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Istituto Nazionale di Fisica Nucleare

UPDATE ON SYNCHROTRON RADIATION BACKGROUND IN THE EXPERIMENTS

Francesco Collamati, Manuela Boscolo, Helmut Burkhardt

EuroCirCol Meeting, CERN, 9-10 October 2017

WHERE WE WERE

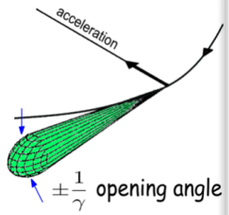
- In the last year, we used the available optics (v6_45) to develop and tune our tools to study SR backgrounds into the detectors:

STARTING POINTS

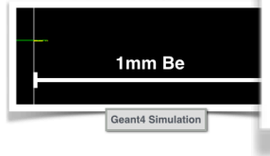
- The synchrotron radiation **cone** is very **narrow**:

$$\gamma_p = \frac{E_p}{m_p} = \frac{50TeV}{938MeV} \sim 5 \times 10^4$$

$$\frac{1}{\gamma_p} \sim 1.9 \times 10^{-5} rad \sim 10^{-3} deg \quad \theta_{BEND} = 3 \times 10^{-4} rad$$

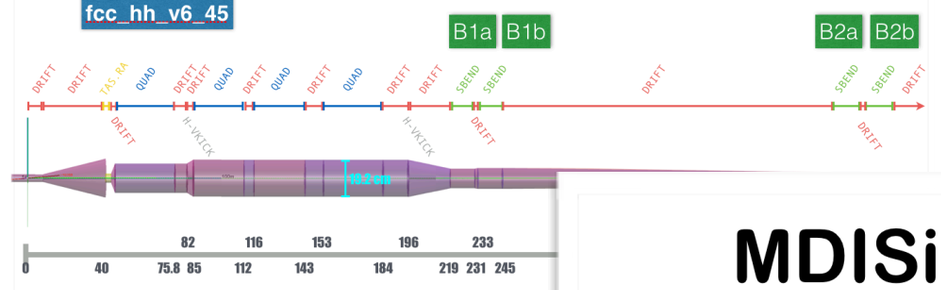


  - ➡ We assume the SR to be “pencil beam”-like (lying on horizontal plane only)
- Critical energy in zone of interest is around **1 keV** (E_{mean}~0.3keV)
  - ➡ All photons hitting the pipe are **locally absorbed** without reflection
- Only particles entering the TAS can in principle reach the experiments
  - ➡ We focus on particles **entering the TAS**



BEAM PIPE SCHEME FROM MADX

optics used:
fcc_hh_v6_45



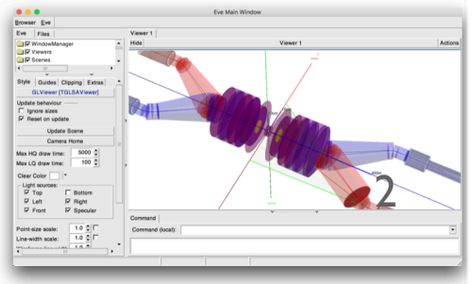
- 5486 Bends in the lattice:
  - All but 4 “strong” (~16T)
  - 4 “soft” (~4T) near the IP

- B=4.27 T
- L=12.5 m
- Θ=-0.3 mrad
- E_C=1.146 keV
- N_γ/proton=0.1
- P=32 W
- E_{TOT}=6.34 TeV

MDISim TOOLKIT

- Developed by *Helmut Burkhardt* (CERN), is a set of C++/Root classes that allow to:
  - Run Madx on the desired lattice of the FCC
  - Read Madx output, plot the lattice
  - **Calculate Synchrotron Radiation** (Power Radiated, Critical Energy..) and plot it over the geometry using Root’s TEve
- Import geometry and SR in Geant4 to perform full simulation

link



Ref. EuroCirCol Alba Meeting, Nov ‘16

WHERE WE WERE

Lattice

MDISim tool

SR power emitted by last elements

v6_45

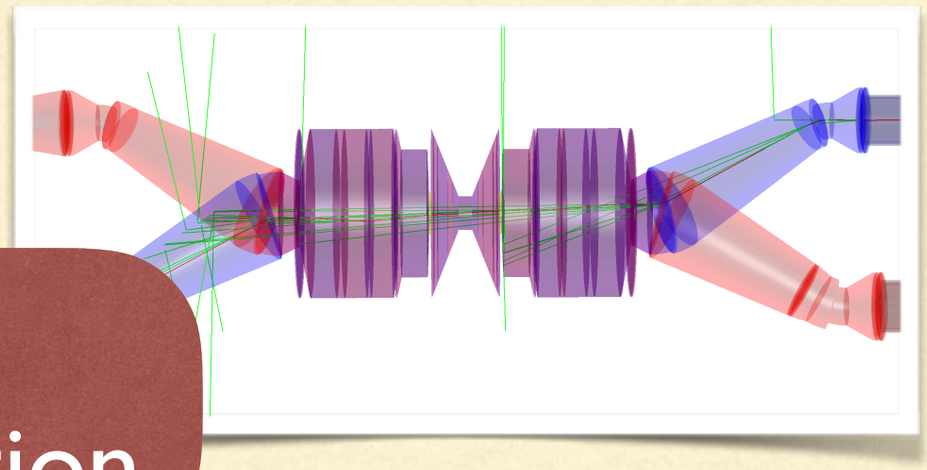
Element	S [m]	l [m]	B [T]	E_{crit} [keV]	P [W]
$D1_A$	231	12.5	-4.3	1.15	32
$D1_B$	245	12.5	-4.3	1.15	32
$D2_A$	427	15	3.6	0.96	27
$D2_B$	443	15	3.6	0.96	27

MDISim tool

GDML geometry and fields

Geant4

Full simulation



+ cfr with SYNRAD

WHERE WE WERE

- Results of the study: Power in the TAS and in Be Pipe

Table 3. Summary of SR power emitted by the last 500 m from the IP that enters the TAS (P_{TAS}) or hits the Be pipe (P_{Be}), coming from the full Geant4 simulation, with or without Crossing Angle. Values are per bunch.

CrAn.	$\mathbf{N}_{\gamma TAS}$	$\bar{E}$ **[keV]**	$\mathbf{P}_{TAS}$ **[W]**	$\mathbf{P}_{Be}$**[W]**
Yes	2.9×10^{9}	1.28	14.6	0.8
No	1.6×10^{9}	1.38	8.6	0.5

Ref.: Published as peer-reviewed proceeding of IPAC17
Collamati, Boscolo, Burkhard, Kersevan

UPDATING THIS STUDY

- On summer 2017, an updated version of the optics was released, including L*=40m, split quads, normal conducting bends etc..
- We generated new gdml files for geometry (with and without CR) and magnetic fields for the new optics
  - The job has been made more difficult due to some problems with the lattice (missing conical apertures, non zero length elements..)
- We run again our machinery going directly to the last step (full Geant simulation)

