578
579
580
581
582
583
584
585
586
587
588
589
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV

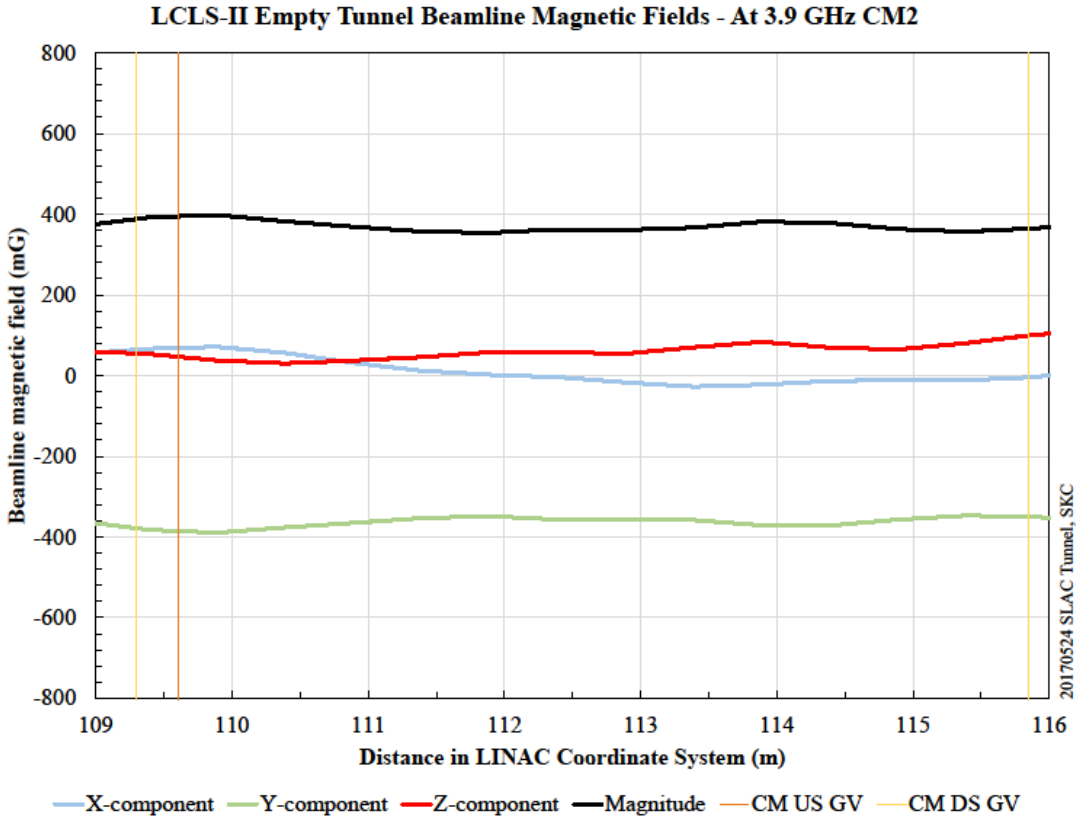

LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM32
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
588
589
590
591
592
593
594
595
596
597
598
599
600
601
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV


LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM33
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
601
602
603
604
605
606
607
608
609
610
611
612
613
614
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV


LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM34
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
613
614
615
616
617
618
619
620
621
622
623
624
625
626
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV


LCLS-II Empty Tunnel Beamline Magnetic Fields - At 1.3 GHz CM35
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
625
626
627
628
629
630
631
632
633
634
635
636
637
638
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV


LCLS-II Empty Tunnel Beamline Magnetic Fields - At 3.9 GHz CM1
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
103
104
105
106
107
108
109
110
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV


LCLS-II Empty Tunnel Beamline Magnetic Fields - At 3.9 GHz CM2
Beamline magnetic field (mG)
800
600
400
200
0
-200
-400
-600
-800
109
110
111
112
113
114
115
116
Distance in LINAC Coordinate System (m)
20170524 SLAC Tunnel, SKC
X-component
Y-component
Z-component
Magnitude
CM US GV
CM DS GV