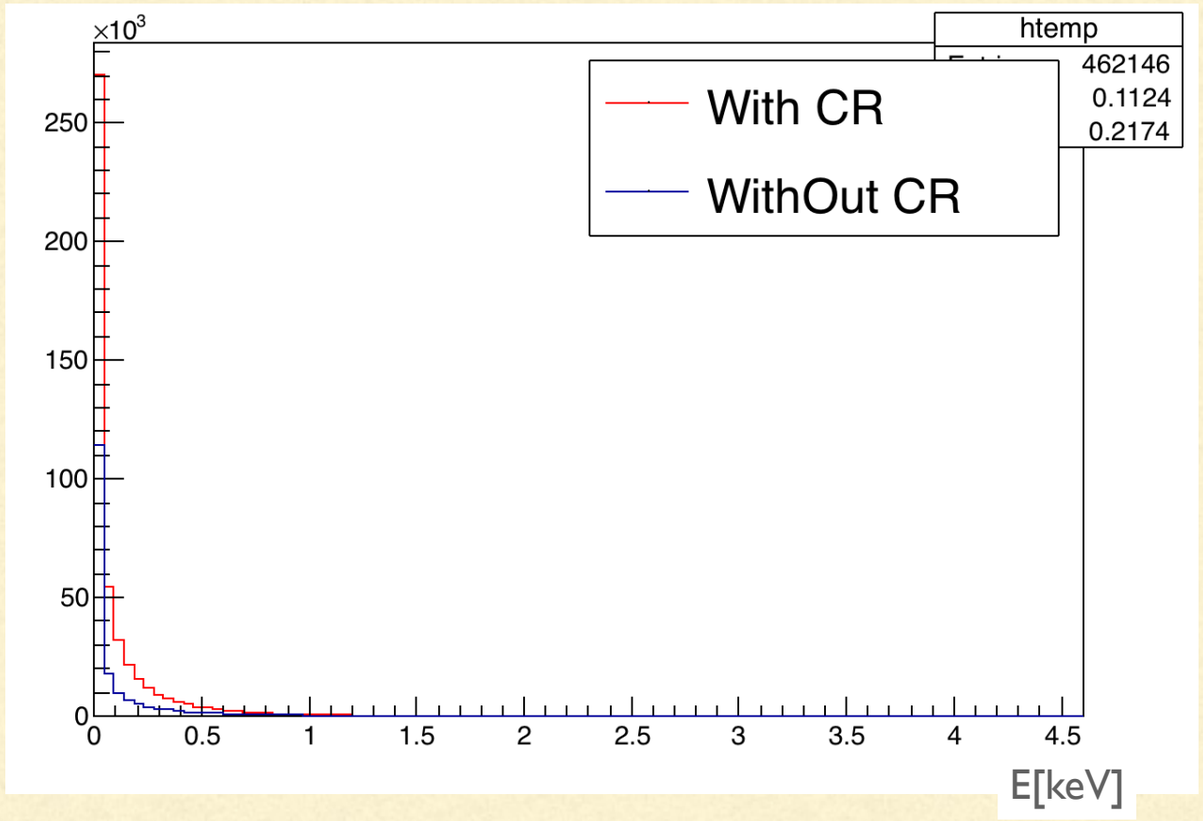
UPDATED RESULTS

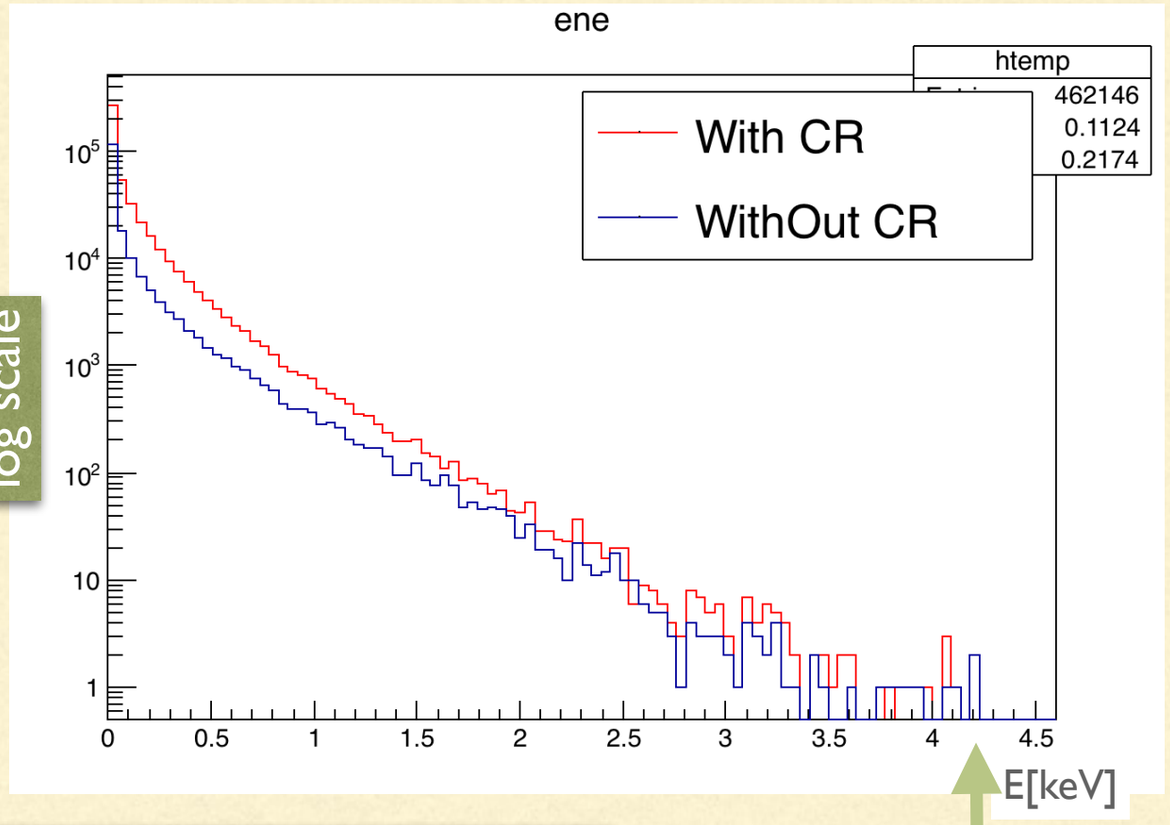
- Power entering the TAS and hitting the Beryllium pipe:

		P @TAS (W)	N_{gamma} @Be	P @ Be (W)
with CR	old	14,6	2,9E+09	0,8
	UPDATED	**20,8**	2,0E+09	0,95
without CR	old	8,6	1,6E+09	0,5
	UPDATED	**8,1**	1,0E+09	0,62

UPDATED RESULTS

- Spectrum of photons entering the TAS:





The maximum energy of these photons has been reduced due to weaker bending magnets

We had already demonstrated that such low energy photons are not a problem into the experiments

CONCLUSIONS

- Updating the study of SR contribution suggests that there is a slightly increase in power into the detector (i.e. into the TAS)
- The new values are however still small, and the photon spectrum even softer:
  ➜ it seems safe to conclude that **SR power is not a concern**
- We demonstrated to be able to update the study with a new optics, useful in view of the CDR
  - However the job is easy only if the optics file gets fixed in some details…
    ➜ simplifying the geometry generation job could allow for easy and quick study of alternative configurations (low β..)

BACKUP

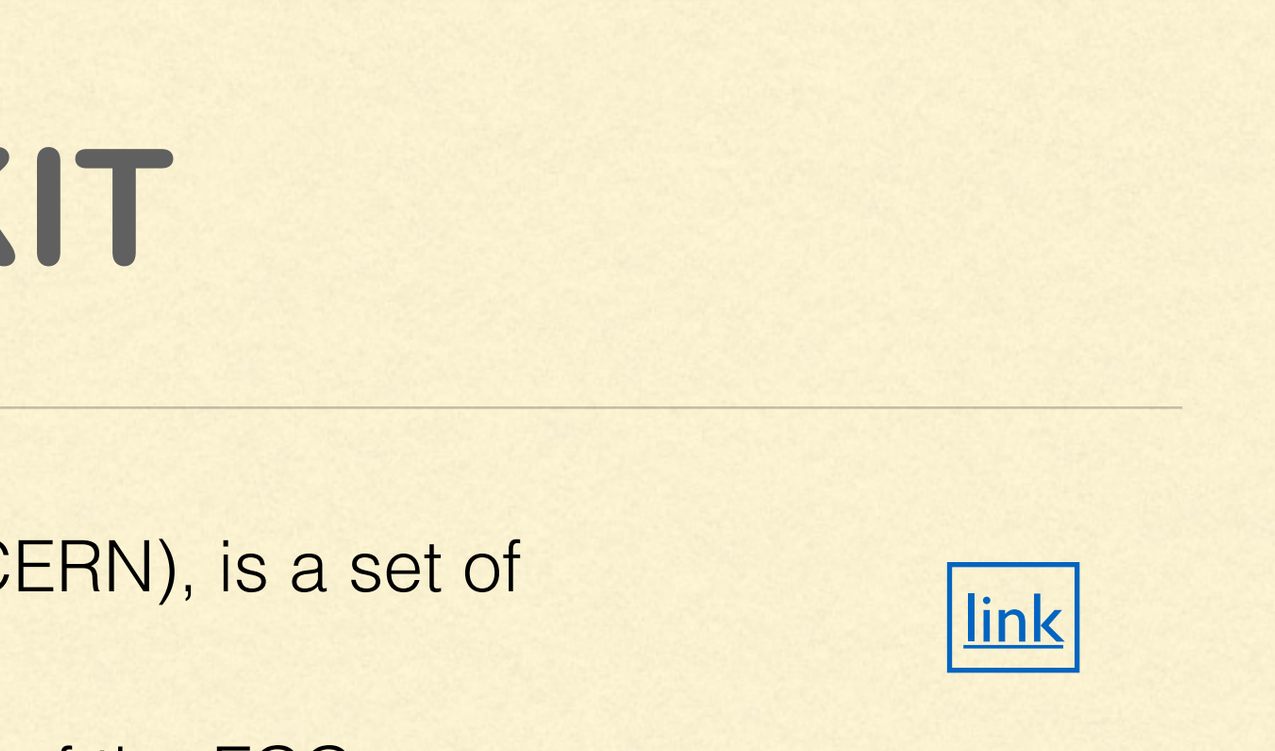
UPDATED RESULTS_2

		P @TAS (W)	N_{gamma} @Be	P @ Be (W)	PnoQauds	NNoQuads	PBeNoQuads
with CR	old	14,6	2,9E+09	0,8			
	UPDATED	**20,8**	2,0E+09	0,95	10,0	1,1E+09	0,70
without CR	old	8,6	1,6E+09	0,5			
	UPDATED	**8,1**	1,0E+09	0,62	7,79	9,9E+08	0,62

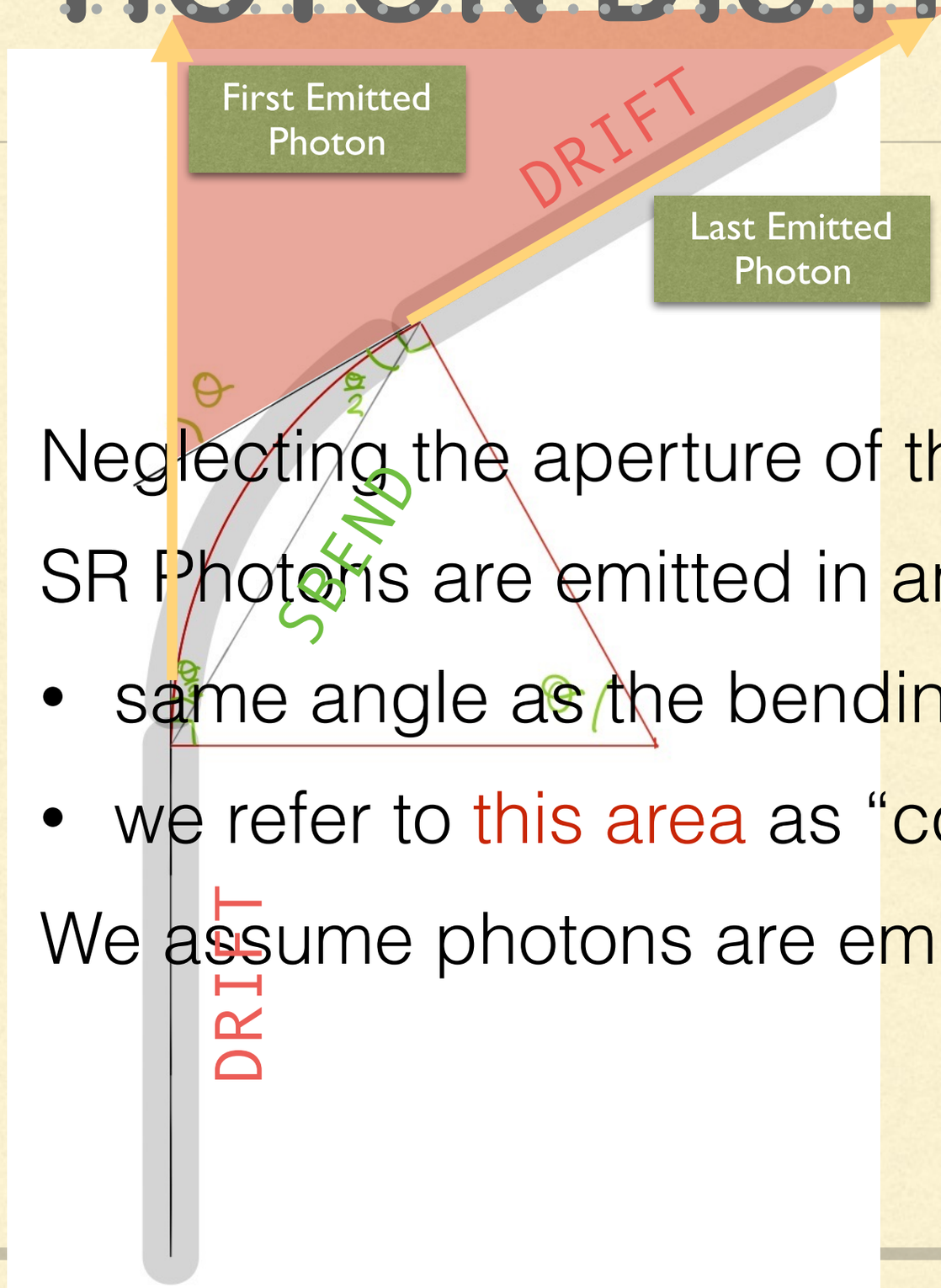
MDISIM TOOLKIT

- Developed by *Helmut Burkhardt* (CERN), is a set of C++/Root classes that allow to:
  - Run Madx on the desired lattice of the FCC
  - Read Madx output, plot the lattice
  - **Calculate Synchrotron Radiati** Energy..) and plot it over the geometry using Root's TEve
- Import geometry and SR in Geant4 to perform full simulation

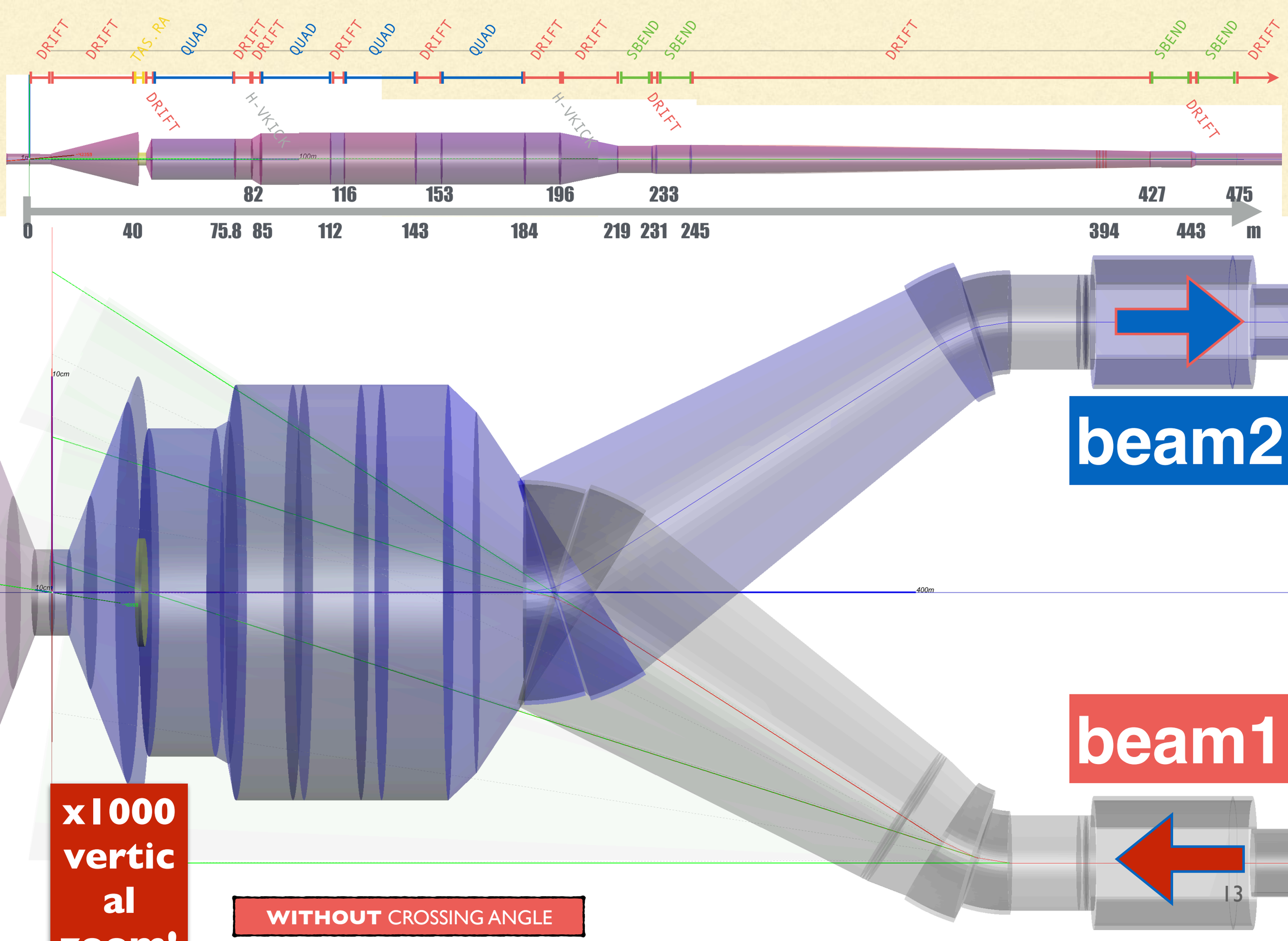
link



PHOTON DISTRIBUTION



- Neglecting the aperture of the SR cone..
- SR Photons are emitted in an area of θ
  - same angle as the bending magnet!
  - we refer to this area as “cone”
- We assume photons are emitted isotropically in this area


DRIFT
DRIFT
TAS.RA
QUAD
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DRIFT
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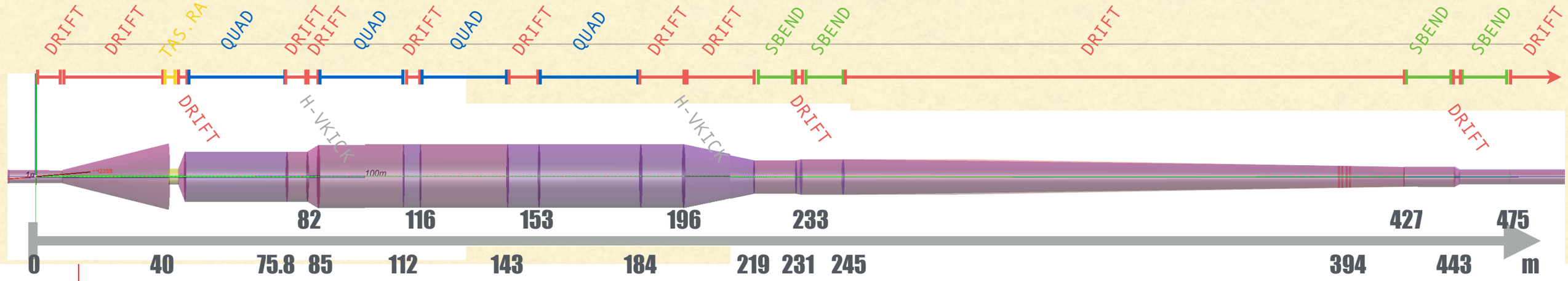
H-VKICK
DRIFT
DRIFT
100m
82
116
153
196
233
427
475
0
40
75.8
85
112
143
184
219
231
245
394
443
m
10cm
10cm
400m
beam2
beam1
x1000 vertical zoom!
WITHOUT CROSSING ANGLE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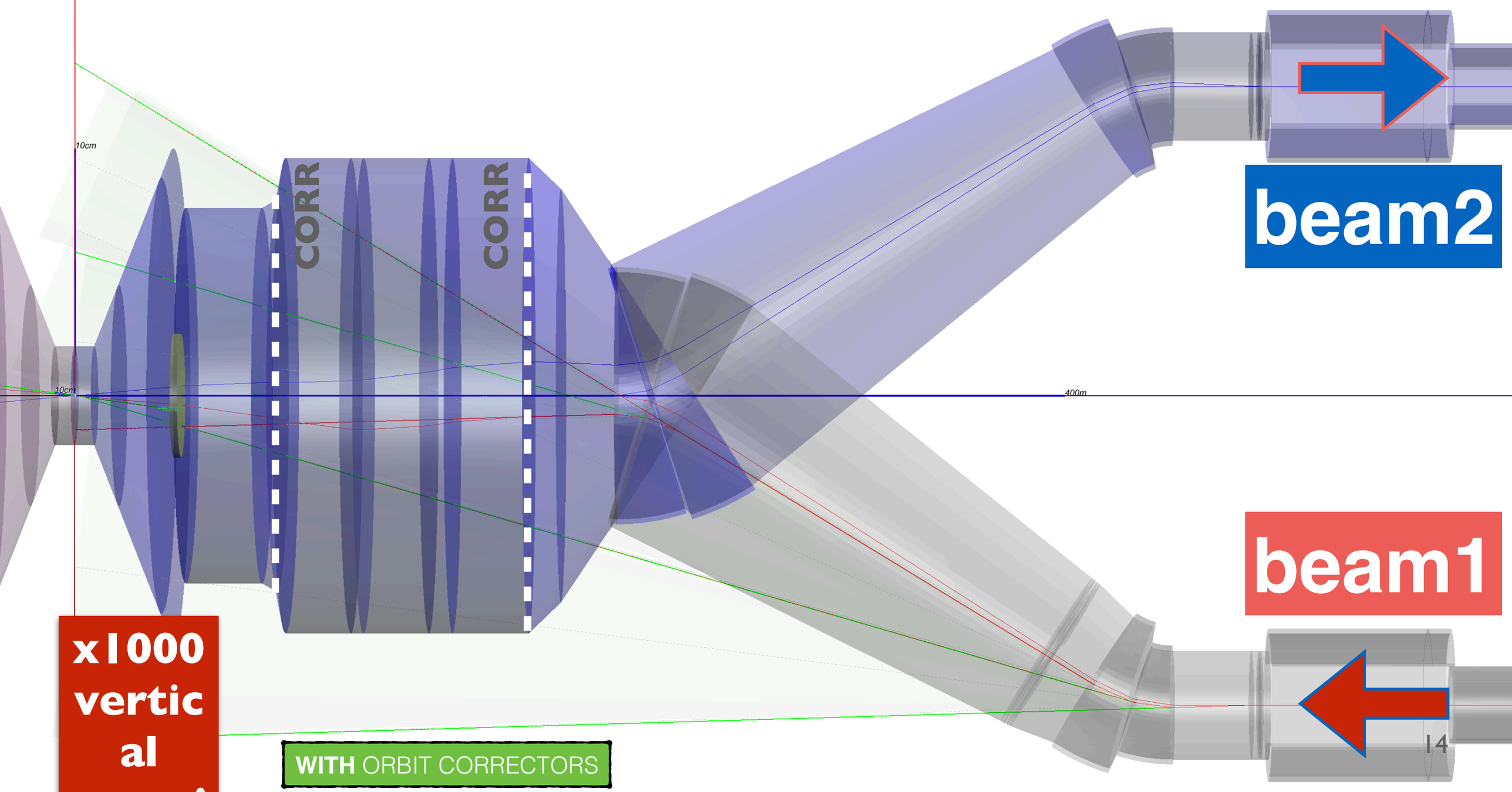
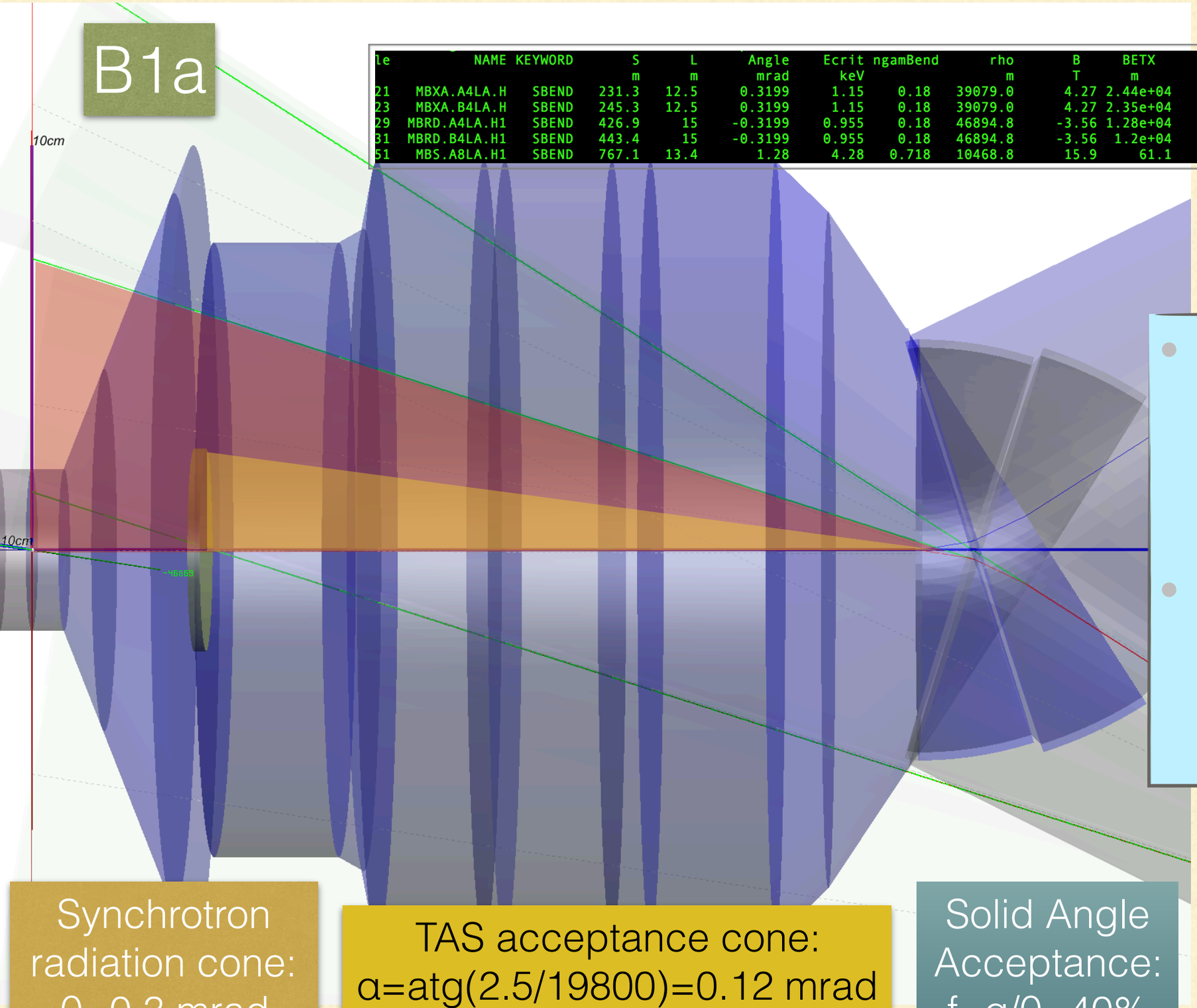

10cm
CORR
CORR
400m
beam2
beam1
x1000 vertical zoom!
WITH ORBIT CORRECTORS

"How many SR photons can physically enter the TAS aperture?"

B1a

le	NAME	KEYWORD	S	L	Angle	Ecrit	ngamBend	rho	B	BETX	SIGX	divx	Power	frac>10MeV	ngam*npart	Egamtot	Em
			m	m	mrad	keV		m	T	m	mm	mrad	kW			GeV	
21	MBXA.A4LA.H	SBEND	231.3	12.5	0.3199	1.15	0.18	39079.0	4.27	2.44e+04	1	0.00141	0.0322	0	1.8e+10	6.34e+03	0.
23	MBXA.B4LA.H	SBEND	245.3	12.5	0.3199	1.15	0.18	39079.0	4.27	2.35e+04	0.984	0.00141	0.0322	0	1.8e+10	6.34e+03	0.
29	MBRD.A4LA.H1	SBEND	426.9	15	-0.3199	0.955	0.18	46894.8	-3.56	1.28e+04	0.728	0.00141	0.0268	0	1.8e+10	5.28e+03	0.
31	MBRD.B4LA.H1	SBEND	443.4	15	-0.3199	0.955	0.18	46894.8	-3.56	1.2e+04	0.705	0.00141	0.0268	0	1.8e+10	5.28e+03	0.
51	MBS.A8LA.H1	SBEND	767.1	13.4	1.28	4.28	0.718	10468.8	15.9	61.1	0.0502	0.000879	0.481	0	7.18e+10	9.46e+04	1



- MDISim gives the total SR power emitted in each element of the lattice
- From geometry the fraction of this power entering the TAS can be evaluated

Synchrotron radiation cone: θ=0.3 mrad

TAS acceptance cone: α=atg(2.5/19800)=0.12 mrad

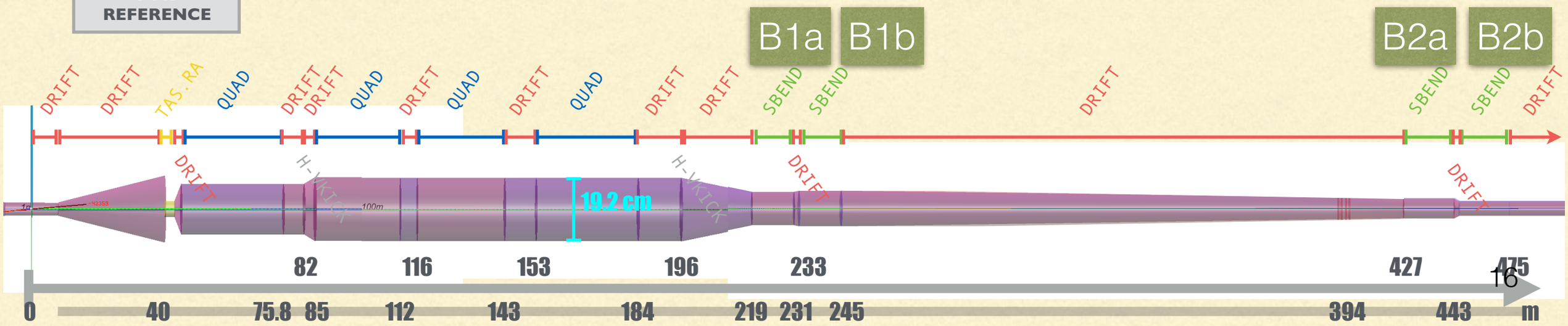
Solid Angle Acceptance: f=α/θ=40%

MADX OUTPUT

iele	NAME	KEYWORD	S	L	Angle	Ecrit	ngamBend	rho	B	BETX	SIGX	divx	Power	frac>10MeV	ngam*npart	Egamtot	Emean
			m	m	mrad	keV		m	T	m	mm	mrad	kW			GeV	keV
21	MBXA.A4LA.H	SBEND	231.3	12.5	0.3199	1.15	0.18	39079.0	4.27	2.46e+04	1.01	0.00142	0.0322	0	1.8e+10	6.34e+03	0.353
23	MBXA.B4LA.H	SBEND	245.3	12.5	0.3199	1.15	0.18	39079.0	4.27	2.36e+04	0.987	0.00142	0.0322	0	1.8e+10	6.34e+03	0.353
29	MBRD.A4LA.H1	SBEND	426.9	15	-0.3199	0.955	0.18	46894.8	-3.56	1.29e+04	0.73	0.00142	0.0268	0	1.8e+10	5.28e+03	0.294
31	MBRD.B4LA.H1	SBEND	443.4	15	-0.3199	0.955	0.18	46894.8	-3.56	1.21e+04	0.707	0.00142	0.0268	0	1.8e+10	5.28e+03	0.294
51	MBS.A8LA.H1	SBEND	767.1	13.4	1.28	4.28	0.718	10468.8	15.9	61.1	0.0502	0.000877	0.481	0	7.18e+10	9.46e+04	1.32

						WITHOUT CROSSING ANGLE			WITH CROSSING ANGLE		
EL.	S (M)	B (T)	ECRIT (KEV)	NΓTOT (J)	P (W)	FTAS (%)	ETAS (J)	PTAS (W)	FTAS (%)	ETAS (J)	PTAS (W)
B1a	231	-4,3	1,146	1,8E+10	32	40	4,0E-07	12,8	77,0	7,7E-07	24,6
B1b	235	-4,3	1,146	1,8E+10	32	0	—	—	—	—	—
B2a	427	3,6	0,955	1,8E+10	27	15,3	1,3E-07	4,1	8,0	6,8E-08	1,2
B2b	443	3,6	0,955	1,8E+10	27	0	—	—	—	—	—
B3	767	15,9	4,279	7,2E+10	480	—	TOT	17W	—	TOT	26W

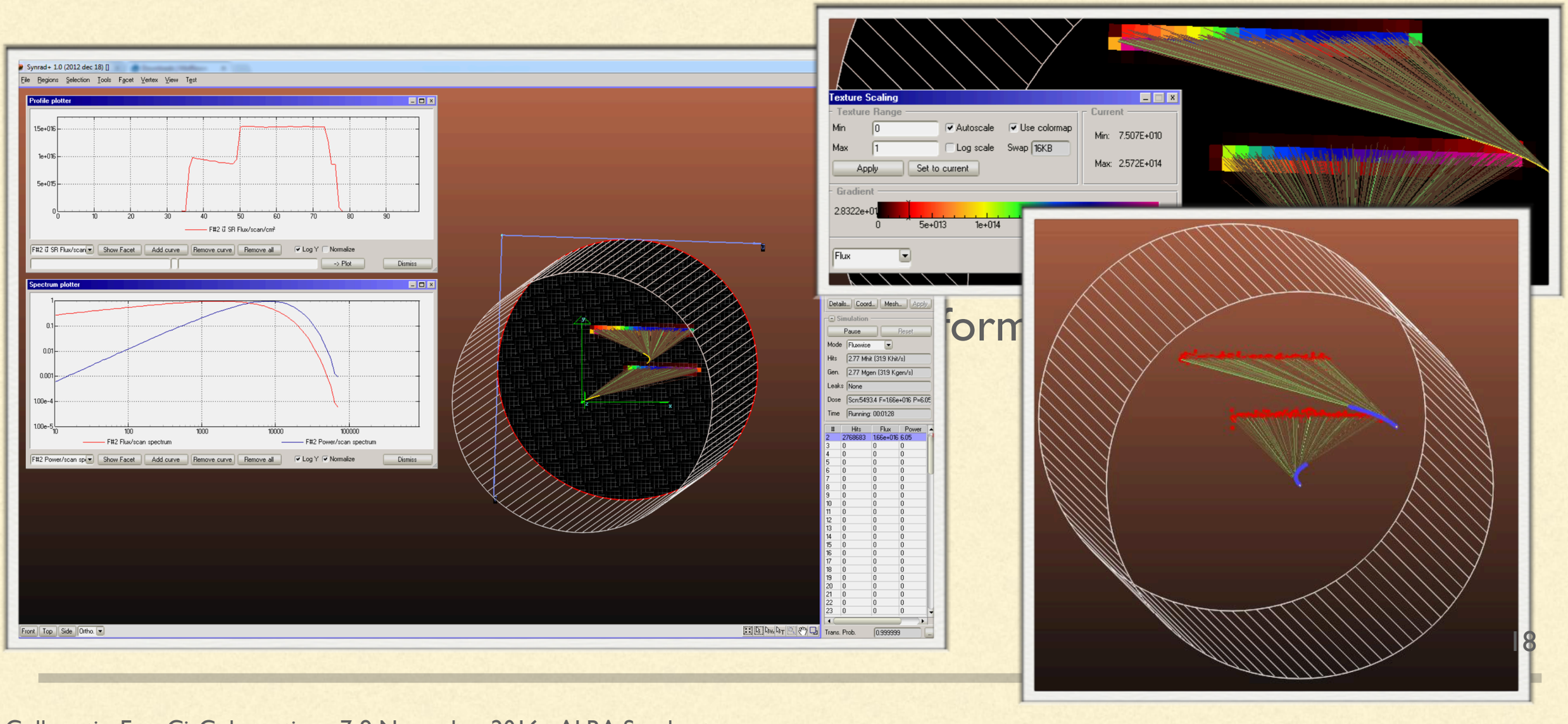
FOR REFERENCE



Second approach: SynRad

Synrad Software

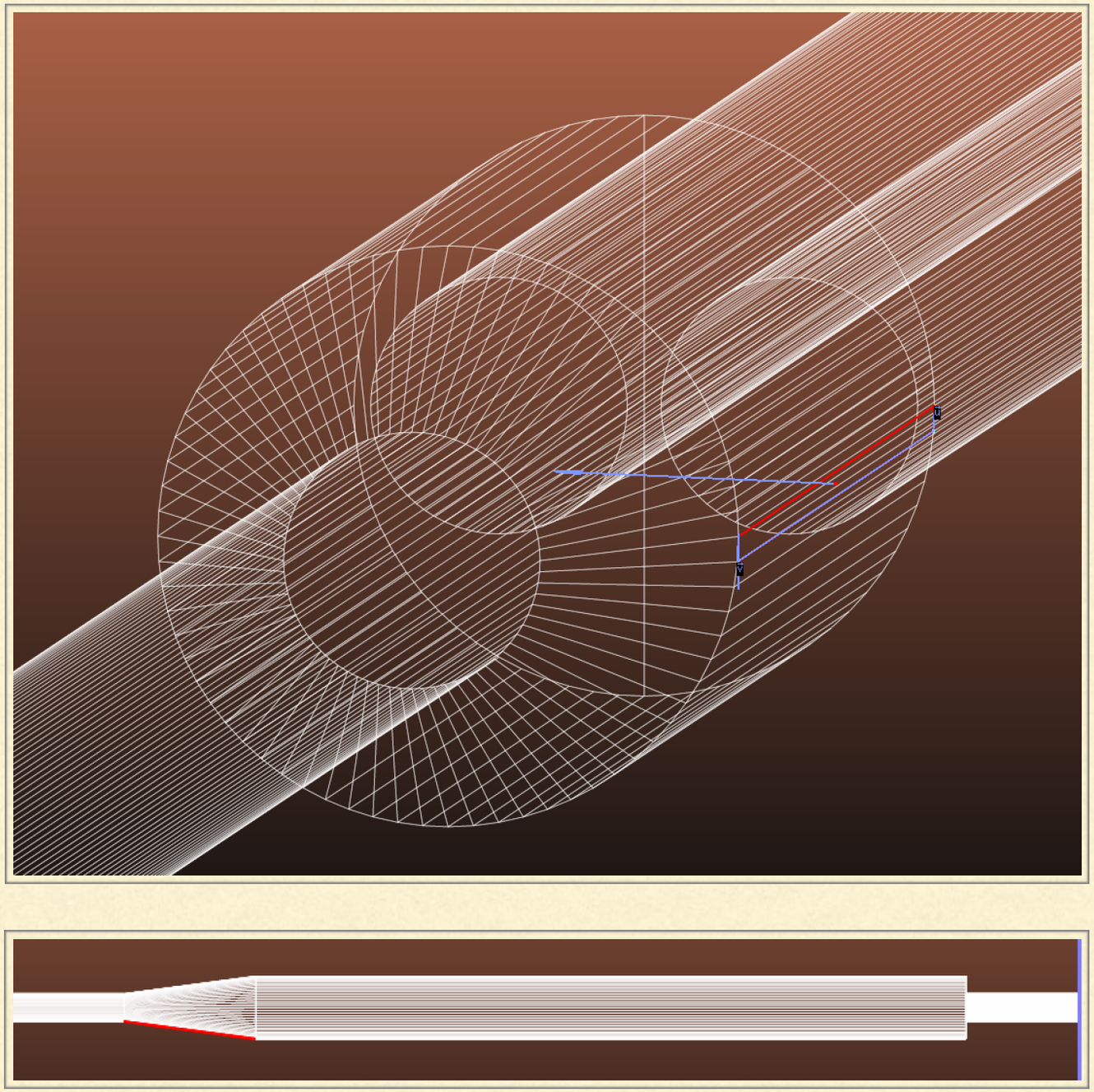
link



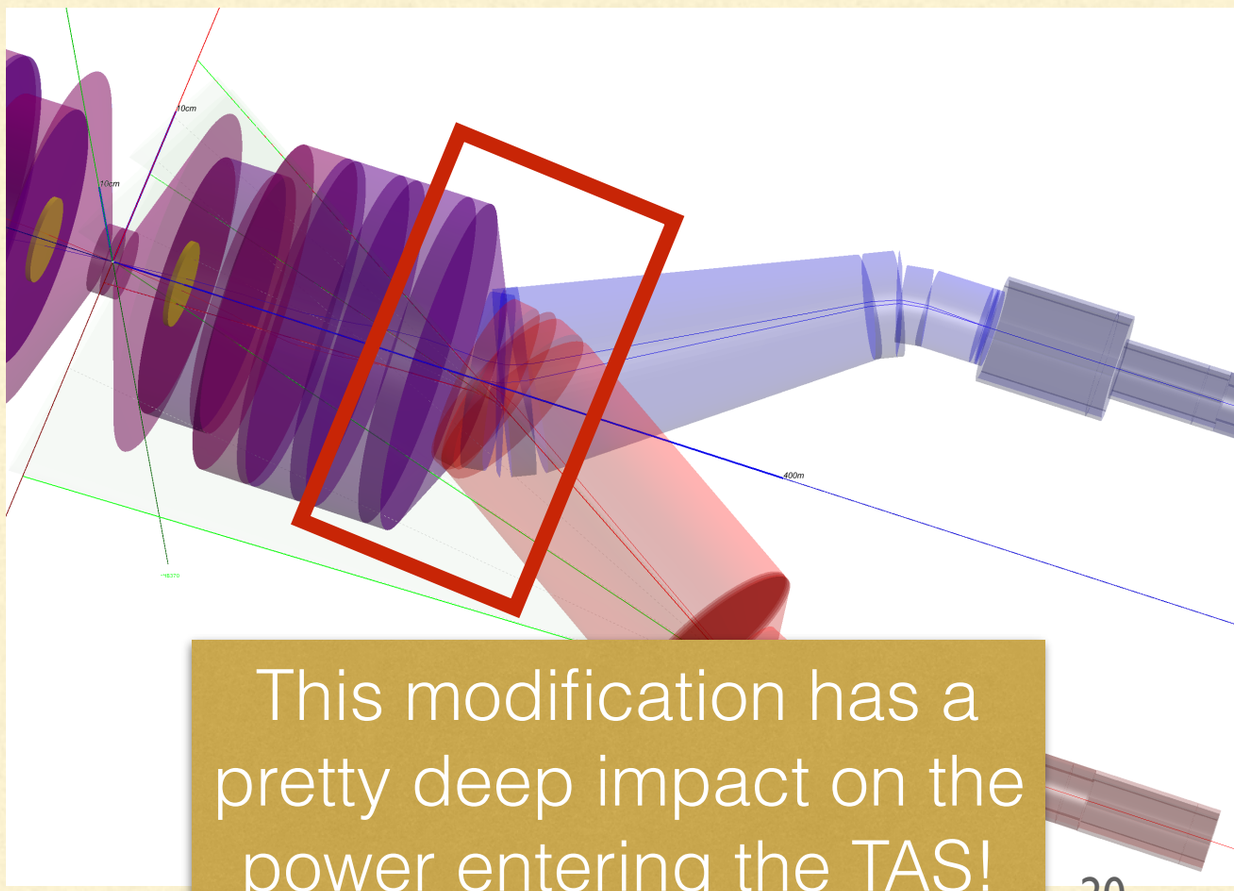
Synrad Simulation

- Roberto Kersevan used the Madx output files (run with MDISim) to:
  - **create the beam**, taking position, displacement, emittance, coupling and all the relevant parameters
  - **create the geometry**, using the apertures provided in the Madx optics file and joining them with the ones added "by hand" (eg for TAS)
  - he added to the geometry some elements not included in the optics file to resolve some "unrealistic" configurations originating from the mere optics files
    - recombination chamber, beam pipe size discontinuities…

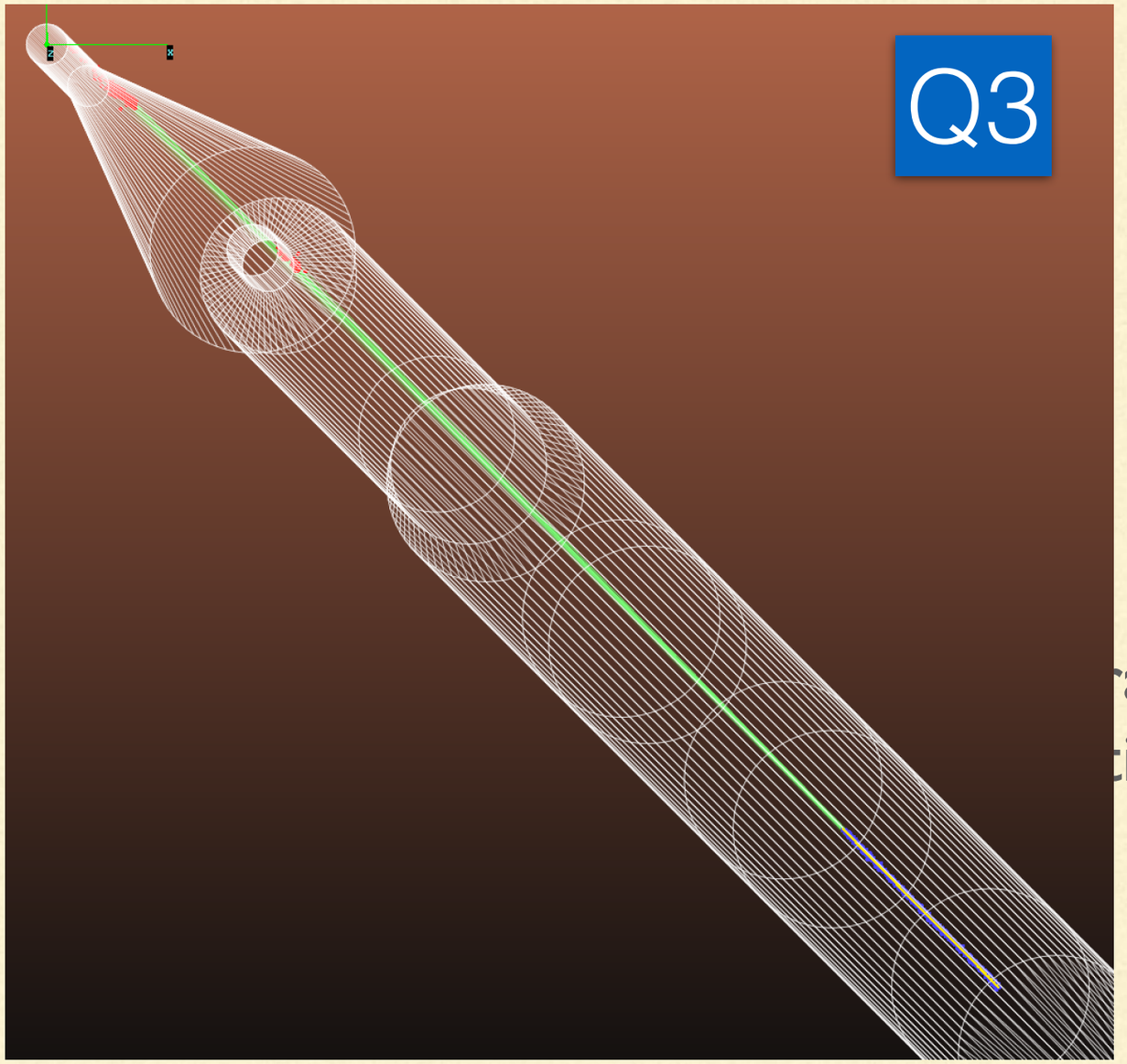
R. Kersevan modifications to the geometry



For recombination chamber and beam pipe size he used as reference LHC, making a sort of "projection"

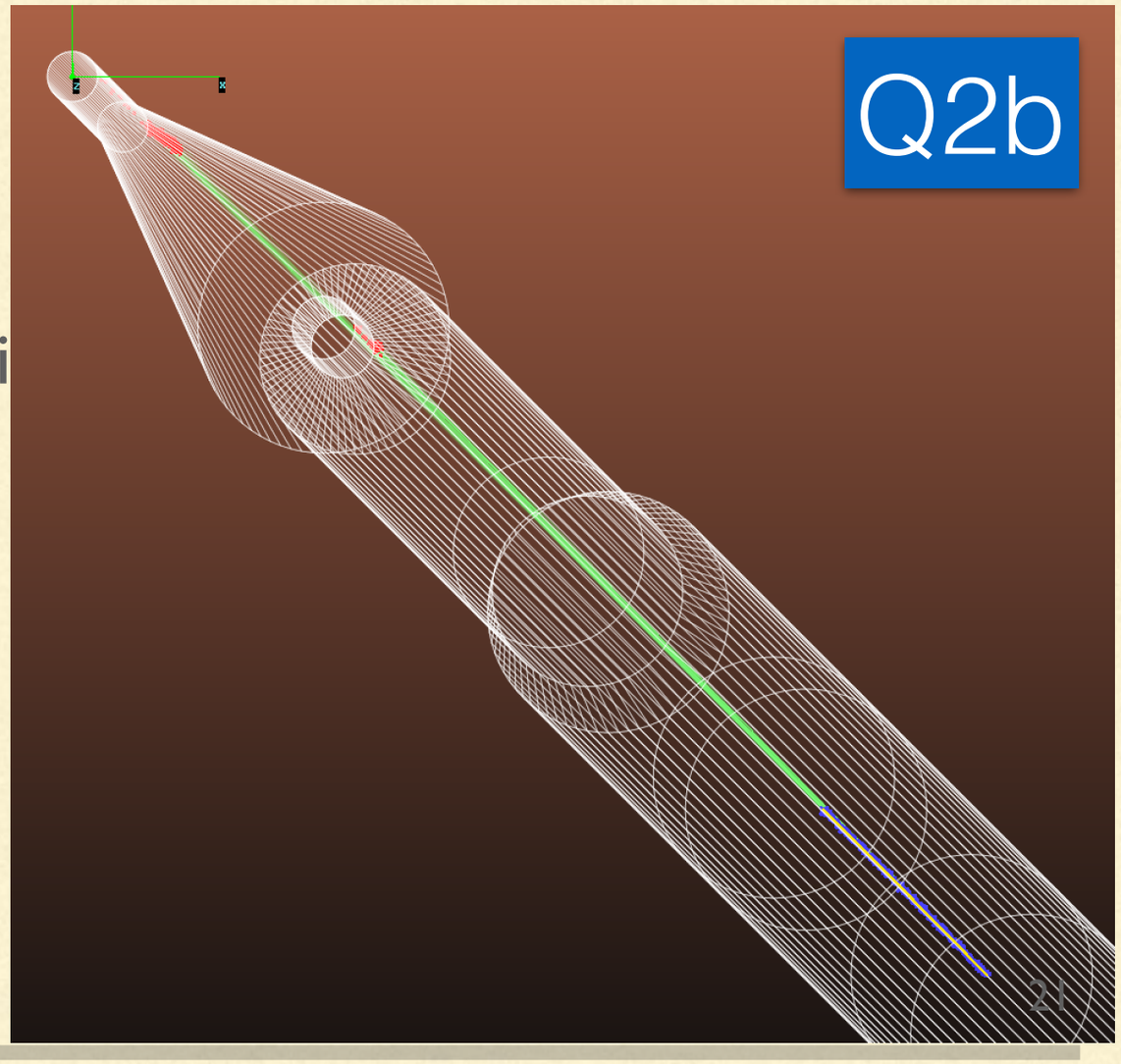


This modification has a pretty deep impact on the power entering the TAS!



here showing

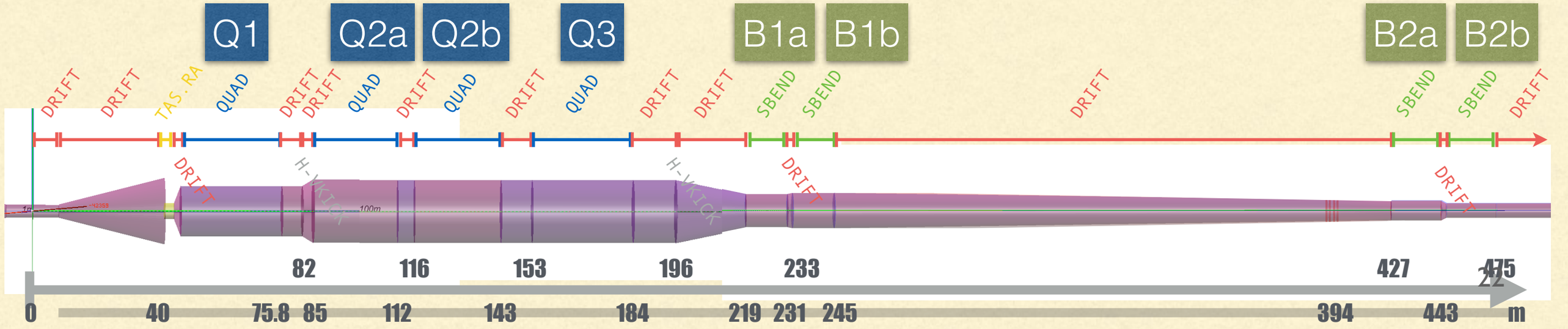
With Crossing Angle



rad i

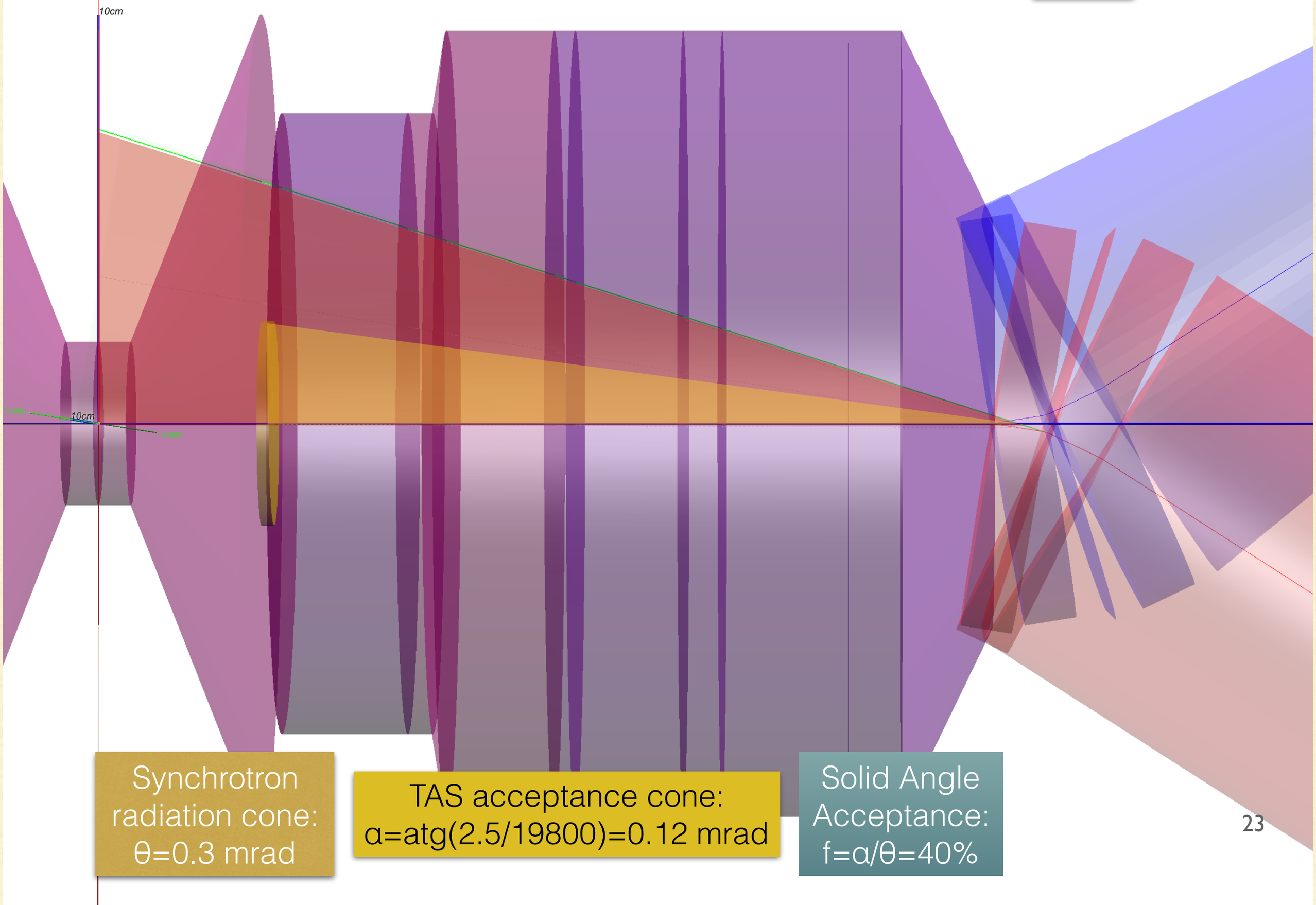
tion

POWER (W)	NO CROSSING ANGLE		CROSSING ANGLE	
	MDISIM	SYNRAD	MDISIM	SYNRAD
B2B	0	0	0	0
B2A	4,1	0,08	1,2	1E-03
B1B	0	0	0	4E-05
B1A	12,8	5,02	24,6	5,75
Q3	—	0	—	1,24
Q2B	—	0,139	—	2,19
Q2A	—	0	—	1E-04
Q1	—	0,0113	—	e-6
TOT	**16,9**	**5,3**	**25,8**	**9,2**



WITHOUT CROSSING ANGLE

B1a



Synchrotron radiation cone: θ=0.3 mrad

TAS acceptance cone: α=atg(2.5/19800)=0.12 mrad

Solid Angle Acceptance: f=α/θ=40%